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MARINE CORPS AIR STATION EL TORO
EL TORO, CALIFORNIA
INSTALLATION RESTORATION PROGRAM
FINAL SOIL GAS SURVEY WORK PLAN
SITES 24 AND 25

16 MAY 1994

Revision 0

PREPARED BY:
Southwest Division, Naval Facilities Engineering Command
1220 Pacific Highway
San Diego, California 92132-5190

THROUGH:
CONTRACT #N68711-89-D-9296
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WITH:
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In association with:
International Technology Corporation
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EL TORO, CALIFORNIA
INSTALLATION RESTORATION PROGRAM
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
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ACRONYMS

A&R	assembly and repair
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CLEAN	Comprehensive Long-term Environmental Action Navy
CLP	contract laboratory program
CRDL	contract required detection limit
CRQL	contract required quantitation limit
CTO	Contract Task Order
DOT	U.S. Department of Transportation
DQO	data quality objective
Cal-EPA, DTSC	California Environmental Protection Agency, Department of Toxic Substances Control
ECD	electron capture detector
EPA	U.S. Environmental Protection Agency
FBRs	fuel bladder revetments
FID	flame ionization detector
FS	feasibility study
GAC	granular activated carbon

GC	gas chromatograph
GIS	geographic information system
HSP	health and safety plan
HWSA	hazardous waste storage area
IAS	initial assessment study
IR	Installation Restoration
Jacobs	Jacobs Engineering Group Inc.
MCAS	Marine Corps Air Station
MDL	method detection limit
ml	milliliter
MS	mass spectrometer
MS/MSD	matrix spike/matrix spike duplicate
mu	mass units
OCWD	Orange County Water District
O.D.	outside diameter
OVA	organic vapor analyzer
OWS	oil/water separator
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PPE	personal protective equipment
psi	pounds per square inch
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RFA	RCRA facility assessment

RI	remedial investigation
ROICC	resident officer in charge of construction
RRT	relative retention time
SAP	sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SDG	sample delivery group
SIE	selected ion extraction
SIM	selected ion monitoring
SOPs	Standard Operating Procedures
SVOC	semivolatile organic compound
SWMU/AOC	solid waste management unit/area of concern
TCL	target compound list
TDGC	thermal desorption gas chromatograph
TDSP	thermal desorption sampling probe
TFH	total fuel hydrocarbons
TIC	total ion current
TM	technical memorandum
ug/L	micrograms per liter
USCS	unified soil classification system
UST	underground storage tank
VOA	volatile organic analysis
VOC	volatile organic compound
VSI	visual site inspection
WP	work plan

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1.0 INTRODUCTION

This work plan for a soil gas survey at Sites 24 and 25 for the Marine Corps Air Station (MCAS) El Toro has been prepared within the context of the Navy Installation Restoration (IR) Program. This program is designed, in part, to evaluate and remediate, if necessary, contamination caused by hazardous substances, pollutants, or contaminants, pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The work plan is prepared under Contract Task Order (CTO) 145 as part of the Comprehensive Long-term Environmental Action Navy (CLEAN) Program under Contract N68711-89-D-9296.

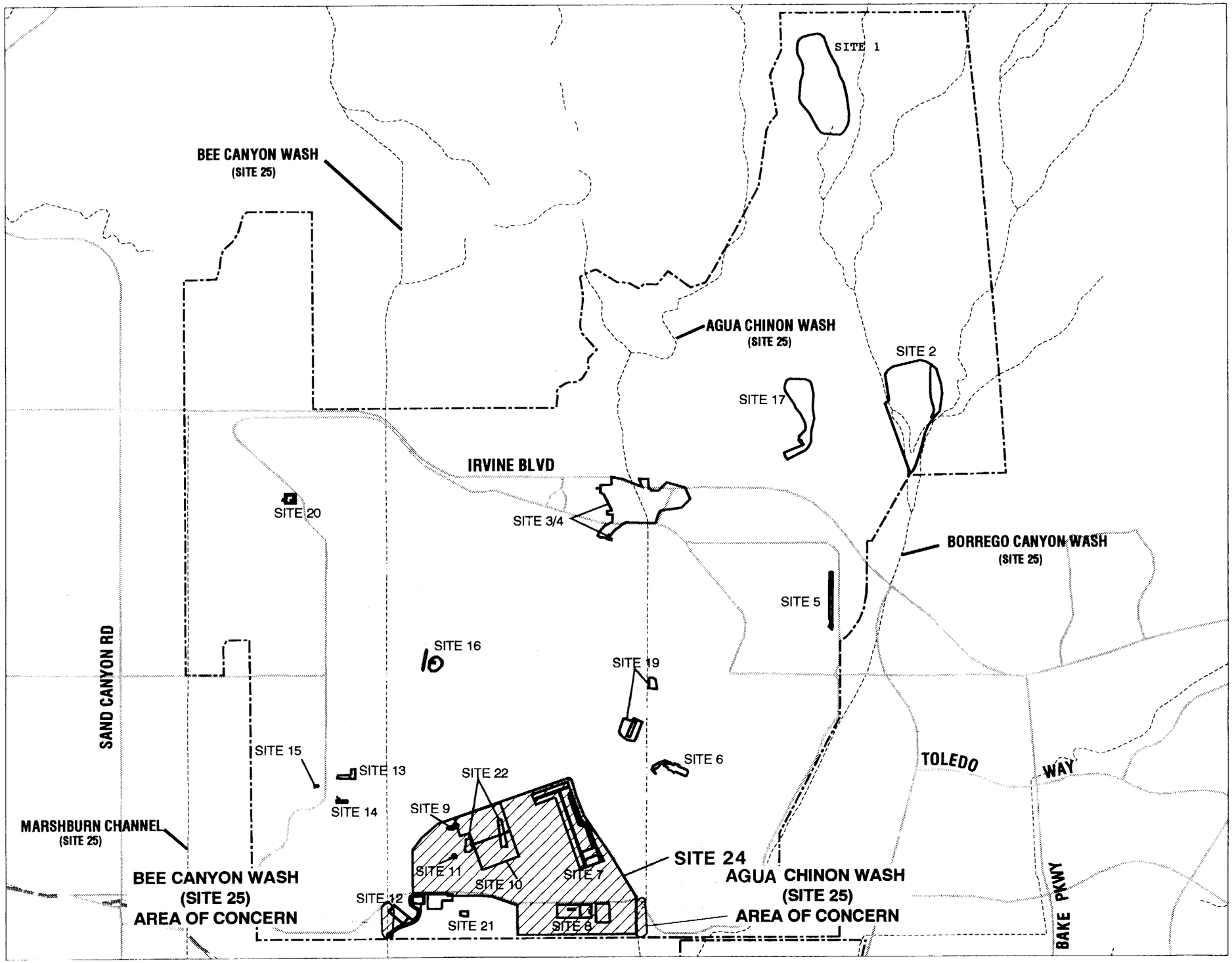
This work plan is the planning document for conducting the soil gas survey in the southwest quadrant of MCAS El Toro (also referred to as the Station) at Remedial Investigation (RI) Sites 24 and 25. Site 24 is the potential volatile organic compound (VOC) source area and Site 25 comprises the major surface drainages. The purpose of this work plan is to develop and describe the approach and methodology that will be used in the soil gas survey. Soil gas sampling has been repeatedly demonstrated to be an effective measurement methodology for VOCs in unsaturated soils.

VOCs were detected at concentrations above regulatory standards in groundwater in the southwest quadrant of MCAS El Toro during the Phase I Remedial Investigation (RI) field investigation (Jacobs, 1993). However, only relatively minor concentrations of VOCs were detected in soil during the Phase I RI and the Resource Conservation and

Recovery Act (RCRA) Facility Assessment (RFA) (Jacobs, 1993) field investigations. The purpose of this soil gas investigation is to locate vadose zone contamination in the southwest quadrant of MCAS El Toro that may contribute to VOC contamination in groundwater. The results of this soil gas survey will be used to revise the Phase II investigation (Phase II RI Work Plan) at Sites 24 and 25.

The Phase II RI Sampling and Analysis Plan (SAP) is Appendix A of this work plan. The SAP provides direction for obtaining the field samples. The Phase II RI Quality Assurance Project Plan (QAPP) addendum is included as Appendix B; the addendum provides soil gas survey program-specific information that is not included in the Phase II RI QAPP (Jacobs, 1993a). An addendum to the Phase II Remedial Investigation/ Feasibility Study (RI/FS) Draft Health and Safety Plan is included as Appendix C (Jacobs, 1993b); both the original plan and addendum will be used in the field.

Figure 1-1 shows the location at Sites 24 and 25 of MCAS El Toro. Sites 24 and 25 are part of Operable Unit (OU) 2. OU 2 sites are considered potential source areas for the regional VOC groundwater contamination found at the Station. Site 24 consists of the majority of the southwestern quadrant of the Station, and encompasses existing RI Sites 7, 8, 9, 10, 11, and 22 (these sites are not specifically addressed in this section) and solid waste management units/areas of concern (SWMU/AOCs) investigated by the RFA where VOCs were detected in previous investigations. The area also has a variety of other significant features, including the former refurbishing operations area. The soil gas survey will be conducted in two sampling rounds. The soil gas sampling locations proposed for the first sampling round are shown on Plate 1.



FEATURES:

- FREEWAY
- ROAD
- MCAS EL TORO BOUNDARY
- WASH OR STREAM

SITE NUMBER AND NAME:

1 EXPLOSIVE ORDNANCE DISPOSAL RANGE
2 MAGAZINE ROAD LANDFILL
3/4 ORIGINAL LANDFILL AND FERROCENE SPILL AREA
5 PERIMETER ROAD LANDFILL
6 DROP TANK DRAINAGE AREA NO. 1
7 DROP TANK DRAINAGE AREA NO. 2
8 DRMO STORAGE YARD
9 CRASH CREW PIT NO. 1
10 PETROLEUM DISPOSAL AREA
11 TRANSFORMER STORAGE AREA
12 SLUDGE DRYING BEDS
13 OIL CHANGE AREA
14 BATTERY ACID DISPOSAL AREA
15 SUSPENDED FUEL TANKS
16 CRASH CREW PIT NO. 2
17 COMMUNICATION STATION LANDFILL
19 AIRCRAFT EXPEDITIONARY REFUELING (ACER) SITE
20 HOBBY SHOP
21 MATERIALS MANAGEMENT GROUP, BUILDING 320
22 TACTICAL AIR FUEL DISPENSING SYSTEM
24 POTENTIAL VOC SOURCE AREA
25 MAJOR DRAINAGES (LABELED BY NAME)

0 1000 2000 4000
SCALE IN FEET

AREA OF CONCERN

FIGURE 1-1

LOCATIONS OF PHASE II RI SITES AND SOIL GAS SURVEY SITES 24 AND 25

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

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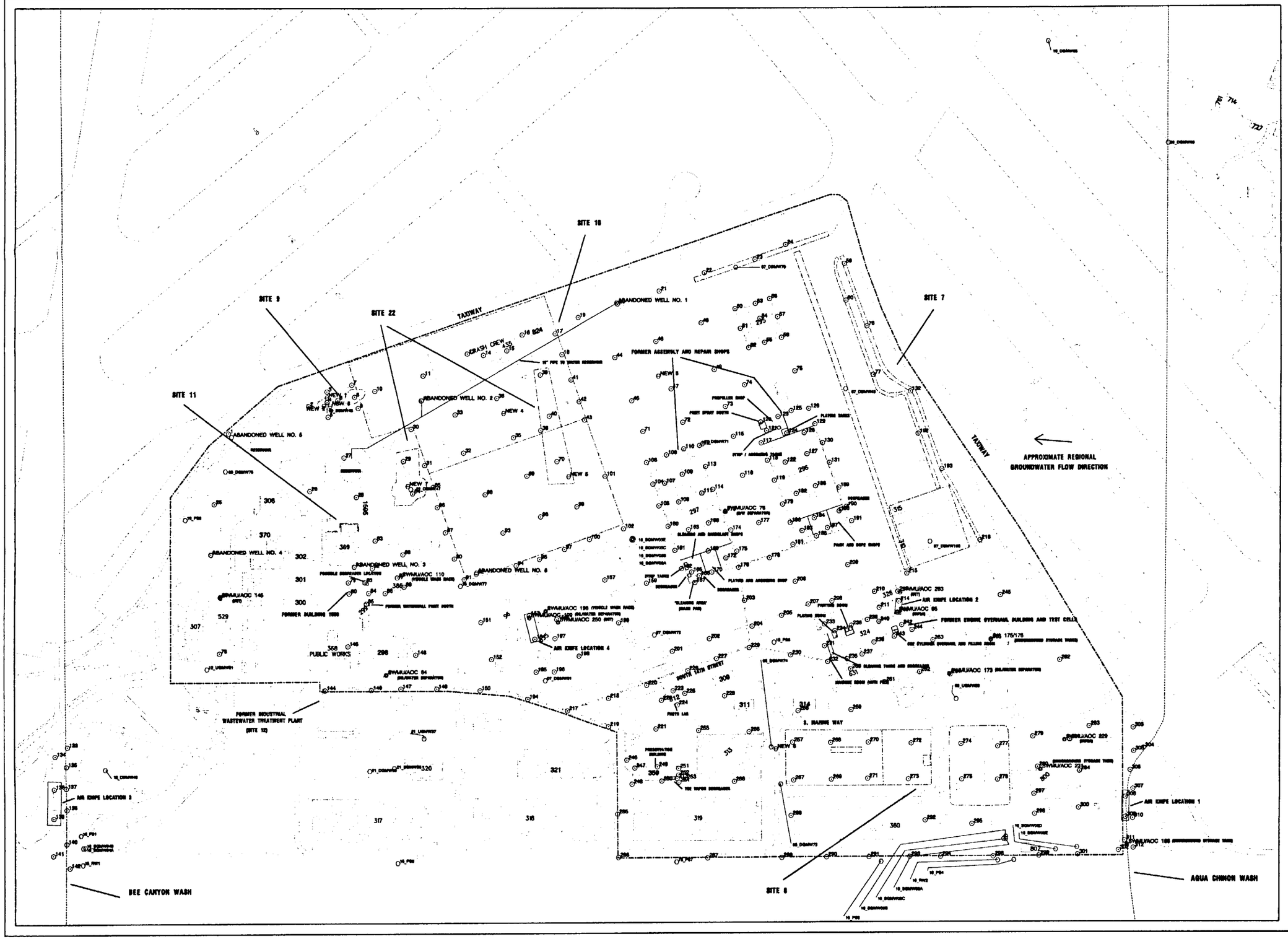

PLATE 1

ROUND 1 SOIL GAS SAMPLE LOCATIONS SITE 24 AND 25

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

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The current boundaries of Site 24 have been drawn to include potential sources of the regional VOC contamination in groundwater, based on Phase I RI data, RFA data, additional file searches, and employee interviews at MCAS El Toro. Existing RI/FS sites that lie within the current Site 24 boundaries are also being investigated separately as part of the Phase II RI.

Site 25 (shown in Figure 1-1) consists of the four primary surface drainage channels that conduct flow through or adjacent to the Station and portions of San Diego Creek. Note that San Diego Creek, which is located southwest of the Station, is not shown on Figure 1-1. The drainages are:

- Agua Chinon Wash
- Bee Canyon Wash
- Borrego Canyon Wash
- Marshburn Channel

Off-Station runoff in the channels (from the hills and upgradient irrigated farmland) is sporadic and combines with on-Station runoff from the storm sewer system and flows into San Diego Creek. The San Diego Creek, in turn, flows into Upper Newport Bay, about 7 miles downstream from its intersection with Marshburn Channel. The channels are mostly lined and/or culverted through the Station.

In the Phase I RI Work Plan and during the Phase I investigation, the channels were discussed as potential sources contributing to the regional VOC groundwater contamination. The unlined portions of the Agua Chinon and Bee Canyon Washes near Site 24, as indicated on Figure 1-1, are included in this soil gas survey.

This soil gas survey will be conducted prior to the initiation of Phase II RI field activities. It is anticipated that potential VOC source areas identified in the soil gas survey will be

investigated further during the Phase II RI. Additional Phase II RI activities may be specified, based on the results of the soil gas survey, in the revised Phase II RI planning documents (Work Plan and SAP).

1.1 Contents

This Soil Gas Survey Work Plan describes the schedule and technical approach of the proposed soil gas survey at MCAS El Toro. As stated earlier, the SAP, QAPP and HSP are included as appendices that will be used in the field in conjunction with the work plan. This work plan includes the following:

- Presentation of the schedule
- A conceptual model diagram for Sites 24 and 25
- Presentation of the regulatory and risk factors that drive the need for additional characterization of the shallow vadose zone
- Technical approach for the field work
- Rationale for first round soil gas sampling locations
- Identification and description of soil gas investigation tasks
- Description of data evaluation methodology
- Description of the contents of the technical report that will present the results of the soil gas survey
- Field team organization and responsibilities

This work plan does not present a comprehensive review or summary of past studies at MCAS El Toro. Background information is presented in the Draft RI Technical Memorandum (TM) (Jacobs, 1993c) and the Phase II RI Work Plan (Jacobs, 1993d),

which summarize the findings of the Phase I RI conducted at MCAS El Toro. The reports present an understanding of the geology, hydrogeology, and nature and extent of contamination at MCAS El Toro.

The Phase II Draft SAP summarizes additional field work and data collection to be performed at OU 2 and 3 sites based on the results of the Phase I RI.

1.2 Schedule

Figure 1-2 presents the schedule for the soil gas survey. The surveying and utility clearance will begin prior to the soil gas sampling. Rounds I and II of the soil gas survey will be conducted one immediately after the other over approximately a 5-week period. The technical report will be submitted approximately 9 weeks after the completion of the soil gas survey.

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Soil Gas Survey Schedule

Name	Duration	Scheduled Start	Scheduled Finish
1. Pre-planning	1d	2/28/94	2/28/94
2. Technical Exchange Mtg.	1d	3/1/94	3/1/94
3. DOCUMENT PRODUCTION	53d	3/2/94	5/13/94
a. Prepare Work Plan	23d	3/2/94	4/1/94
b. Prepare Health & Safety Plan	23d	3/2/94	4/1/94
c. Internal Review	5d	4/4/94	4/8/94
d. Incorporate Comments	5d	4/11/94	4/15/94
e. Navy/Agency Review	10d	4/18/94	4/29/94
f. Incorporate Comments	10d	5/2/94	5/13/94
4. Procure Subcontractors	45d	3/14/94	5/13/94
5. Acquire Utility Maps	5d	3/28/94	4/1/94
6. FIELD WORK	65d	4/4/94	7/1/94
a. Mark Survey Locations	10d	4/4/94	4/15/94
b. Utility Clearance	55d	4/11/94	6/24/94
c. Soil Gas Survey	24d	5/31/94	7/1/94
7. SUBCONTRACT SUPPORT	94d	4/25/94	9/1/94
a. Air Knife	35d	5/9/94	6/24/94
b. Coring, Patching	36d	5/6/94	6/24/94
c. GC/MS (Mobile Lab)	15d	6/13/94	7/1/94
d. CLP Lab	36d	6/13/94	8/1/94
e. Data Validation	39d	7/11/94	9/1/94
8. Data Reduction/Tabulation	37d	7/13/94	9/1/94
9. Waste Disposal Support	25d	6/13/94	7/15/94
10. a. GC Audit	4d	5/31/94	6/4/94
b. GC/MS Audit	5d	6/20/94	6/24/94
11. REPORT PREPARATION	63d	7/6/94	9/30/94
a. Data Analysis	13d	7/6/94	7/22/94
b. Write Report	15d	7/25/94	8/12/94
c. Internal Review	5d	8/15/94	8/19/94
d. Incorporate Comments	10d	8/22/94	9/2/94
e. Navy/Agency Review	10d	9/5/94	9/16/94
f. Incorporate Comments	16d	9/9/94	9/30/94

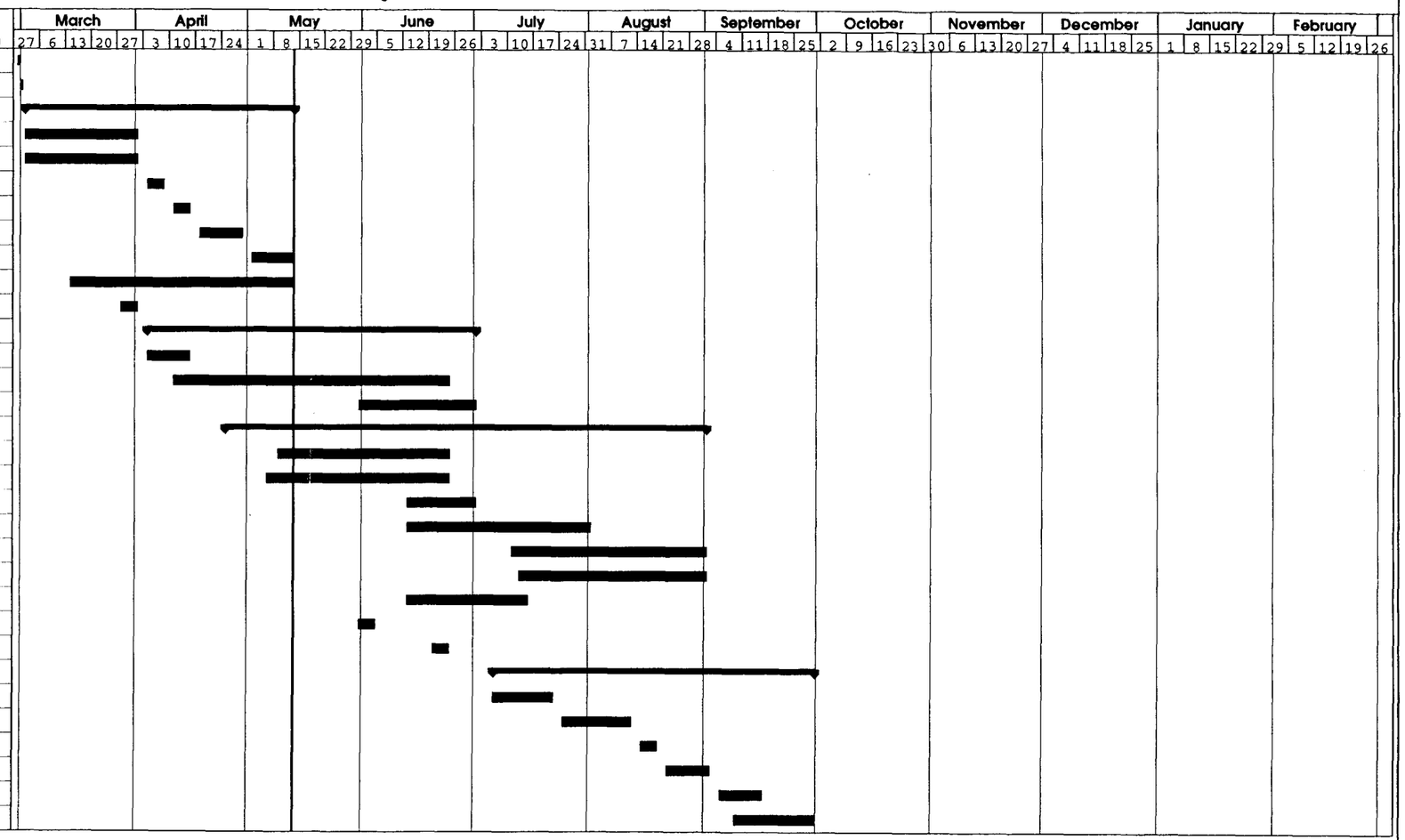

FIGURE 1-2
SOIL GAS SURVEY SCHEDULE

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Project: El Toro
Date: 5/13/94

Progress Summary

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2.0 OBJECTIVES

The overall goal of this soil gas investigation is to collect sufficient data to identify shallow vadose zone source(s) of VOCs that may be the cause of groundwater contamination, which appears to originate from the southwest portion of MCAS El Toro.

Soil data collected from depths of 0 to 10 feet during the Phase I RI field investigation at MCAS El Toro were evaluated using risk criteria during the data quality objective (DQO) process to select sampling locations within statistical strata to be sampled during the Phase II RI field investigation. A sampling stratum consists of an area within which there is an equal probability of detecting contaminants in a sample, based on available information. As part of this process, chemical concentrations detected in shallow soil during Phase I were compared to human health and ecological risk-based criteria to identify statistical strata with a potential to cause significant adverse health effects. If the chemical concentration detected in soil exceeded criteria, the statistical stratum was recommended for further investigation in Phase II. For statistical strata where the estimated risk was near the upper end of the U.S. Environmental Protection Agency (EPA) acceptable range (areas with estimated excess cancer risk $> 5 \times 10^{-5}$) or the statistical strata boundaries were being redefined based on new information, field screening sampling was proposed to estimate the nature and extent of contamination. Site 24 is newly defined and, therefore, field screening is appropriate as an initial nature and extent of contamination investigative tool.

Data collected for use in the OUs 2 and 3 Baseline Risk Assessment, to be conducted after the Phase II investigation, must meet Level 3 (standard EPA methods) or Level 4 (EPA Contract Laboratory Program [CLP]) protocol in order for the sampling results to meet EPA criteria. Field screening methodologies typically do not achieve these levels of data quality. However, field methods are a more cost-effective way to preliminarily investigate the extent of contamination at a statistical stratum. Once the extent of contamination is better defined, Level 3 or 4 samples may be more effectively placed for use in the Risk Assessment.

Figure 2-1 presents the conceptual model for VOC contamination at Sites 24 and 25. Within Site 24, there are a number of possible sources identified from Phase I RI data, RFA data, and additional records searches. These are conceptually depicted as releases of VOC contamination into the vadose zone. Surfaces releases of chlorinated solvents may move through the vadose zone down to the water table. At the water table, the contamination may: (1) Dissolve and travel with the groundwater, (2) Continue to move deeper or laterally as a dense nonaqueous phase liquid (DNAPL) within the groundwater, (3) Sorb onto the organic carbon fraction in the aquifer matrix, or (4) A combination of the above. The conceptual model also depicts potential VOC contamination travelling from the washes (where disposal of solvents is suspected) into the vadose zone and potentially into the groundwater. VOCs in the shallow soil contamination may also move in the vapor phase to the water table, where they dissolve and enter the groundwater, or infiltrating water may pick up dissolved VOCs as it moves through the vadose zone. Soil gas dissolves into unsaturated infiltrating water. The soil gas survey and soil field screening sampling are designed to provide sufficient data to identify possible shallow vadose zone sources of VOC contamination. Specific objectives of the soil gas survey are to:

- Identify shallow vadose zone sources of VOC contamination to groundwater during Round I.

- Target Round II soil gas and soil samples to identify the nature and better delineate the extent of VOC contamination at identified source areas (from Round I) in the shallow vadose zone.

- Use soil gas and soil sample results to assist in locating Phase II RI sampling locations.

- Collect soil data for use in the risk assessment and FS.

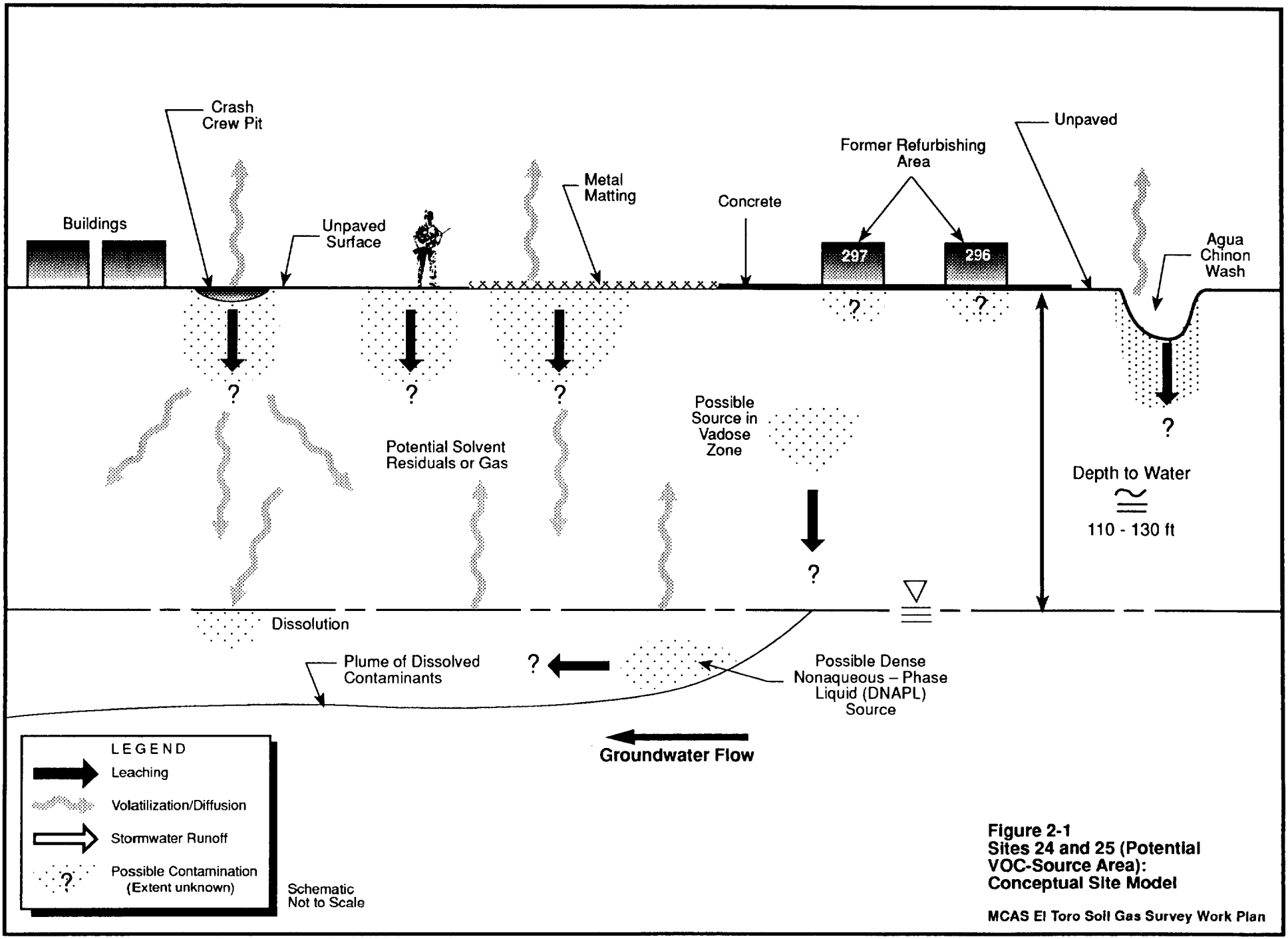

Figure 2-1
Sites 24 and 25 (Potential VOC-Source Area): Conceptual Site Model

MCAS El Toro Soil Gas Survey Work Plan

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3.0 TECHNICAL APPROACH OF FIELD WORK

The soil gas survey will be conducted in two rounds, each lasting 2 to 3 weeks. A flow chart depicting the field activities for Round I soil gas sampling is presented in Figure 3-1. During the first round, approximately 300 locations will be sampled. Locations are shown on Plate 1 and the rationale for these locations are described in Subsection 3.2.

The locations will initially be marked and surveyed for location and elevation to an accuracy of 0.1 feet in the field by a registered surveyor. A field engineer will accompany the surveyor to identify locations for survey and check for obstructions such as overhead wires. This work will be conducted several weeks prior to Round I soil gas sampling.

It will be necessary to check for buried utility lines before pushing the soil gas probe into the soil. This will be accomplished prior to the first round of sampling with preliminary utility check, using nonintrusive techniques such as checking utility maps and conducting geophysical surveys. In areas where the surface is covered by metal matting, the preliminary utility check will be conducted by checking utility maps. In other locations, a geophysical technique (ground penetrating radar) will be used in conjunction with the utility map checks.

Prior to driving the soil gas probe, however, it will be necessary to bore a hole to a depth of 7 feet as a final utility clearance, based on Jacobs Engineering Group Inc. (Jacobs) standard operating procedures (SOPs) 7.7. This will be accomplished using an air knife, a nondestructive drilling method. A dual-tube apparatus is pushed into the ground and soil is displaced by air injected under pressure through an inner tube. The soil is then removed through an outer tube under suction. The first soil vapor samples will be collected at a depth of 12 feet below the ground surface (bgs), leaving a 5-foot buffer between the bottom of the air knife hole and the first sample.

The air knife final utility check will be conducted up to a few weeks before the first round soil gas samples are collected. The air-knifed hole will be backfilled immediately

after being drilled in order to allow the soil gas to re-equilibrate. The order of the air knife utility check will mimic the order of the soil gas sample, to the extent possible, to maximize the time between the air knife utility check and the soil gas sampling. A test will be conducted during the first week of the soil gas survey to evaluate the effect of the air knife on soil gas concentrations collected from 12 feet bgs. This test is described in Subsection 3.4.

During Round I sampling, soil gas samples will be collected at depths of 12 and 20 feet (unless modified based on investigation results) at each location using a truck-mounted hydraulic stainless-steel probe. Sample collection techniques are described in Subsection 3.3.1 and sample handling is described in Subsection 3.3.2.

Two soil gas sampling rigs will be utilized to collect samples. Each of these rigs is capable of collecting soil gas samples at depths of 12 and 20 feet bgs from 10 to 15 locations per day. Thus, the first round may be expected to take up to 15 field days (3 weeks) to complete. Samples will be analyzed during the first phase at a field laboratory equipped with two gas chromatographs (GCs). Chlorinated hydrocarbons will be analyzed with an electron capture detector (ECD). Petroleum hydrocarbons will be analyzed with a flame ionization detector (FID).

Results of analyses will be available on a daily basis. As results are obtained, they will be plotted using a computer and specialized software. Based on these results and possible patterns or contours that may be interpreted from the first round data, soil gas sample locations will be selected for the second sampling round.

Approximately 200 locations will be sampled during the second round. A flow chart for Round II field activities is presented in Figure 3-2. As described above, the locations will be selected based on the results of the first round of sampling. Utility clearance will be conducted in a similar manner to Round I. As the data are analyzed from Round I and

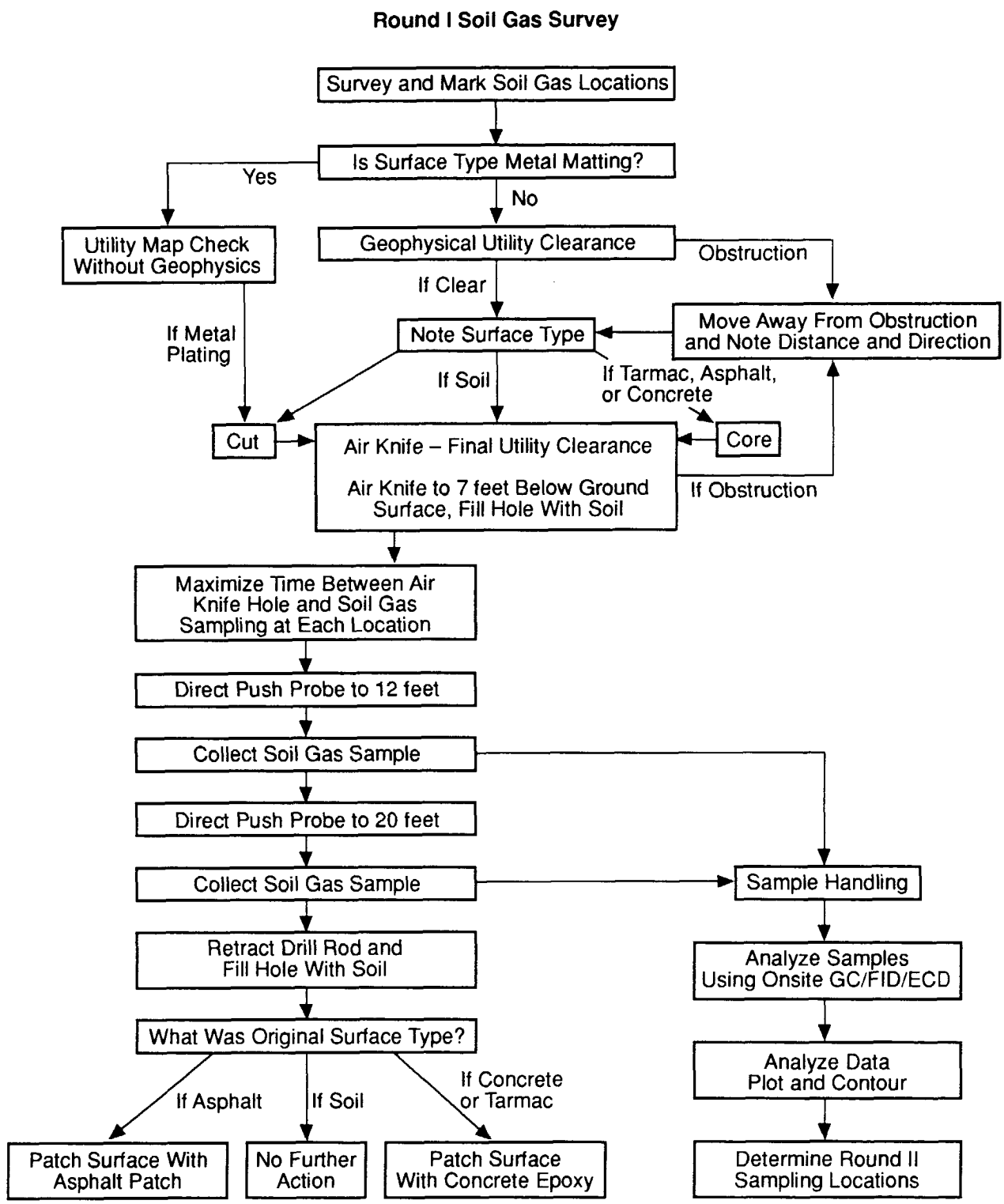

Figure 3-1
Flow chart of Round I Soil Gas Survey Field Activities

Note: Sample depths may be modified based on air knife results.

MCAS El Toro Soil Gas Survey Work Plan

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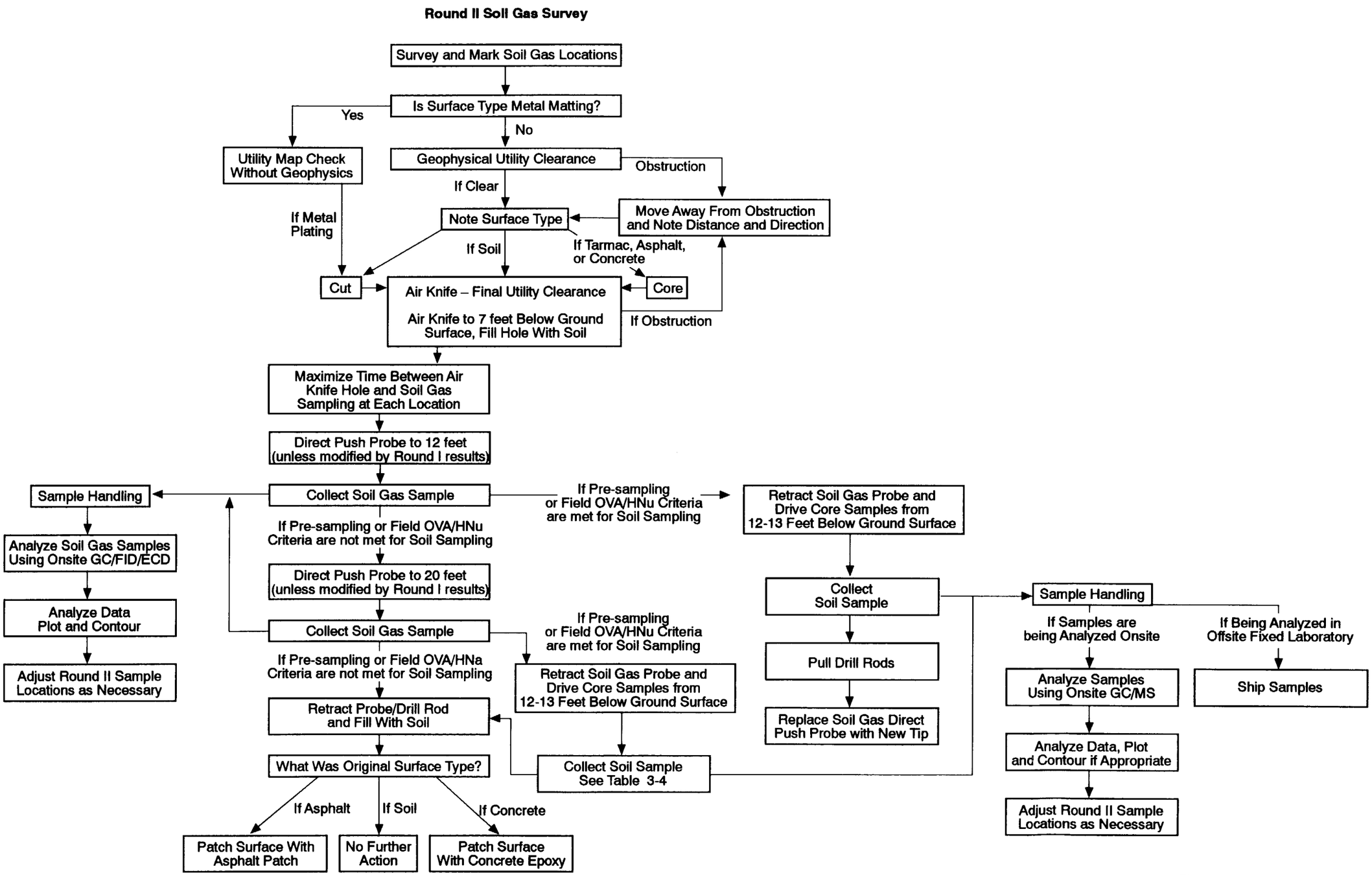

Figure 3-2
Flowchart of Round II Soil Gas Survey Field Activities

Note: Sample depths may be modified based on air knife and/or Round I Results.

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Round II soil gas probe locations are selected, Round II utility clearances will be conducted. Once again, two sample rigs will be operating in the field. As before, soil gas samples will be transported to the field laboratory and analyzed on two GC units. Also, up to 200 soil samples will be distributed among the final 200 soil gas locations during the second round; subsurface soil samples will be collected with direct push soil samplers for analysis by a thermal desorption gas chromatograph (TDGC). Soil samples will be targeted at locations based on the results of the first round soil gas data. For the second round, each rig is expected to average between 6 to 10 locations per day. Thus, it may take up to 15 field days (3 weeks) to collect the samples.

The soil samples will be used to define the nature of contamination in the soil and to evaluate the TDGC/MS. Each of the 200 soil samples will be analyzed for VOCs.

An additional 40 soil samples (20 percent of the 200 soil samples) will be collected and transported to a fixed conventional laboratory for analysis of VOCs during the second round. The soil samples will be duplicates of the field screening soil samples.

Five surficial (0 to 3 inches) soil samples will be collected at five different RI/FS site locations (sites 7, 8, 9, 11, and 12) where the presence of SVOCs, pesticides, and/or PCBs has been confirmed. The samples will be analyzed both onsite with the TDGC/MS and offsite in a conventional fixed laboratory for SVOCs, pesticides, and PCBs.

The regulatory agencies will provide two, and the contractor will provide three, certified soil samples for analysis by onsite TDGC/MS of SVOCs, pesticides, and PCBs. The certified soil samples will be used to evaluate the performance of the TDGC/MS. In addition, the regulators will provide certified soil gas audit samples for analysis onsite by GC. The soil gas samples will be used to evaluate the performance of the GC.

The preparer of the certified samples will provide the analytical limits for each standard. A comparison of field results with preparer reported certified limits will be used to assess data quality and uses.

3.1 Sample Depth Rationale

The goal of the soil gas survey is to locate potential shallow vadose zone sources of VOCs that may contribute to the regional VOC contamination in groundwater. Soil gas samples must be collected deep enough in the soil so that losses to the atmosphere (or false positives due to migration and accumulation under the tarmac) are minimized. The normal approach in soil gas surveys is to collect one sample at each location at a depth of about 5 feet bgs. However, at MCAS El Toro, it is likely that VOCs were released as long as 40 years ago and have migrated into the vadose zone and the groundwater. The greatest possibility of detecting residual VOCs in the soil, based on available information, is to collect samples deeper than 5 feet bgs. Because of sample depth limitations (<30 feet bgs) of the direct push rigs, cost constraints, and possible influences of the air knife; soil gas samples will be collected at 12 feet and 20 feet bgs during the first round of soil gas sampling. These depths were agreed upon during the Remedial Project Manager (RPM) meeting held on 23 March 1994.

After the first round, it may be possible to reduce the number of samples collected at each location from two to one if data do not support the continued collection of two samples. For example, if zones of elevated soil gas are detected at 12 feet bgs and the soil gas concentrations are not significantly greater at 20 feet bgs, it may be decided to take all Round II samples at 12 feet bgs. The depth at which the second round samples are collected will be decided with input from the agencies at the same time that second round locations are selected.

It may also be desirable to collect soil gas samples from more than two depths from a few selected locations during the second round. This would allow a vertical profile to 30 feet at potential "hot spots" identified during the first round. Because of direct push technique depth constraints, opportunities for multidepth sampling will be limited during the soil gas survey. However, it will be possible to collect deep soil vapor samples using drill rigs if desired during the Phase II RI.

3.2 Sampling Location Rationale

Site 24 represents the possible source area for primary VOC groundwater contamination found at the Station. Site 24 consists of a considerable portion of most of the southwestern quadrant of the Station. Unlined portions of the Agua Chinon and the Bee Canyon Washes, part of Site 25, are also located in the southwestern quadrant of the Station. These areas will be the focus of the soil gas survey and soil screening sampling. Plate 1 shows the locations of the sites that will be investigated during the soil gas survey and the sampling locations for the initial 300 soil gas locations (Round I).

Of these, 228 have been targeted at potential source areas. These source areas were selected based on the results of the Phase I RI, the RFA record searches, employee interviews, and meetings and discussions with regulatory agencies (principally the Department of Toxic Substances Control [DTSC]). Other locations were selected by gridding the remaining areas within Site 24. Grid spacing is smaller in areas considered to have the greatest potential for containing the VOC source, such as the area southeast of Site 9. Grid spacing is greater in areas considered to have the least potential to contain the VOC source area, such as the western portion of Site 24.

3.2.1 Site 24 (Potential VOC Source Area)

Potential Site 24 VOC source areas are listed and described below. The source areas include SWMU/AOCs, sites identified during records searches, and RI sites.

OU 2 RI Sites

The following section summarizes the OU 2 RI sites within the soil gas survey area (Potential VOC source areas). Locations of Round I soil gas probes are described.

Site 7 (Drop Tank Drainage Area No. 2): Drop Tank Drainage Area No. 2 is in the southwest quadrant of the Station, north and east of Hangar Buildings 295 and 296. From 1969 to 1983, aircraft fuel drop tanks reportedly were drained of residual JP-5 fuel in this area. From 1972 to 1978, portions of this area served as an unpaved parking lot, and lubricant oils were applied for dust control. The concrete pad was placed in 1978. In 1982, 2,000 gallons of JP-5 fuel were accidently spilled from a tank truck in this area, and was washed with water onto the soil at the edge of the pad. A surface drainage runs to the south.

The site has five areas of concern:

- The edge of the pavement, north of Building 295, where drop tanks were drained and washed, and fuel residuals and rinse water drained from the pavement onto the adjacent grassy area. Approximately 7,000 gallons of JP-5 fuel and lubrication oil are estimated to have been disposed of at this location between 1969 and 1983. Three soil gas probes will be located along the north edge of the pavement edge at approximately a 200-foot spacing.

- The former edge of pavement east of Buildings 295 and 296 (pre-1973), where drop tanks were reportedly drained and flushed. Approximately 11,000 gallons of lubrication oil and 4,000 gallons of JP-5 fuel were applied for dust control at this location from 1972 to 1983. This area has been identified as an area for no further action because of calculated low risk (Draft Phase II RI Work Plan). No soil gas probes will be installed at the former edge of the pavement.

- Three soil gas probes will be installed at the current edge of pavement, east of Buildings 295 and 296. The probes will be spaced at approximately 200 feet.

- Five soil gas probes, spaced at approximately 200 feet, will be located along the drainage ditch, east of the pavement.

- One soil gas probe will be located in the open and (since about 1991) partially paved area south of Building 296.

Prior to the Phase I RI, suspected contaminants at this site included lubricant oils, JP-5 fuel, and other petroleum waste products.

Site 8 (DRMO Storage Yard): Site 8 (Defense Reutilization and Marketing Office [DRMO] Storage Yard), is a storage area for containerized liquids of unknown origin and various scrap materials (including mechanical and electrical components). Located on the southwest corner of South Marine Way and "R" Street, the Storage Yard is a fenced, unpaved lot located north of Building 360, which is still in use as a storage yard.

The site has two primary areas of concern: the Old Salvage Yard (eastern portion) and the current storage yard (western portion). The Old Salvage Yard location is now a gravel-topped pad elevated several feet above the surrounding street culverts which is used as a parking lot for Building 800; apparently, the parking lot is elevated as a result of paving over the Old Salvage Yard. In 1984, several gallons of PCB oil were spilled in the current Storage Yard. Refuse piles and staining are evident in site aerial photographs taken since 1952.

Prior to the Phase I RI, contaminants of potential concern at the site included PCBs, fuels, solvents that may have leaked from the scrap materials, and miscellaneous liquids.

Twenty-eight soil gas probes will be located at a grid spacing of approximately 200 feet at the two storage yards.

Site 9 (Crash Crew Pit No. 1): The Crash Crew Pit No. 1 is located in the west quadrant of the facility, east of Building 306 and just south of an aircraft taxiway. The site consists of two pits (east and west), both formerly used during firefighting training. The former pits are currently filled with dirt and covered with grass; the east pit is partly covered with aircraft matting. The

terrain in the vicinity of the pits is flat, and lies at an elevation of about 300 feet above msl. The potential for surface water runoff currently appears to be negligible.

The west pit is estimated to have been approximately 150 feet long (from east to west), and 25 to 50 feet wide (from north to south), and 3 to 4 feet deep. During training, the pit was filled with water and layered with JP-5 fuel, aviation gasoline, and possibly crankcase oil and other wastes. Then the liquids were ignited. From 1965 through 1971, an estimated 123,700 gallons of waste liquids were used in the west pit training exercises, 10 percent of which may have infiltrated into the subsurface (Brown and Caldwell, 1986).

Operational information for the east pit is not available. On aerial photographs, the east pit appears elliptical in shape, about 90-feet long (from east to west), and about 60-feet wide (from north to south); its depth is uncertain.

Prior to the Phase I RI, the pits' suspected contaminants were VOCs, SVOCs, petroleum hydrocarbons, and metals.

Nine soil gas probes will be located at Crash Crew Pit 1. One probe will be placed in the center of each pit and seven probes will be located surrounding both pits.

Site 10 (Petroleum Disposal Area): Site 10 (Petroleum Disposal Area) is located south of Building 435 and east of Building 369 (see Plate 1). It comprises an area of approximately 1,200 by 800 feet. From 1952 through 1970, an estimated 52,000 gallons of waste crankcase oil, antifreeze, hydraulic and transmission fluids, motor oils, and solvents were applied to an area of approximately 960,000 square feet for dust control. Since 1970, the areas that were previously sprayed have been excavated and concreted or built upon.

The site is currently covered with metal aircraft matting (installed in 1973) and a concrete apron (placed in 1971). As part of the installation of aircraft matting, soil was mixed with dry cement, then wetted. During construction of

the concrete apron, soil was excavated to a depth of 2 feet. The disposition of the excavated soil is unknown (Brown and Caldwell, 1986). Thus, Site 10 has essentially been paved since 1973. Very little migration has probably occurred since then, either by infiltration of contaminated water through the vadose zone to groundwater or by surface water runoff.

Prior to the Phase I RI, suspected contaminants at the site included crankcase oil, antifreeze, hydraulic and transmission fluids, motor oils, and solvents.

The site was divided into two statistical strata (subareas) for sampling and discussing shallow soil contamination:

- Stratum 1: Aircraft Matting Area
- Stratum 2: Concrete Apron Area

Dust control activities took place over the areas defined by both strata. Historical aerial photographs indicate that nearly the entire area was discolored by heavy staining. The two strata are differentiated by the paving materials on their surfaces; the concrete parking apron and the metal aircraft matting likely have different permeabilities. Because solvents may have been among the fluids discharged for dust control, Site 10 is considered to be a potential source area for the regional groundwater VOC contamination. However, a specific source of this contamination has not yet been located. The source of the VOC contamination will be investigated as part of Site 24 activities, which will include the area contained within Site 10.

Thirty-six soil gas probes will be located at Site 10: 18 at the Aircraft Matting Area and 18 at the Concrete Apron Area. Within the areas, grid spacing will be approximately 200 feet. Surrounding the edges, the grid spacing will be approximately 150 feet.

Site 11 (Transformer Storage Area): Site 11 (Transformer Storage Area) is a 30-square foot concrete pad located northeast of Building 369, where approximately 50 to 75 transformers were stored (1968-1983) (see Plate 1).

Reportedly, five transformers leaked and one spilled an estimated 60 gallons of PCB transformer oil that may have leaked onto the concrete pad. In 1983, the transformers were removed and disposed of off-Station (Brown and Caldwell, 1986).

Prior to the Phase I RI, suspected contaminants at the site were PCBs. One soil gas probe will be located at the perimeter of the concrete at Site 11. The probe location (#28) is at the edge of the concrete to detect oil that may have run off the concrete and seeped into the soil.

Site 22 (Tactical Air Fuel Dispensing System): Site 22 (Tactical Air Fuel Dispensing System [TAFDS]), is located both within and west of Site 10 (Petroleum Disposal Area) (see Plate 1). Site 22 has an undocumented history of fuel spills and leaks from routine operations. Aerial photographs from 1965 and 1970 show that the TAFDS was originally located at the eastern portion of Site 10. The TAFDS was later relocated to the west of Site 10, as shown in 1980 and 1986 photographs. Heavy staining was reportedly observed at both the west and east TAFDS locations.

Several fuel bladder revetments (FBRs), each containing a fuel bladder, were located at the TAFDS. Numerous stained areas surrounded these FBRs. In 1984/1985, a spill reportedly occurred, and unknown quantities of fuel and soil were removed.

Prior to the Phase I RI, suspected contaminants at Site 22 included VOCs, SVOCs, and petroleum products.

The site was divided into two strata:

- Stratum 1: Western Area (the west fuel dispensing area, located west of Site 10, south of Building 435, and east of Building 369 [1980-1986])

- Stratum 2: Eastern Area (the east fuel dispensing area, originally [pre-1980] located within Site 10)

At both strata, historical aerial photographs reveal the former presence of fuel bladders and FBRs, together with numerous stained areas. The differences between the two strata include their periods of operation and the fact that Stratum 2 is presently covered with concrete, while Stratum 1 is unpaved. Two soil gas probes will be located within the western area. The eastern area is addressed by soil gas probes within Site 10.

RFA SWMU/AOCs

Below is a list of SWMU/AOCs investigated during the RFA field work. The SWMU/AOCs listed include either areas where VOCs were detected or areas that are considered potential VOC source areas, or both. The rationale and number of soil gas probes are discussed under each SWMU/AOC.

SWMU/AOC 76 (Oil/Water Separator): The oil/water separator (OWS) (Tank 297-B) is a 100-gallon, steel-walled tank located adjacent to the east side of Building 297. The OWS, installed in 1972, is currently active and receives wastewater from Building 297. One soil gas probe will be located adjacent to the OWS.

SWMU/AOC 84 (Oil/Water Separator): South of Building 298 and north of South Marine Way. One soil gas probe will be located across South Marine Way, along the industrial sewer line.

SWMU/AOC 95 (Engine Test Cell): The former Engine Test Cell (Building 324) is currently used as an aircraft maintenance training facility (northern portion) and a storage facility for the Station Fire Department (southern portion). During the visual site inspection (VSI), a potential former hazardous waste storage area (HWSA) was identified (near the southeastern corner of Building 324). One soil gas probe will be located within the former hazardous waste storage area.

Building 359: Five SWMU/AOCs of interest are adjacent to Building 359. Figure 3-3 shows the SWMU/AOC locations and soil gas probe locations for Round I. The following is a description of the SWMU/AOCs.

SWMU/AOC 98 (Vehicle Wash Rack): A vehicle wash rack is located on the southeast side of Building 359. One soil gas probe will be located in the vehicle wash rack area.

SWMU/AOC 99 (Drum Storage Area): One soil gas probe will be located within the drum storage area south of Building 359.

SWMU/AOC 100 (TCE Degreaser): One soil gas probe will be located adjacent to the TCE Degreaser south of Building 359.

SWMU/AOC 101 (Oil/Water Separator): One soil gas probe will be located adjacent to the oil/water separator south of Building 359.

SWMU/AOC 303 (Underground Storage Tank): There is a UST located in Building 359. One soil gas probe will be located immediately outside of the building adjacent to the UST.

SWMU/AOC 110 (Vehicle Wash Rack): This wash rack is located adjacent to the northwest side of Building 386, and consists of a concrete wash surface surrounded by a 4-inch-concrete berm. The wash rack area is approximately 3,200 square feet. A drain in the center of the wash rack led to an OWS (labeled 386-B in the RFA). The wash rack is currently inactive, but was formerly used for washing vehicles and equipment. A 500-gallon aboveground waste oil tank is stored on the wash rack. During the VSI, the wash rack surface was observed to be cracked and darkly stained. One soil gas probe will be located on the vehicle wash rack.

SWMU/AOC 145 (Underground Storage Tank): UST 529 is a waste oil tank located adjacent to the northeast side of Building 529. The UST is concrete and has a 25,000-gallon capacity. The tank was installed in 1944 and is

currently active. It has not been tank-tested. One soil gas probe will be located adjacent to the UST, as shown in Figure 3-4.

SWMU/AOC 173 (Oil/Water Separator north of Site 8 and Well 29): One soil gas probe will be located adjacent to the OWS, as shown in Figure 3-5.

SWMU/AOC 175, 176 (Underground Storage Tanks north of Building 672/Oil Water Separator): One probe will be placed between the two USTs, as shown in Figure 3-6.

SWMU/AOC 188 (Underground Storage Tank at Oil/Water Separator along Agua Chinon Wash): One soil gas probe will be located adjacent to the UST, as shown in Figure 3-7.

SWMU/AOC 198 (Vehicle Wash Rack): This wash rack is located adjacent to the northeast side of Building 655, and consists of a concrete wash surface surrounded by a concrete berm. The wash rack measures 15 feet by 60 feet. There are two drains located in the center of the wash area that lead to an OWS (RFA site SWMU/AOC 199). The concrete surface has several large cracks and is darkly stained. The construction date of the wash rack, which is currently active, is not known. One soil gas probe will be located within the vehicle wash area.

SWMU/AOC 199 (Oil/Water Separator): The OWS located near SWMU 198 west of the north end of Building 655 along the street. One soil gas probe will be located adjacent to the OWS.

SWMU/AOC 229 (Hazardous Waste Storage Area): This HWSA is located east of Building 800, adjacent to the southeastern boundary fence of the Station. The area consists of a concrete pad measuring 10 feet by 20 feet with an 8-inch-concrete berm. The HWSA is currently active and is used to store waste oil, antifreeze, used batteries, hydraulic fluid, and waste grease. During the VSI, the concrete surface was slightly stained but no cracks were observed.

The construction date of the HWSA is not known. One soil gas probe will be located within the hazardous waste storage area, as shown in Figure 3-8.

SWMU/AOC 231 (Underground Storage Tank): This UST is located on the north side of Building 800 in the Motor Pool area. One soil gas probe will be located adjacent to the UST (see Figure 3-8).

SWMU/AOC 250 (Underground Storage Tank): A UST for waste oil storage is located at the eastern corner of Building 655. The size, construction materials, and installation date of the tank are not known. The UST has not been tank-tested. During the VSI, the pavement around the tank fill box was observed to be darkly stained and cracked. One soil gas probe will be located adjacent to the UST.

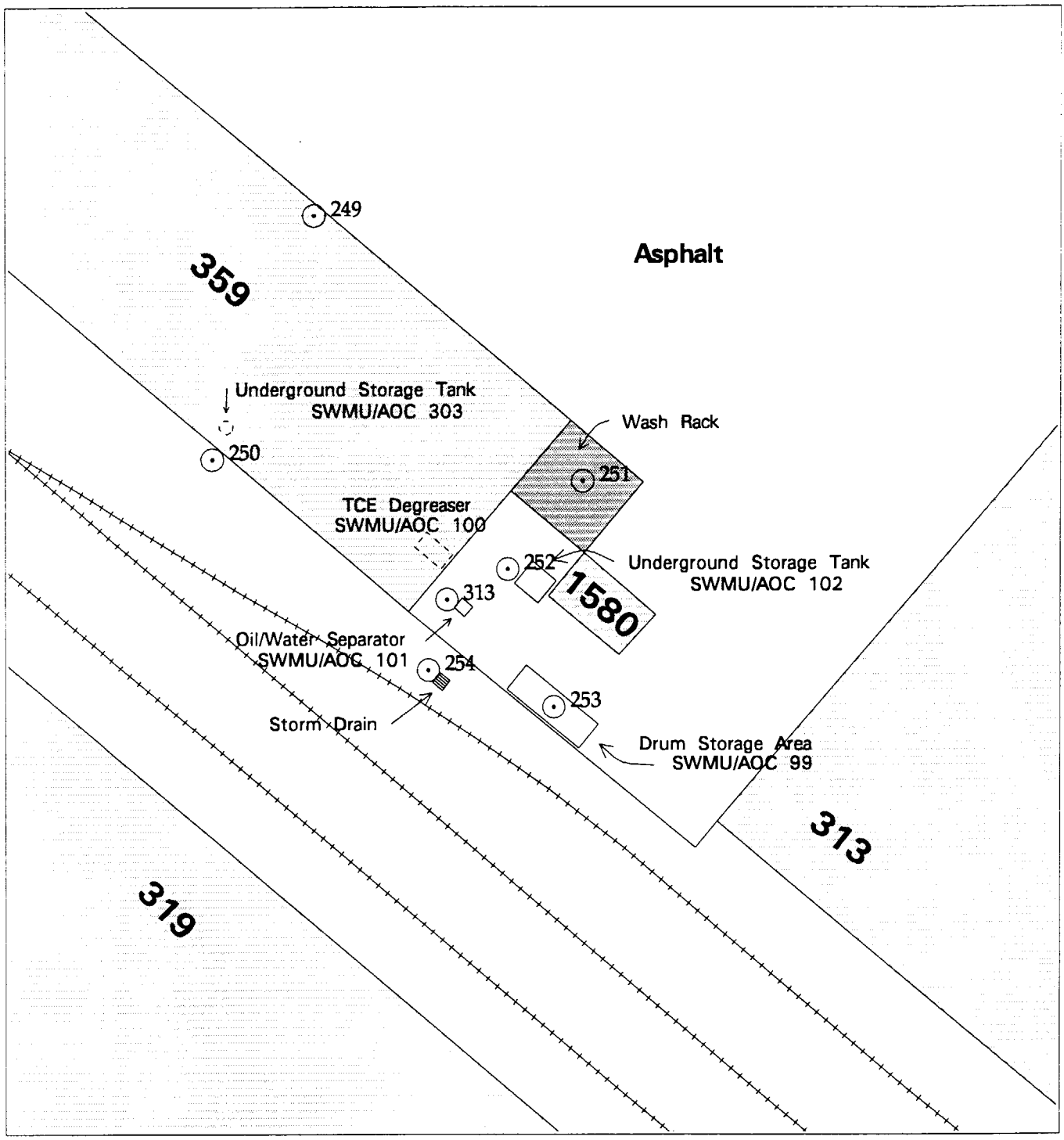
SWMU/AOC 283 (Underground Storage Tank): Tank 326-B is located adjacent to the south side of Building 326; its construction material and contents are unknown. The tank was installed in 1945 and is currently inactive. Building 326 is currently abandoned. One soil gas probe will be located adjacent to the UST.

Other Site 24 Features

Several features within the Site 24 boundary will be further investigated as potential sources of VOC contamination. The features were identified during the Phase II Work Plan/DQO process. These features and soil gas locations are discussed below.

Refurbishing Operations

During the 1940s, aircraft refurbishing operations were conducted in the southwest portion of the Station, and were centered in Buildings 296, 297, and 324. Refurbishing operations consisted of cleaning and plating activities that may have included the use of solvent materials. The types of materials used in



FEATURES:

- ROUND 1 PROPOSED SOIL GAS SAMPLE LOCATION
- BUILDING
- CONCRETE
- FENCE
- RAILROAD

SWMU/AOC Number and Type:
98 - Vehicle Wash Rack
99 - Drum Storage Area
100 - TCE Degreaser
101 - Oil/Water Separator
102 - Underground Storage Tank
303 - Underground Storage Tank

0 20 40 80
SCALE IN FEET

FIGURE 3-3
BUILDING 359
SOIL GAS PROBE LOCATIONS

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Plot date: 09 May 94 16:32:55 Monday

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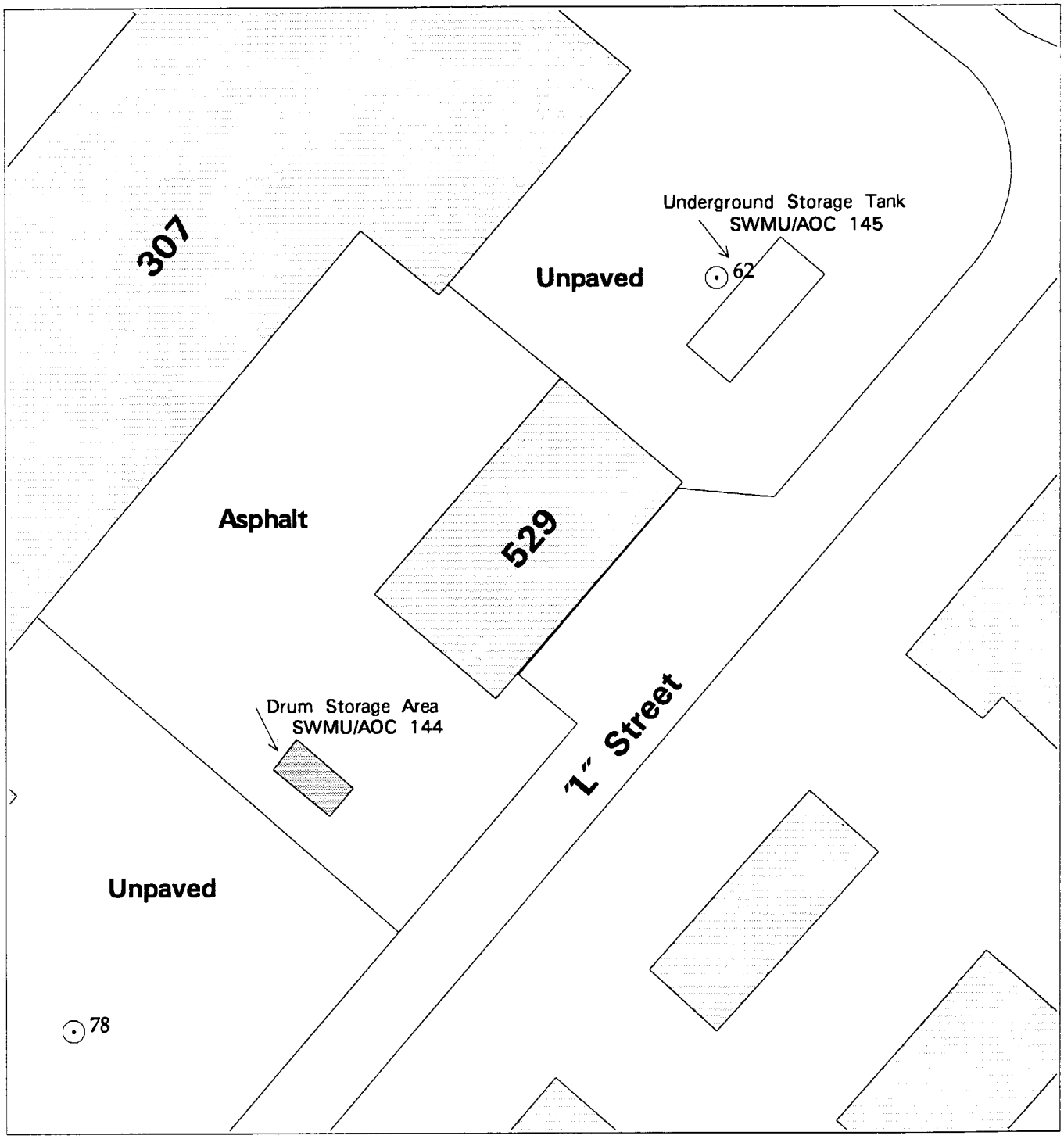

FEATURES:

- ROUND 1 PROPOSED SOIL GAS SAMPLE LOCATION
- BUILDING
- CONCRETE
- FENCE
- RAILROAD

SWMU/AOC Number and Type:
144 - Drum Storage Area
145 - Underground Storage Tank

0 20 40 80
SCALE IN FEET

FIGURE 3-4
SWMU 145
SOIL GAS PROBE LOCATIONS

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Plot date: 09 May 94 16:54:47 Monday

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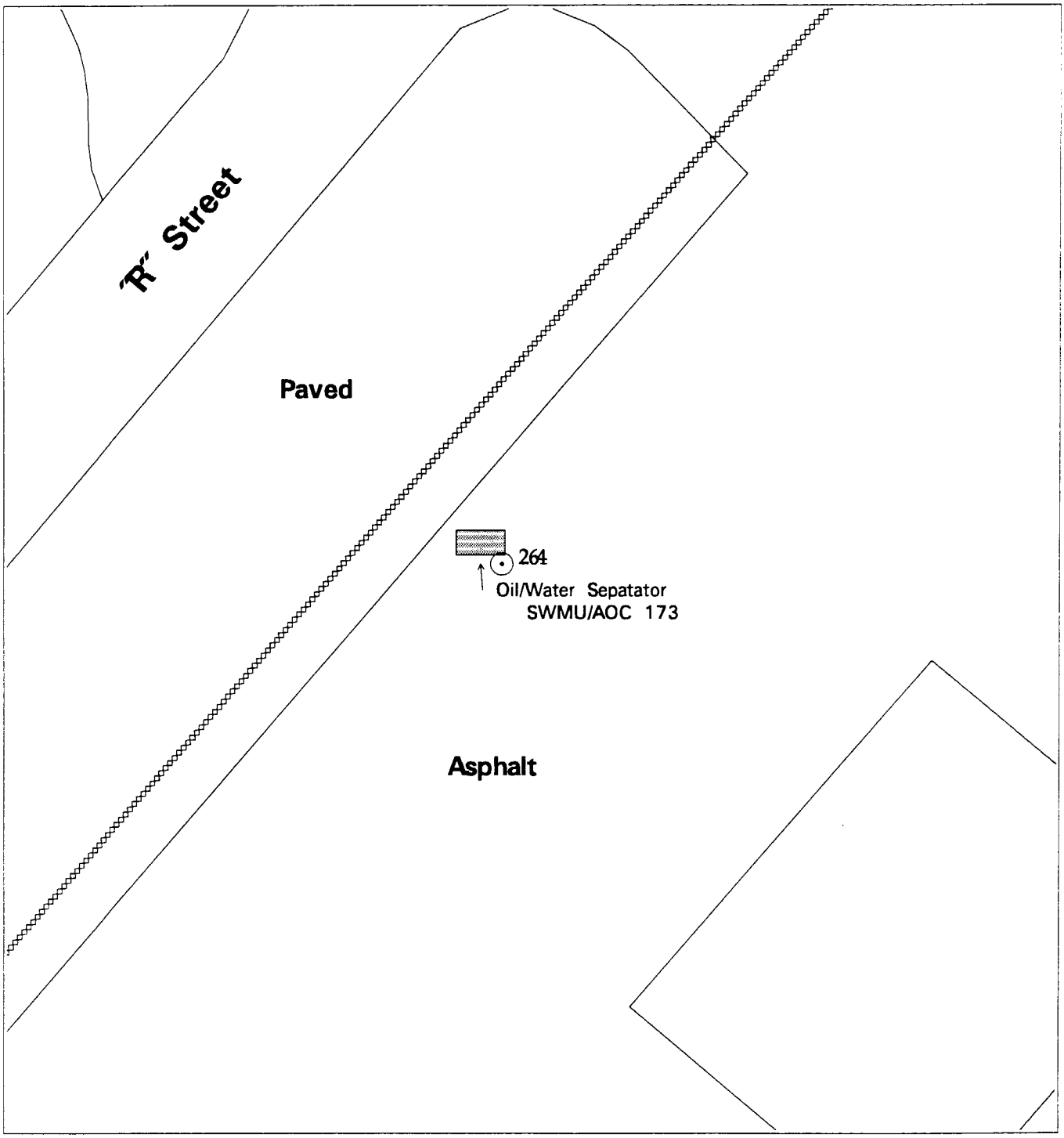

FEATURES:

- ROUND 1 PROPOSED SOIL GAS SAMPLE LOCATION
- BUILDING
- CONCRETE
- FENCE
- RAILROAD

SWMU/AOC Number and Type:
173 - Oil/Water Separator

0 10 20 40
SCALE IN FEET

FIGURE 3-5
SWMU 173
SOIL GAS PROBE LOCATIONS

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Plot date: 09 May 94 17:04:33 Monday

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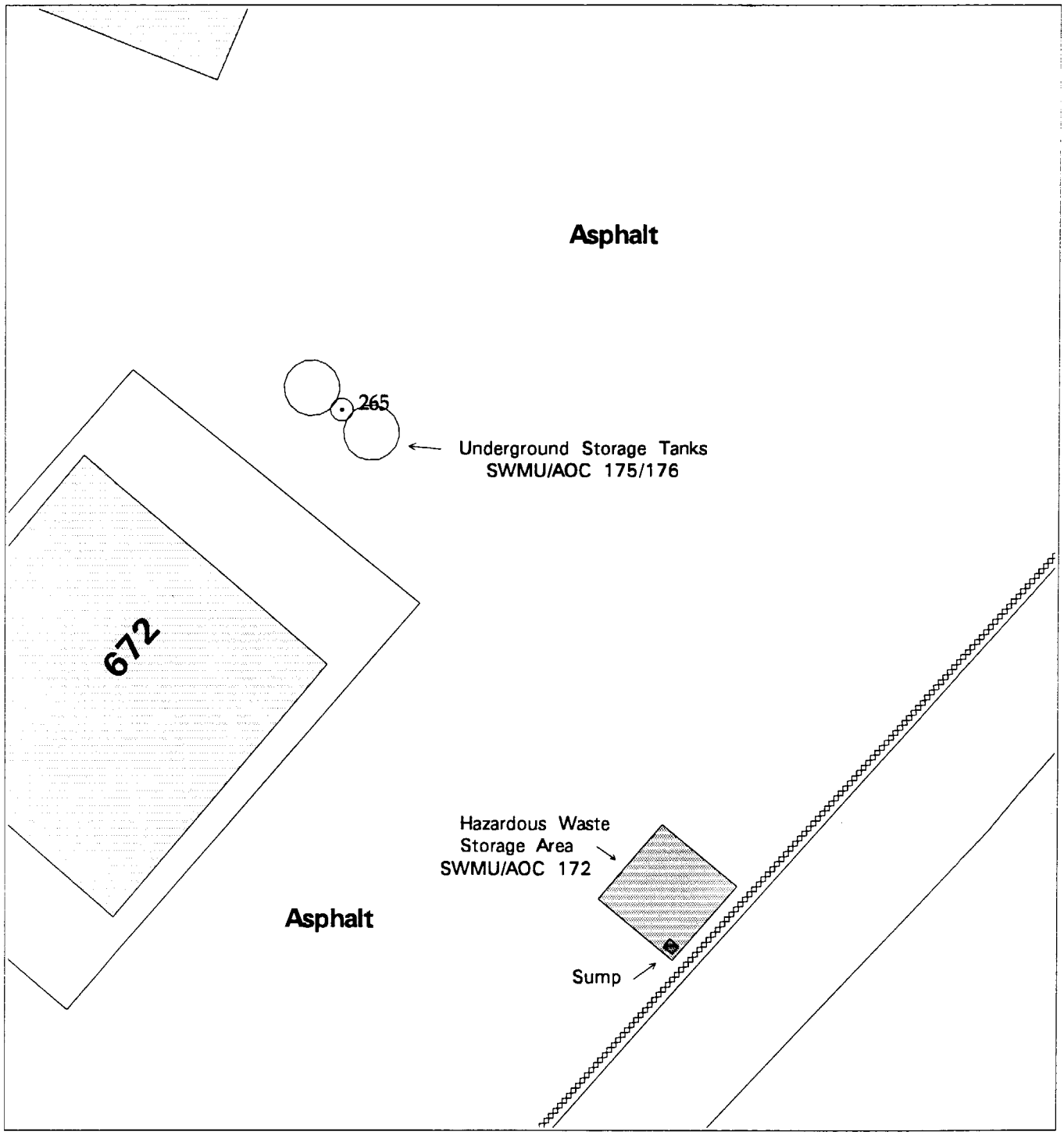

FEATURES:

- ROUND 1 PROPOSED SOIL GAS SAMPLE LOCATION
- BUILDING
- CONCRETE
- FENCE
- RAILROAD

SWMU/AOC Number and Type:
172 - Hazardous Waste Storage Area
175 - Underground Storage Tank
176 - Underground Storage Tank

0 10 20 40
SCALE IN FEET

FIGURE 3-6
SWMU 175/176
SOIL GAS PROBE LOCATIONS

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Plot date: 09 May 94 16:48:53 Monday

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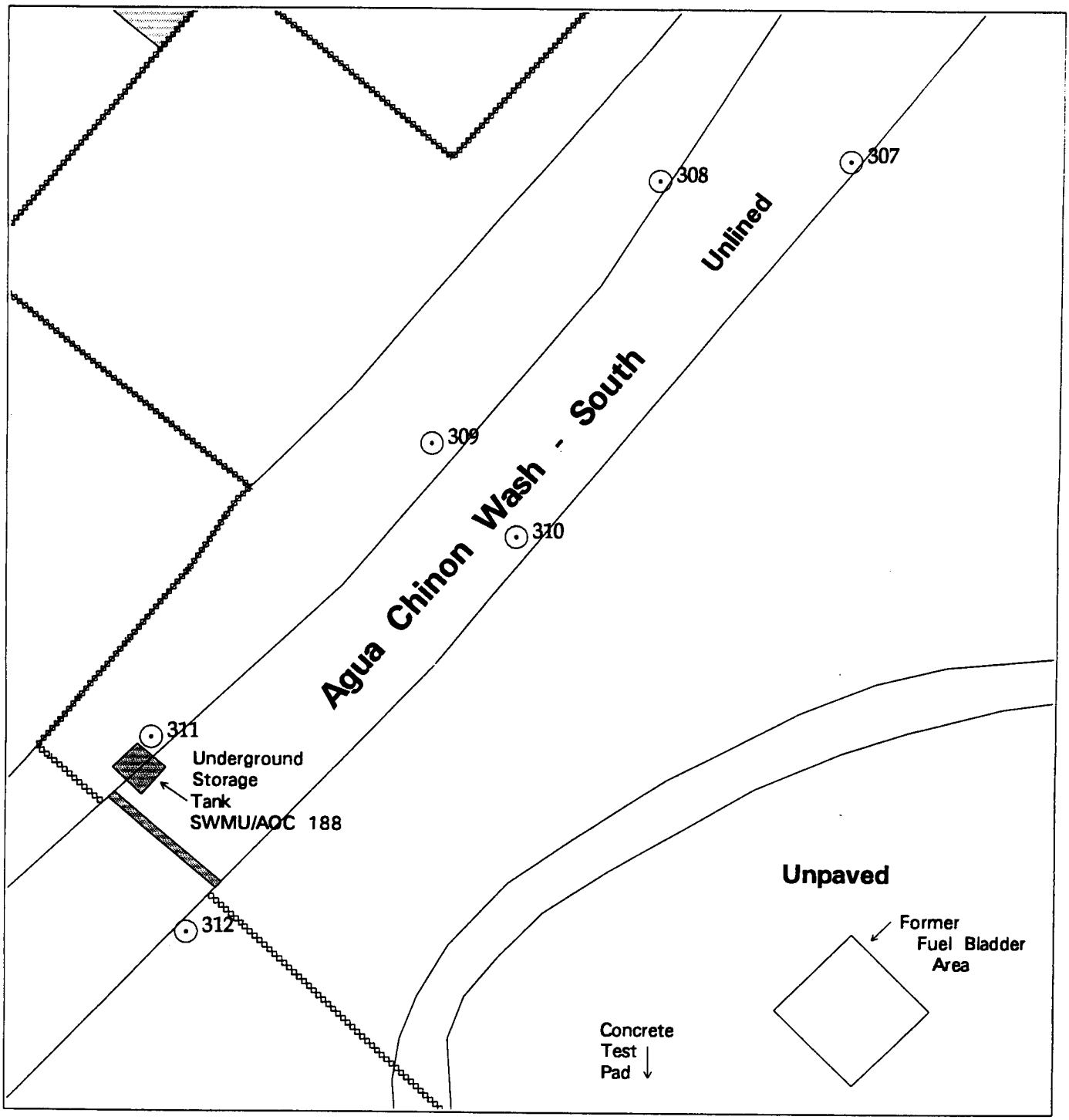

FEATURES:

- ROUND 1 PROPOSED SOIL GAS SAMPLE LOCATION
- BUILDING
- CONCRETE
- FENCE
- RAILROAD

SWMU/AOC Number and Type:
9 - Fuel Bladder
11 - Agua Chinon Wash
188 - Underground Storage Tank

0 20 40 80
SCALE IN FEET

FIGURE 3-7
SWMU 188
SOIL GAS PROBE LOCATIONS

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Plot date: 09 May 94 17:12:32 Monday

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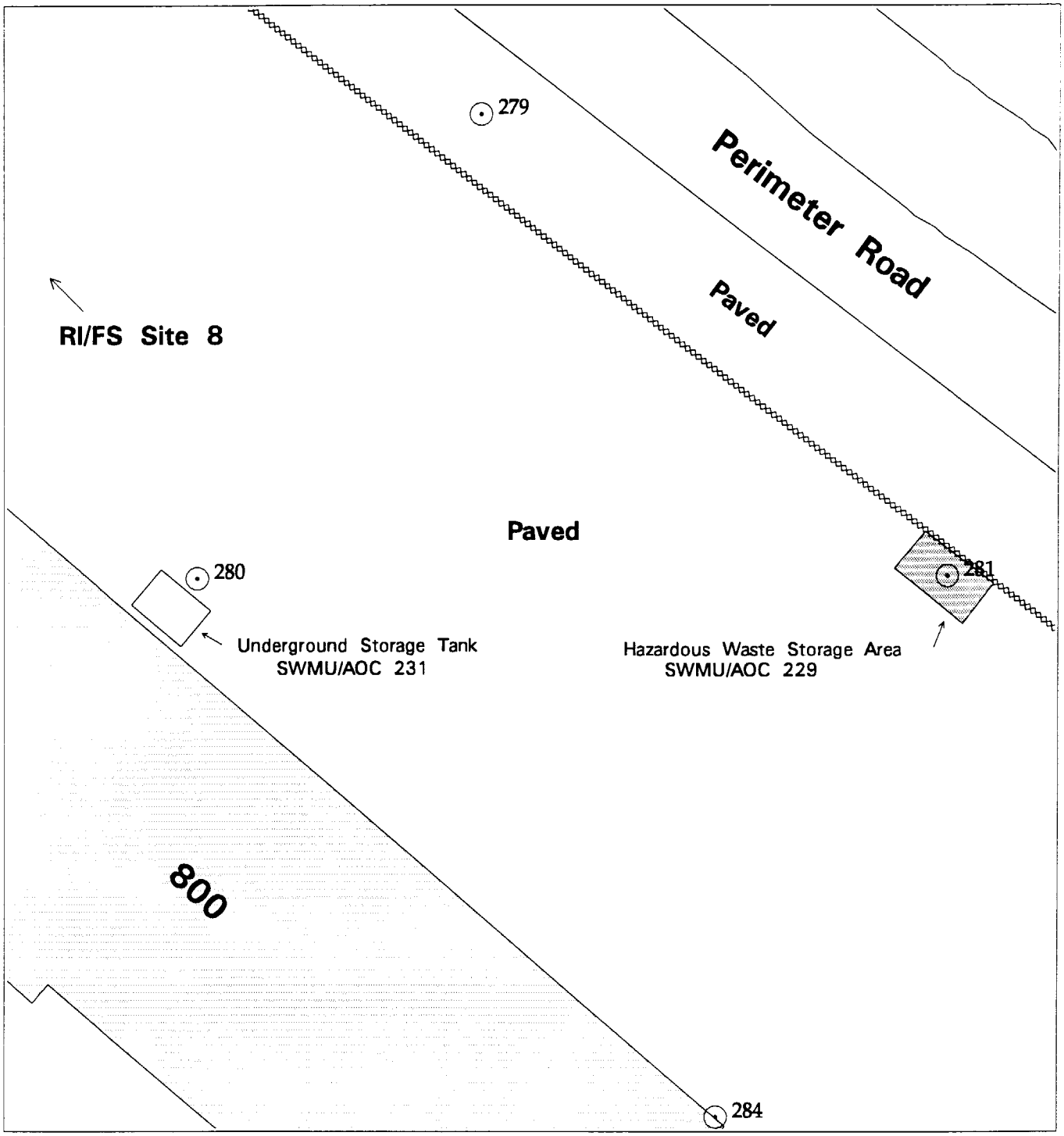

FEATURES:

- ROUND 1 PROPOSED SOIL GAS SAMPLE LOCATION
- BUILDING
- CONCRETE
- FENCE
- RAILROAD

SWMU/AOC Number and Type:
229 - Hazardous Waste Storage Area
231 - Underground Storage Tank

0 20 40 80
SCALE IN FEET

FIGURE 3-8
SWMU 229/231
SOIL GAS PROBE LOCATIONS

MCAS EL TORO
SOIL GAS SURVEY WORK PLAN

Plot date: 09 May 94 16:41:43 Monday

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the degreasers and cleaning tanks are not known. Wastewater from these buildings was discharged to the abandoned industrial wastewater sewer lines. Information on the locations of the refurbishing equipment is based on building plans from the 1940s obtained from the Station's Public Works Department. Based on interviews with a retired Station employee, the equipment associated with the refurbishing operations was used for only 6 months, and was then transferred off-Station within the next 3 months. The following sections describe the refurbishing materials and equipment used. The general locations of these former refurbishing facilities, along with the initial soil gas probe locations are shown in Plate 1.

- Building 296: Building 296, along with Building 297, comprised the Assembly and Repair (A&R) Shops at the Station. Building 296 is located north of South Marine Way, adjacent to the west side of Building 297. Activities potentially involving the use of solvent materials were located in the north and south portions of the building. During the first round of soil gas sampling, 28 soil gas probes will be located in the vicinity of Building 296 at approximately a 150-foot grid spacing.

  A Paint Shop and a Dope Shop were located in the southeast corner of the building; a degreaser was located in the north portion. This area also housed a Paint Mixing Room.

  A Propeller Shop was located in the northwest corner of Building 296, and was used for stripping, plating, and painting. Cadmium and zinc plating tanks were located in the southeast corner of the shop, as well as a degreaser machine, a nitric acid strip tank, and two rinse tanks. Adjacent to these plating tanks were tanks for paint stripping, alkali soaking and rinsing, and anodizing. A paint spray booth was located in the northwest corner of the shop.

- Building 297: Building 297 (located west of Building 296) housed activities potentially involving solvent materials in the south portion of

the building. During the first round of soil gas sampling, 25 probes will be located in the vicinity of Building 297 at approximately a 150-foot grid spacing.

A Cleaning Shop was located in the southwest corner of Building 297. The shop housed a degreaser, a stripping tank, three solution tanks, and numerous steam-cleaning units. Also, a cleaning area was located at the south side of the shop, outside of Building 297; this area consisted of a concrete pad. It is not known if runoff from this area entered the sewer. There is currently a sump in this area that may have been part of the wash area; the sump is not connected to the sewer system.

A Sandblast Shop (east of the Cleaning Shop) had a sandblast room and a degreaser. The degreaser was located at the south side of other shop in the Elevator Room.

A Plating and Anodizing Shop (east of the Sandblast Shop) housed numerous tanks built in a pit:

- Degreaser
- Anodizing Tank
- Acid Dip Tanks (4)
- Alkali Strip Tanks (2)
- Cadmium Plate Tank
- Cadmium Strip Tank
- Chronic Dip Tank
- Hard Chrome Tank
- Reverse Chrome Tank
- Chromium Plating Barrel
- Copper Plate Tank
- Cyanide Dip Tank
- Nickel Plate Tank
- Zinc Plate Tank

- Zinc Strip Tank
- Rinse Tanks (8)
- Cleaning Tank
- Wax Dip Tank

o Building 324: The former Engine Overhaul Building is located south of Buildings 296 and 297, west of "R" Street. The western portion of this building formerly housed plating, cleaning, and painting facilities. The east side comprised two engine test cells. The building plan for Building 324 shows a Machine Room located at the west side of the structure. A steam pit and second pit with no use identified were located in the Machine Room. During the first round of soil gas sampling, 14 probes will be located surrounding Building 324 at approximately a 100-foot spacing.

A Cleaning Shop (adjacent to the Machine Room) had a series of cleaning tanks for steel and aluminum alloy parts and a degreaser. The building plan indicates that these tanks were in a pit.

A Plating Room was located east of the Cleaning Shop at the north side of the building. Types of plating tanks included arsenic, chromium, cadmium, lead, magnesium, tin, and zinc. The shop also had a degreaser, hot rinse, and strip and acid tanks; these tanks were within a pit.

A Painting Room was located west of these shops at the north side of the building. This room housed a paint booth and a degreaser; the degreaser was in a pit.

An Accessory Cleaning Area was located in the eastern side of the building adjacent to the engine test cells. The room housed several cleaning tanks with unknown contents, a varsol booth (stoddard solvent), and a degreaser pit.

A Carbon Dioxide (CO_2) Cylinder Overhaul and Filling Room was located at the southeast corner of Building 324. This room contained a spray paint booth and two pits for hydrostatic testing of the cylinders.

Abandoned Industrial Sewer Lines

Based on an interview with a retired Station employee, these industrial lines, constructed of vitrified clay, were installed in 1945. Their general layout is shown in Plate 1; the alignments of the industrial lines shown are based on Station utilities maps.

The industrial lines received wastewater discharges from the buildings associated with the refurbishing operations described above. According to the retired Station employee, this occurred for approximately 6 months. These wastes may have included solvents and metal plating wastes.

Wastewater from the industrial lines was treated at the Former Industrial Wastewater Treatment Plant, located adjacent to the Former Wastewater Treatment Plant (SWMU/AOC 90), south of Site 24. Based on construction maps dated 1945 and historical aerial photographs, the Industrial Wastewater Treatment Plant was present at the Station from approximately 1945 to the late 1950s or 1960s. (The vertical tanks associated with the plant are present in a 1955 photograph and absent in a 1965 photograph.) The Industrial Wastewater Treatment Plant will be investigated in the Phase II RI as part of SWMU/AOC 90 (see Site 12). During the first round of soil gas sampling, 16 soil gas probes will be located along the industrial sewer lines at approximately 200-foot spacings.

Station utilities maps indicate that Building 359 (Preservation Building) was also connected to the industrial lines. Station building records indicate that Building 359 was constructed in 1952. Building plans indicate that the building contained a TCE-based vapor degreaser and four cold dip tanks with unknown contents; a waste sump connected to the industrial lines was located on the

south side of the building. The TCE-based vapor degreaser, a UST connected to the degreaser, and the waste sump were investigated in the RFA as SWMUs/AOCs 100 and 303, respectively. No chlorinated VOCs were detected in the soil samples from these SWMUs/AOCs, and no further action was recommended (RFA, 1993). The duration of discharges from Building 359 to the industrial lines is not known. Soil gas probe numbers 246 and 219 are located along the industrial line from Building 359.

Station utilities maps indicate that the Photography Laboratory (Building 312) was also connected to the industrial lines. Building 312 was constructed in approximately 1945. Building plans indicate that "acid wastes" were generated at this building. The duration of discharges from the laboratory to the industrial lines is not known.

Former Building 1589

Former Building 1589 is a vehicle maintenance facility located west of Site 10 and south of Site 11. According to the Initial Assessment Study (IAS) Report (NEESA, 1986), Building 1589 was used as a vehicle repair/maintenance facility. The IAS Report identified several features at this building, including two 500-gallon tanks for mixing oil and solvents, a degreaser, and a waterwall curtain paint booth. During August and September 1993, the Jacobs Team visited the Station to research information on these features. According to a 1977 construction plan obtained at the Station's Public Works Building, Building 1589 was joined with the building located directly to the east (Building 386) to form current Building 386. In September 1993, the Jacobs Team interviewed a worker to obtain additional details regarding the features identified by the IAS Report. The individual interviewed, who has worked at Building 386 since approximately 1966, confirmed that features identified by the IAS Report had been present at or near former Building 1589.

The two 500-gallon tanks, referred to as "buffalos," were aboveground storage tanks (ASTs) mounted on wheels so that they could be moved around the shop area. One tank was kept on the north side, and one on the west side of

Building 1589. The tanks stored waste oil generated from vehicle maintenance at the shop (e.g., oil changes, engine overhauls). According to the worker, an off-Station contractor periodically pumped the waste oil from the tanks and transported it off-Station for recycling. The tanks were always stored on a paved surface and no spills, other than minor drippings onto the concrete surface, have occurred at the shop (personal communication, Mr. Porter Lilly, MCAS El Toro, September 1993).

A solvent degreaser was formerly located in the eastern portion of former Building 1589. This area served as a Machine Shop (Lilly, 1993). The precise location of the degreaser could not be identified during the site visit, and no as-built plans have been obtained at the Station. However, floor markings observed during the site visit indicate that the degreaser have been located along the northern wall of the Machine Shop.

A waterwall curtain paint booth was formerly located at Building 299 located, south of former Building 1589. The booth, located at the north side of the building on a concrete-paved area, was a complete unit provided by an outside contractor (Lilly, 1993). No additional details about the booth were available.

During the first round of soil gas sampling, seven probes will be located surrounding Building 386 at approximately 100-foot spacing.

Abandoned Water Wells

Station records indicate the presence of six abandoned water production wells (Wells 1 through 6) at Site 24. Available information indicates that these wells were used from the 1940s up to the early 1970s. The Station began using water from the Orange County Water District (OCWD) in the early 1970s. Information on these abandoned wells is provided below. Plate 1 shows the approximate locations of the wells based on Station drawings from the 1940s. One soil gas probe will be located adjacent to each of the abandoned wells, although no reports of improper use of these wells exist.

- Well No. 1: This abandoned well is located approximately 300 feet east of Site 10 adjacent to a taxiway. The well was drilled in 1943 to a depth of 527 feet bgs, and had 14-inch steel casing to a depth of 427 feet bgs. The well was connected via an underground pipeline to a water reservoir located to the west. No information on the well's demolition was available.

- Well No. 2: This abandoned well is located in the northern portion of Site 10, approximately 300 feet west of the Crash Crew Building 435. The well was drilled in 1943. The boring depth was 645 feet bgs, with 12-inch steel casing to a depth of 470 feet bgs. The well was demolished in November 1971; no specific information on the demolition was available.

- Well No. 3: This abandoned well is located west of Site 10 at the south side of Building 369. The entire area in the vicinity of the well is currently paved, and the well may be covered over by Building 369. No information on well construction or demolition was available.

- Well No. 4: This well is located west of Building 370 in an unpaved area near the western border of Site 24. No information on well construction or demolition was available.

- Well No. 5: This abandoned well is located approximately 250 feet west of Site 9, near the western water reservoir. This well was drilled in 1944; the boring depth was 500 feet bgs with 12-inch steel casing to a depth of 450 feet bgs. The well was demolished in August 1963; no specific information on its demolition was available.

- Well No. 6: This abandoned well is located in the western corner of Site 10. The well was drilled in 1944 to a depth of 450 feet bgs; the depth of the well's 14-inch steel casing is not known. No information on its demolition was available.

The California Department of Water Resources was contacted regarding information on these wells, but does not have any records of these wells.

3.2.2 Site 25 (Major Drainages)

Site 25 (shown in Figure 1-1) consists of four main drainage channels that flow through or adjacent to the Station, and portions of San Diego Creek. As described earlier, the unlined portions of the Bee Canyon and Agua Chinon Washes at the southwest side of the Station will be investigated. A detailed description of their flow paths is presented below.

Agua Chinon Wash. This channel traverses the east-central portion of MCAS El Toro, entering the Station at Site 3/4 on the northeast edge of MCAS El Toro and into a culvert. The wash is culverted across the entire Station, except for a short reach adjacent to Site 19. It emerges from the culvert about 100 yards from the southwestern boundary, but then is culverted again at the Station boundary and continues nearly to San Diego Creek. The unlined portion of Agua Chinon Wash near the southwestern boundary is currently being realigned and lined with concrete. Ten soil gas probes at approximately 150-foot spacing will be located along the portion of the Agua Chinon Wash, which passes the southern side of Site 24 (see Plate 1).

Bee Canyon Wash. This channel traverses the west-control portion of MCAS El Toro. As with the Agua Chinon Wash, it enters a culvert at the Station Boundary and remains culverted across MCAS El Toro, re-emerging for about 100 yards at the southwestern boundary. The wash then re-enters a culvert and remains culverted for the remainder of the way to San Diego Creek. Ten soil gas probes will be located at approximately 150-foot spacing along the Bee Canyon Wash where the wash passes the west side of Site 24, as shown on Plate 1.

3.3 Sampling and Analysis Procedures

This section describes the methods and procedures to be used during the soil gas investigation at MCAS El Toro. Occasional deviations, as dictated by unusual field conditions, will be made by the field engineer as necessary. The modifications to these procedures will be recorded in the field notebook and described in the soil gas investigation technical report submitted at the conclusion of the investigation.

Approximately 1,000 soil gas samples will be collected from approximately 500 locations within the southwest quadrant of the Station to evaluate subsurface source areas of VOCs. The soil gas samples will be collected in two consecutive rounds. During the second round of soil gas sampling, approximately 200 subsurface soil samples will also be collected. Soil gas and soil samples will be analyzed for selected VOCs and BTEX. Forty soil samples will be sent offsite for analysis of VOCs.

The first round of soil gas samples will consist of approximately 600 soil gas samples collected from 300 locations. Based on the results of the first round, a second round of 400 soil gas samples will be collected from 200 locations with the purpose of defining the extent of the higher concentration locations. Depths and locations will be determined based on the first round sample results. In addition, five surficial soil samples will be collected to evaluate the performance of the onsite TDGC/MS. Soil gas samples will be analyzed for up to 12 VOCs and BTEX compounds, using a GC equipped with an FID and an ECD.

Up to 200 subsurface soil samples will be collected during the second round of the soil gas investigation. The locations and depths of soil samples will be predetermined based on Round I soil gas results. Additional locations may be sampled based on organic vapor analyzer (OVA) or HNu detections in the field. Soil samples will be collected in areas of:

- Elevated VOC soil gas concentrations
- At Sites 8 and 11 (which are suspected to have PCB contamination)
- Along the edge of pavement areas where pesticides may be concentrated

Soil samples will be analyzed in the field for VOCs and fuel hydrocarbons using a thermal desorption gas chromatograph/mass spectrometer (TD GC/MS). In addition, SVOCs and pesticides/PCBs will be analyzed from approximately half of the samples. Twenty percent of the soil samples will be sent to a fixed offsite laboratory for confirmation of the field TD GC/MS analyses. Analyses performed on the soil in the fixed offsite laboratory will be for the same analytical groups as the duplicate field soil sample that will be analyzed in the field. TPH-gasoline and TPH-diesel will also be analyzed on soil samples sent to the offsite laboratory.

3.3.1 Sampling Procedures

This section describes the field procedures for probe installation, soil gas sampling, surficial soil sampling, and subsurface soil sampling.

Probe Installation. A truck-mounted hydraulic probe (approximately 1-inch O.D.) will be driven up to 30 feet bgs. A typical soil gas sampling probe is shown in Figure 3-9. Driving techniques are preferred over borehole installations due to problems with ambient air leakage down the borehole. Soil gas samples will be collected upon reaching the desired depth. If soil samples are to be collected, the soil gas probe will be removed and a 1-inch O.D. sampling core will be driven. If soil samples will not be collected, the soil gas probe will be pushed the next sample depth. Once the probe has been installed to the desired depth and soil and/or soil gas samples have been collected, the probe point will remain in the ground and the probe assembly removed. The remaining hole will be filled with fine-grade bentonite pellets. The pellets will be hydrated with the manufacturer suggested amount of potable water and the surface appropriately patched. Concrete and tarmac surfaces will be patched with concrete epoxy, asphalt surfaces with asphalt patch, and soil surfaces with soil from the hole.

Soil Gas Sampling. Soil gas samples will be extracted immediately after 12 feet and 20 feet are penetrated with the probe. Samples of soil gas will be extracted using an active sampling technique. The portable sampling system consists of a stainless steel probe that is connected to a stainless steel sampling box by TFE Teflon tubing of inert material. After reaching the desired sample depth, the annulus between the tubing and casing is sealed by a packer to isolate the probe from the atmosphere. A syringe in the sampling box is used to pull a volume of in-situ soil gas vapor from the ground through the probe and tubing. Three hundred milliliters (ml) (15 purge volumes) of gas is extracted to purge the air from the sampling system and then vented to the atmosphere. A second sample is then extracted and drawn into a 30 ml pre-evacuated, self-sealing EPA-clean glass vial where it is encapsulated at two atmospheres (15 pounds per square inch [psi]) pressure. The system is then closed from the probe tip to the glass vial to prevent the loss of VOCs. Following the sample extraction, the sample vial is packaged in an airtight bag, labeled, and logged in a field notebook and chain-of-custody form. It is then transported to a field laboratory for analysis.

OVA/HNu measurements will be taken in the field by attaching the instrument probe tip to a port on the sampling system. These measurements will be recorded in the field notebook.

Surficial Soil Sampling. Surficial soil samples will be collected using a stainless steel trowel or hand auger from a depth of 0 to 3 inches bgs. The soil sample will be homogenized and split; half the sample will be analyzed onsite by TDGC/MS and half offsite in a conventional fixed laboratory. OVA or HNu readings will be taken in the field and recorded in the field notebook. The soil type will also be noted.

Subsurface Soil Sampling. Soil samples will be collected by advancing a hydraulically driven 1-inch hollow-stem rod using a truck-mounted rig to the desired sample depth. The soil sampling equipment is graphically depicted in Figure 3-9. Three 4-inch long decontaminated stainless-steel liners will be inserted into the 1-foot sampling core at the base of the drive rod at each

sample location. Prior to collecting the soil, an open tip is exposed; a soil core will be collected by driving the core through the desired soil layer. After the drive rod is removed from the soil, the stainless-steel liners containing the soil will be separated from the drive rod. Soil from the middle liner will be used for the VOC analysis. Approximately 25 grams of soil from this liner will be removed and placed into a preweighed 60 ml volatile organic analysis (VOA) vial. Within 2 hours of collection, the VOA vial with soil will be weighed, theweight of soil calculated, and an equivalent volume (i.e. 25 gm soil to 25 ml methanol) of purge and trap grade methanol added to the vial. Vial weights, soil weights, and methanol weights will be recorded in the field notebook and reported to the laboratory on the Chain-of-Custody Forms (SAP, Attachment 3).

If there is soil remaining in the liner after the appropriate VOC samples have been collected, the liner may be capped and sealed with teflon tape for PCB/Pesticide analysis. The bottom liner will be capped with teflon-lined lids and sealed with teflon tape. Soil from the bottom liner will be analyzed for the remaining compounds, SVOCs and TFH. At locations where additional samples are necessary, such as onsite laboratory duplicates, fixed laboratory samples, fixed laboratory duplicates or MS/MSD samples, then the subcontractor may need to drive additional consecutive soil cores to collect enough soil for analysis. Duplicate samples will be collected in the following manner: The VOC samples will be collected for the samples, duplicates, and MS/MSD samples from the same stainless-steel liner, if possible. Then, soil for the remaining analyses should be collected consecutively for each analyte.

If the recovery is insufficient to obtain enough soil for all samples, a consecutive core will advanced to obtain more soil. If the consecutive core does not supply a sufficient sample, then a soil sample will not be collected from that depth.

3.3.2 Sample Collection, Handling, and Numbering

Detailed sample collection and handling procedures are described in the SAP provided as Appendix A. Soil gas samples will be collected from the soil gas

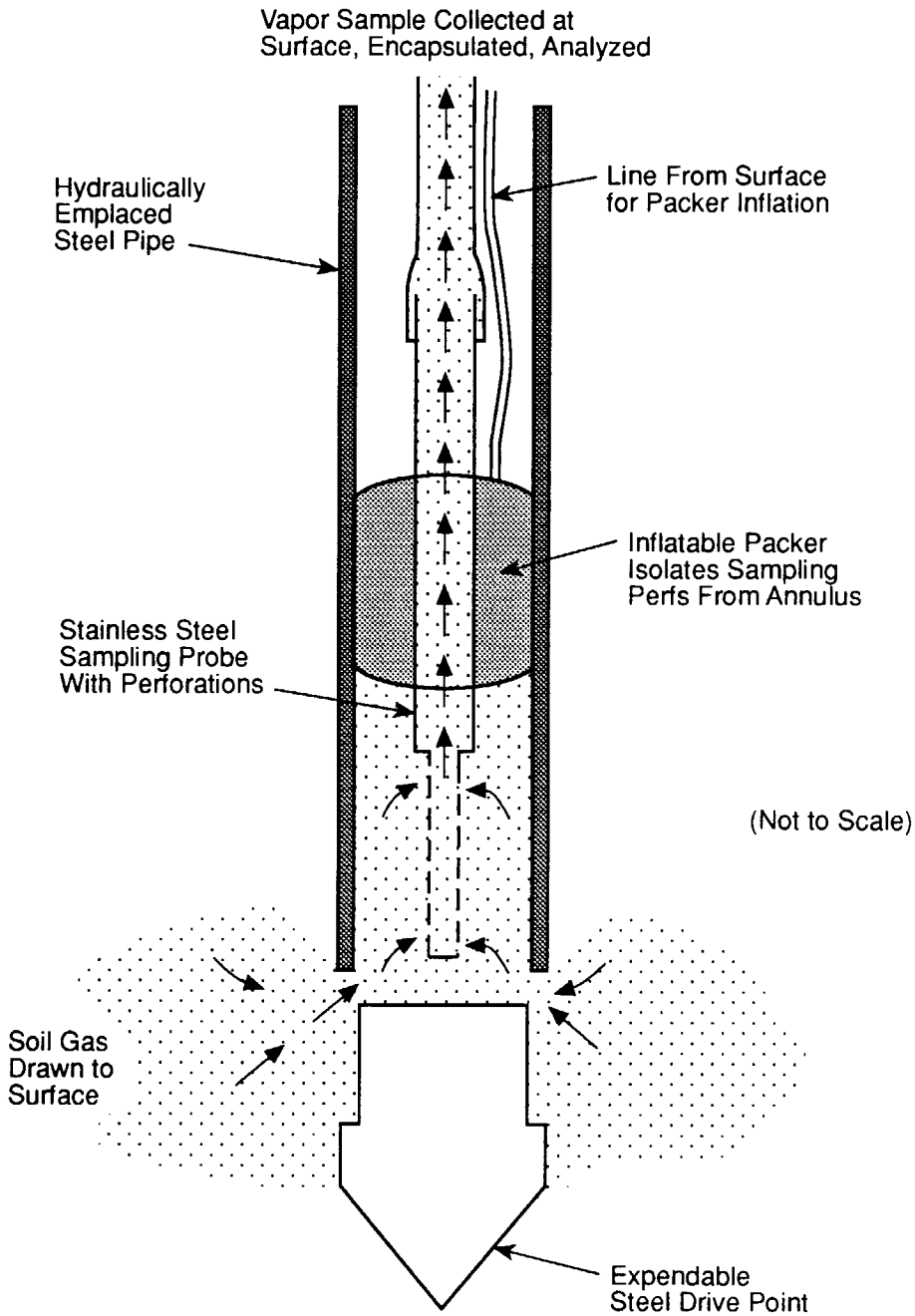

Figure 3-9
Schematic of Deep Soil Gas Sampling System
MCAS El Toro Soil Gas Survey Work Plan

Source: Target Environmental Services, 1992

mSC31981.SQ.10 fig3-9 5/94

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sampling system, as shown in Figure 3-9 and described in Subsection 3.3.1. Soil samples will be collected as described in Subsection 3.3.1.

Sample collection and analyses requested will be documented on a Chain-of-Custody Form (Figure 3-10). Each sample will have a location station number and sample name. For Round I, the station identification numbers will be 24_SG_001 through 24_SG_300. For Round II, the station identification numbers will be 24_SG_301 through 24_SG_500.

Samples will be numbered according to Table 3-1.

3.3.3 Sample Analysis

This section describes the methods and analyses that will be conducted on the soil gas samples, field laboratory soil samples, and fixed laboratory soil samples. Table 3-2 describes the compounds to be analyzed for each medium, data uses, data users.

Soil Gas Analysis. Soil gas samples will be analyzed in an onsite mobile laboratory equipped with two GCs with auto samplers to provide 24-hour-per-day operations. Standard GC methods will be used. Laboratory standard operating procedures and QC procedures are described in the Phase II RI/FS QAPP addendum (Appendix B).

Soil gas samples will be analyzed for the compounds listed in Table 3-3. Detection limits proposed for this project are shown in Table 3-3. Samples will be analyzed within 24 hours of collection.

Onsite Subsurface Soil Analysis. An onsite field laboratory will be set up with a TD GC/MS for quick turnaround semiquantitative field screening analyses (described in more detail in the QAPP). Twenty percent of the soil samples will be sent to a fixed laboratory (offsite commercial analytical laboratory) for verification analysis. A description of the standard operating procedure and QC for the TDGC/MS is provided in Appendix B.

Two types of quantitative analytic measurement can be made in the field:

- Direct thermal desorption of VOCs/SVOCs/PCBs/or Pesticides from soil or organic extract with selected ion monitoring (SIM)

- Direct thermal desorption of VOCs/SVOCs/PCBs/or Pesticides from soil or organic extract with total ion current/selected ion extraction (TIC/SIE) mass spectrometry

It is anticipated that most of the soil samples will be analyzed in the SIM mode. The SIM mode is capable of simultaneous detection of 12 compounds.

Chemicals of interest for soil include those chemicals detected in strata recommended for field screening that exceed human health or ecological risk-based criteria. This includes contaminants that caused the estimated risk at a stratum to exceed 5×10^{-5} based on Phase I RI data. Table 3-4 lists the compound groups and criteria for sampling. Based on the estimated risk and method and cost constraints, subsurface soil samples will be analyzed for the compounds listed in Table 3-4.

Method detection limits (MDLs) and detection limit considerations for the chemicals are listed in Table 2-16 of the QAPP (Appendix B). As shown in Table 2-16, semiquantitative and/or quantitative method detection limits for field methods exceed human health criteria for benzo(a)pyrene, benzo(k)fluoranthene, PCBs, and dieldrin. EPA CRDLs for PAHs listed in

CH2M HILL *QUALITY ANALYTICS*

CHAIN OF CUSTODY RECORD

PROJECT NUMBER	PROJECT NAME	# OF CONTAINERS	CLIENT ADDRESS AND PHONE NUMBER	LAB ID	FOR LAB USE ONLY
CLIENT NAME			ANALYSES REQUESTED		LAB#
					LAB#
PROJECT MANAGER	COPY TO:				PROJECT NO.
					ACK / VERIFIED
REQUESTED COMP. DATE	SAMPLING REQUIREMENTS: SDWA ☐ NPDES ☐ RCRA ☐ OTHER ____				QUOTE# / BS
					NO. OF SAMP / PG / OF

STA NO.	DATE	TIME	COMP	GRAB	SOIL	SAMPLE DESCRIPTIONS (12 CHARACTERS)											REMARKS

SAMPLED BY AND TITLE	DATE/TIME	RELINQUISHED BY	DATE/TIME	HAZWRAP/NEESA Y N
				QC LEVEL 1 2 3
RECEIVED BY:	DATE/TIME	RELINQUISHED BY:	DATE/TIME	COC / ICE
				ANA REQ / TEMP
RECEIVED BY:	DATE/TIME	RELINQUISHED BY:	DATE/TIME	CUST SEAL / Ph
				SAMPLE COND.
RECEIVED BY LAB:	DATE/TIME	SAMPLE SHIPPED VIA UPS BUS FED-EX HAND OTHER ____	AIR BILL#	
REMARKS				ENTERED INTO LIMS ____ COC REVIEWED ____

Figure 3–10
Chain-of-Custody Form
MCAS El Toro Soil Gas Survey Work Plan

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Table 3-1
Soil Gas Survey Sample Numbers
MCAS El Toro Soil Gas Survey Work Plan

	Soil Gas Data				Soil Data		
	12'	20'	Additional	QA/QC	TDGC/MS	Fixed Lab	QA/QC
Round 1	S145G1001-S14561300	S145G1301-S145G1600	S145G2001-S145G2999	S145G3001-S145G3999	NA	NA	NA
Round 2	S145G1601-S145G1800	S145G1801-S145G2000	S145G2001-S145G2999*	S145G3001-S145G3999	S1457301-S1457599	S1457600-S1457699	S1457700-S1457799

NA = Not Applicable (no soil samples will be collected during Round 1)
* Numbers to be continued from Round 1 Additional Soil Gas Samples.

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Table 3-2
Data Uses
MCAS El Toro Soil Gas Survey Work Plan

Compounds to be Analyzed	Matrix	Data Use	Data Users
Volatiles (VOCs)	Subsurface soil (onsite analysis)	Refine Conceptual Model Screening tool for further investigation Evaluation of Remedial Action Human Health Risk Assessment Potential Impact on Groundwater	Remedial Investigation team Feasibility Assessors Risk Assessors
	Subsurface soil (offsite analysis)	Verification of Onsite Soil Analysis Refine Conceptual Model - Characterization of volatile organic contamination in the shallow vadose zone Evaluation of Remedial Action Human Health Risk Assessment Potential Impact on Groundwater	Remedial Investigation Team Feasibility Assessors Risk Assessors
	Soil Gas	Screening tool for further investigation Characterization of volatile organic contamination in the shallow vadose zone Safety Monitoring	Remedial Investigation Team
Semivolatiles (SVOCs)	Soil (onsite analysis)	Refine Conceptual Model ARAR Comparison Evaluation of Remedial Action Potential Impact on Groundwater Human Health Risk Assessment	Feasibility Study Assessors Risk Assessors
	Subsurface Soil (offsite analysis)	Verification of Onsite Soil Analysis Evaluation of Remedial Action Refine Conceptual Model Human Health Risk Assessment Potential Impact on Groundwater ARAR Comparison	Feasibility Study Assessors Risk Assessors
Pesticides/PCBs	Subsurface Soil (onsite Analysis)	ARAR Comparison Evaluation of Remedial Action Human Health Risk Assessment Refine Conceptual Model	Feasibility Study Assessors Risk Assessors
	Subsurface Soil (offsite analysis)	Verification of Onsite Soil Analysis Evaluation of Remedial Action Refine Conceptual Model Human Health Risk Assessment ARAR Comparison	Feasibility Study Assessors Risk Assessors
Fuel Hydrocarbons	Subsurface Soil (Onsite analysis)	ARAR Comparison Evaluation of Remedial Action Human Health Risk Assessment Potential Impact on Groundwater	Feasibility Study Assessors Risk Assessors Regulators
	Subsurface Soil (Offsite analysis)	Verification of Onsite Soil Analysis Evaluation of Remedial Action Human Health Risk Assessment Potential Impact on Groundwater ARAR Comparison	Feasibility Study Assessors Risk Assessors

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Table 3-2
Data Uses
MCAS El Toro Soil Gas Survey Work Plan

Compounds to be Analyzed	Matrix	Data Use	Data Users
	Soil Gas	Screening tool for further investigation Refine Conceptual Model- Characterization of petroleum contamination in the shallow vadose zone soils Evaluation of Remedial Action Human Health Risk Assessment Potential Impact on Groundwater Safety Monitoring	Remedial Investigation Team

(a) For relevant ARAR and health based limits, see Tables 3-4.
(b) CRDL/CRQL - EPA Contract Laboratory Program defined contract required detection/quantitation limits.
MDL - Method detection limit, see Table 3-4.
(c) Levels I-IV as defined in EPA guidelines [(EPA 1987. Data Quality Objectives for Remedial Response Activities. Two parts. Development Process (EPA-540/G-87/003).
Example Scenario (EPA-540/G-87/004)]. See Table 2-1d.

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Table 3-3
Analytes for Soil Gas Analysis
MCAS El Toro Soil Gas Survey Work Plan

Analytes	Modified EPA Method	Detection Limit Goal[a] (ug/L)
1,2-dichloroethylene (1,2-DCE)	8010	1.0
Trichloroethylene (TCE)	8010	1.0
Tetrachloroethylene (PCE)	8010	1.0
1,1,1-trichloroethane (1,1,1-TCA)	8010	1.0
1,1,2-trichloroethane (1,1,2-TCA)	8010	1.0
1,1-dichloroethane (1,1-DCA)	8010	1.0
Methylene Chloride (dichloromethane)	8010	1.0
1,1-dichloroethylene (1,1-DCE)	8010	1.0
carbon tetrachloride (CT)	8010	1.0
Chloroform (CF)	8010	1.0
1,2-dichloroethane (1,2-DCA)	8010	1.0
1,2-dichloropropane	8010	1.0
Vinyl chloride	8010	1.0
Benzene	8020	1.0
Ethylbenzene	8020	1.0
Toluene	8020	1.0
Meta- and para-xylene	8020	1.0
Ortho-xylene	8020	1.0
Total Fuel Hydrocarbons (TFH) - Diesel/Gasoline	GC/FID	Qualitative Fingerprint

[a]Actual detection limits may be different depending on sample size, instrument performance, and matrix effects.

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Table 3-4
Chemical Group and Sampling Criteria for Onsite Soil Analysis
MCAS El Toro Soil Gas Survey Work Plan

Analyte	Sampling Criteria
VOCs	All samples
SVOCs	If total fuel hydrocarbon fingerprint from soil gas or soil sample indicates PAHs
PCBs	If soil boring is located in Site 11 or Site 8
Pesticides	Shallow (12 feet)soil samples collected from locations where soil is exposed at the surface (i.e. paved surface and road edges, along washes, and between buildings)

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Table 2-16 are only slightly lower than the MDLs estimated for field methods. The field analysis will be used as a screening tool. The 20 percent of the samples that are sent to the fixed laboratory will meet the CRDLs. (The fixed laboratory and field data can be used as a part of the risk assessment and FS.)

The number of samples that can be analyzed per day (assuming approximately 12 hours per day) per instrument are listed in Table 3-5.

Offsite Laboratory Subsurface Soil Analysis. Approximately 40 subsurface soil samples (20 percent of the soil samples collected) will be submitted to an offsite commercial analytical laboratory for verification analysis. The samples will be analyzed for the same compound groups as the onsite soil sample that they duplicate. The following methods will be used to analyze the soil:

- VOCs - EPA Method 8010/8020
- SVOCs/PAHs - EPA Method 8270
- PCBs/Pesticides - EPA Method 8080
- TFH-gas and TFH-diesel - CA Luft Method

The data will be used to verify the onsite soil analyses. The data quality level will be EPA CLP. Detection limits will meet EPA CRDLs. These limits are provided in the addendum to the Phase II QAPP (Appendix B).

3.4 Air Knife Test

The main objective of the air knife field test, to be conducted during the first week of the soil gas survey, is to evaluate the effect of the air knife (used for utility clearance) on soil gas concentrations of the 12-foot bgs sample. Regulatory agency representatives have expressed concern that the use of the air knife may effect VOC soil gas concentrations. If soil gas concentrations are affected by the air knife, an additional objective is to assess how quickly the soil gas concentration re-equilibrates; this will be used to assess a "safe" equilibration period between air knife utility clearance and collection of the 12-foot soil gas sample.

Three analyses will be used to assess the two objectives of the air knife test. First, soil gas samples will be collected and analyzed for the list of VOC constituents listed in Table 3-3, and second, percent oxygen in the soil gas will be measured. In addition, pressure will be monitored in a limited number of holes.

This section presents the air knife test configuration, rationale for configuration and procedures, test procedures, quality assurance/quality control, and data evaluation. A description of the air knife drilling method is summarized in the Air Knife Fact Sheet, dated 23 March, 1994 (Appendix D).

3.4.1 Air Knife Test Configuration

Each test consists of four holes. Three holes will be hand augered and one air knifed to a depth of 7 feet bgs. The configuration of the holes and drilling methods (air knife or hand-auger) are depicted in Figure 3-11. Two holes will be placed adjacent (within 2 feet) to each other (one air knifed and one hand augered), and two distal adjacent (<2 feet) holes will be placed greater than 100 feet away (hand augered). Dedicated soil gas sampling probes will be installed to a depth of 12 feet bgs in one of the distal hand-augered holes and in the air knife hole. Temporary probes will be installed in the proximal and the other distal hand augered hole. This four hole test configuration will be conducted in four locations (three sets of four borings and one set of six borings) that are identified as likely to have VOC or BTEX contamination, based on previous investigations. The location with six borings consists of duplicate borings at three of the borings for QA/QC purposes; the rationale is described in Subsection 3.4.4.

In summary, each test will consist of the following (see Figure 3-11):

- Three hand augered holes to 7 feet bgs (1 to 3 inches diameter)
- One air knife hole to 7 feet bgs (approximately 3 inches diameter)
- One temporary soil gas probe at 12 feet bgs
- One temporary soil gas probe at 20 feet bgs
- Two dedicated soil gas probes at 12 feet bgs

Table 3-5
Expected Daily Onsite Soil Sample Analysis Quantities
MCAS El Toro Soil Gas Survey Work Plan

Chemical Group	Semiquantitative Methods (SIM) (Maximum Samples/Day)	Quantitative Methods (TIC/SIE) (Maximum Samples/Day)
VOCs	40	20-25
PAHs	15-20	10-15
PCBs	50	--
Pesticides	20-25	10-15

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Samples that will be collected are listed in Table 3-6 and described below:

- A soil gas sample and percent oxygen measurement from the proximal temporary soil gas probe at 12 feet bgs and 20 feet bgs. Pressure will be monitored in the temporary probe at 12 feet while the air knife is advanced in the adjacent hole.

- One soil gas sample and percent oxygen measurement from the distal 20 foot bgs temporary soil gas probe.

- Time series testing of soil gas and percent oxygen percentage from the 12 foot bgs dedicated soil gas probes; initially, after 1 hour, 4 hours, 1 day, and 4 days (five samples per dedicated probe). Time intervals may be changed by the technical manager based on field results.

Thus, 13 soil gas samples and percent oxygen measurements will be collected for each test. Duplicate soil gas samples will be collected from the 12-foot soil gas samples at air knife test location 3, which was arbitrarily selected. (Twenty-four soil gas samples will be collected.) Additional duplicate samples may be added by the technical manager based on field results.

Four locations have been selected for the air knife test based on lithologic homogeneity and relative coarseness of the soil and probability of encountering VOC and/or BTEX contamination. Location 1 includes soil probes 308 and 309 along the west side of the Agua Chinon Wash. Location 2is located at SWMU/AOC 095 (probes 241 and 214). Location 3 is located along the Bee Canyon Wash (probes 136 and 139, respectively). Location 4 is located at SWMU/AOC 198 (probes 153 and 154). In each test, one probe location will be chosen as the paired proximal auger/air knife set, while the other probe will be used as the distal augered time-series location.

3.4.2 Rationale for Air Knife Test

The air knife test has been configured with the adjacent augered and air knife holes and a distal (>100 feet) augered hole for the following reasons:

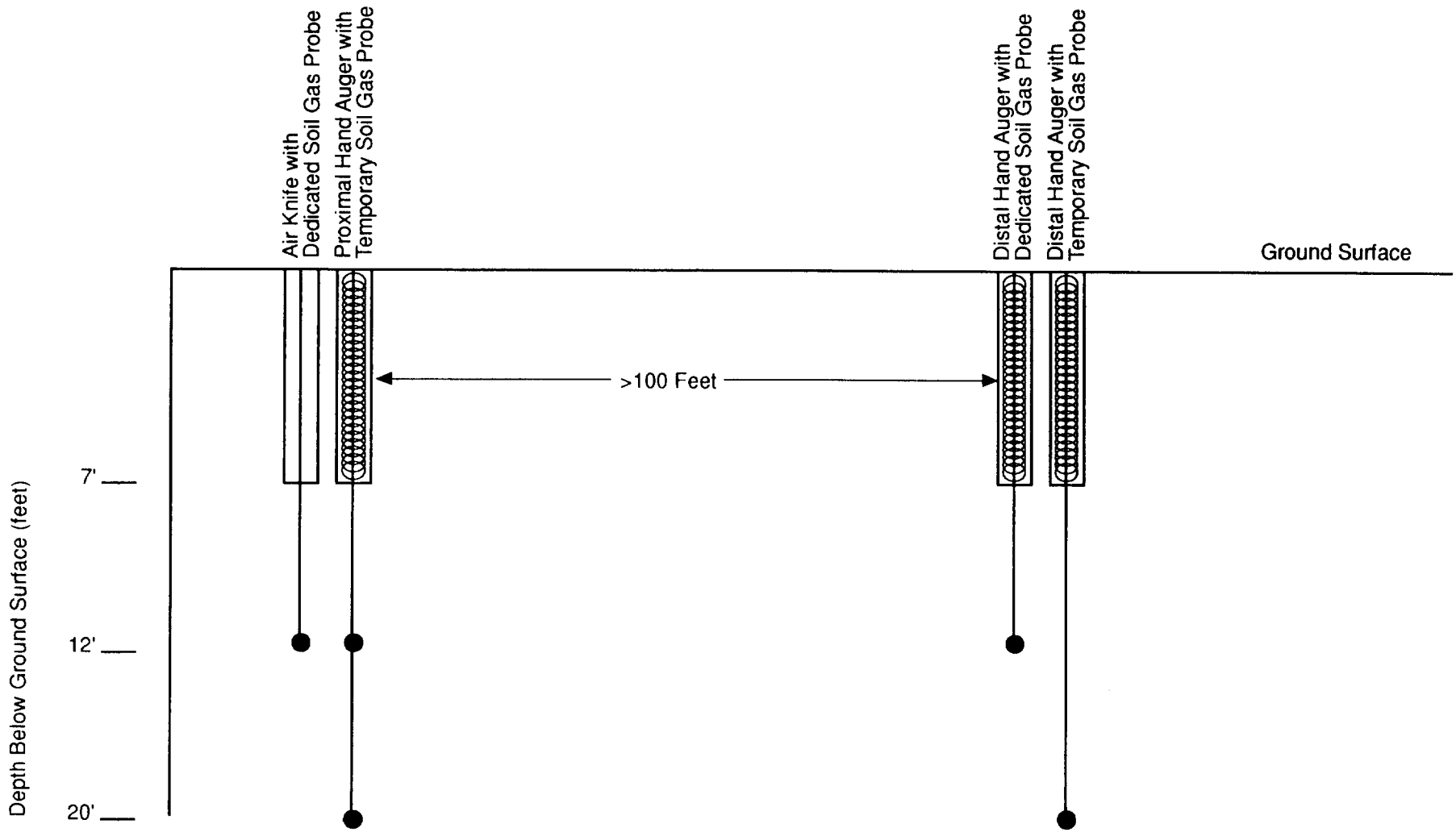
- Soil gas data from the adjacent holes will be used to compare spatially close (<2 feet) soil gas samples. After the air knife hole has been advanced, the adjacent augered hole may be affected by the air knife. Therefore, no more samples will be collected from the augered hole adjacent to the air knife hole.

- The distally placed auger hole with a dedicated 12 foot bgs soil gas probe is located outside of the estimated area of influence of the air knife. Therefore, although the initial soil gas concentration may differ, the trend of the time-series data may be compared to the trend in time-series data collected from the air knife hole.

- Samples collected at the distally placed auger hole with a temporary 20 foot bgs soil gas probe will be used to meet the objectives of the overall soil gas investigation, not in the evaluation of the air knife.

- For each test, an attempt was made to place probes close enough so that the soil will be similar in intrinsic permeability and soil gas concentration.

- Oxygen percentages in the soil gas will be measured to assess the influence of the air knife on the 12 foot bgs soil gas sample. The difference between percent oxygen in the atmosphere (21 percent oxygen) and in vadose zone soil gas (12 to 19 percent oxygen) will be used as described in the data evaluation Subsection 3.4.5.



Soil Gas Sampling Location

Figure 3-11
Test Configuration for Effects of Air Knife on 12 Foot Soil Gas Sample

MCAS El Toro Soil Gas Survey Work Plan

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Table 3-6
Number of Samples for Each Air Knife Test
MCAS El Toro Soil Gas Survey Work Plan

	Analytes			Location				
				Proximal Air Knife	Proximal Hand Auger		Distal 12-foot Hand Auger	Distal 20-foot Hand Auger
Time	VOCs in Soil Gas	Oxygen	Pressure	12 ft bgs	12 ft bgs	20 ft bgs	12 ft bgs	20 ft bgs
Initial	X			1*	1*	1	1*	1
		X		1	1	1	1	1
			X	NM	M	NM	NM	NM
1-hour	X			1*	A	A	1*	A
		X		1	A	A	1	A
				NM	A	A	NM	A
4-hours	X			1*	A	A	1*	A
		X		1	A	A	1	A
				NM	A	A	NM	A
1-day	X			1*	A	A	1*	A
		X		1	A	A	1	A
				NM	A	A	NM	A
4-days	X			1*	A	A	1*	A
		X		1	A	A	1	A
				NM	A	A	NM	A

ft bgs - feet below ground surface
* Duplicate samples will be collected at Location 3 (Bee Canyon Wash).
A - Abandoned
M - Pressure will be monitored during air knife advancement
NM - Not measured

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- Pressure will be monitored in the proximal hand-augered hole at 12 feet during advancement of the air knife in the proximal air knife hole: The pressure measurement will be used to assess subsurface air connection between the air knife and 12 feet.

3.4.3 Air Knife Test Procedures

Figure 3-12 is a flow chart that presents the procedures for each test as described in more detail below:

- Three holes will be hand augered to 7 feet bgs. After determining that they are clear of utilities, the holes will be backfilled with the excavated soil. The paired hand augered holes will be greater than 100 feet from the auger hole paired with the air knife hole to ensure that the augered hole with the 12 foot bgs dedicated soil gas probe for time-series testing is not influenced by the air knife.

- A soil gas probe will be driven to a depth of 12 feet bgs into one of the filled hand-augered holes (temporary soil gas sampling location). Percent oxygen in the soil gas will be measured. A soil gas sample and duplicate soil gas sample will be collected for analysis. The probe will then be driven to 20 feet bgs to collect a soil gas sample and measure percent oxygen in the soil gas. After the 20-foot sample has been collected, the probe will be removed and the hole abandoned. (Note: The 20-foot soil gas sample is not a part of the airknife study; it will be taken to satisfy the general requirements of the soil gas survey work plan.)

- Adjacent to the temporary soil gas location (within 2 feet), a 7-foot hole will be advanced using the air knife technique. The hole will be backfilled with the excavated soil. A dedicated soil gas probe will be driven to 12 feet bgs. An oxygen concentration measurement will be

collected from the soil gas. A soil gas sample and duplicate soil gas sample will be collected for analysis.

- A dedicated soil gas probe will be driven to 12 feet bgs into one of the backfilled distal holes. An oxygen measurement, soil gas sample, and duplicate soil gas sample will be collected for analysis at a depth of 12 feet bgs. Logistically, this work may be performed at the same time that the air knife utility check hole is being advanced.

- A temporary soil gas probe will be driven into the other distal hole at a depth of 20 feet bgs, and a soil gas sample will be collected for analysis. The probe will be removed and the hole abandoned.

- Samples will be collected from the dedicated soil gas probes after approximately 1 hour, 4 hours, 1 day, and 4 days. Sample analyses will include VOCs in soil gas (a sample, a duplicate sample and oxygen). Documentation should include actual times for: (1) Utility check 7 foot hole advancement (hand auger or air knife); (2) Probe installation; (3) Oxygen measurements; and (4) Soil gas sample collection. Information will be recorded in a field notebook.

3.4.4 Quality Assurance/Quality Control

The following section describes the QA/QC procedures that are specific to the air knife test. The QA/QC sampling will provide some control of small scale spatial temporal variability.

QC will include the following:

- At one of the air knife test locations, holes will be paired to obtain data on small scale spatial variability. Figure 3-13 depicts the configuration and Table 3-7 describes the number of samples to be collected (24 soil gas samples). This test location has been arbitrarily selected as Location 3 (probes 136 and 139).

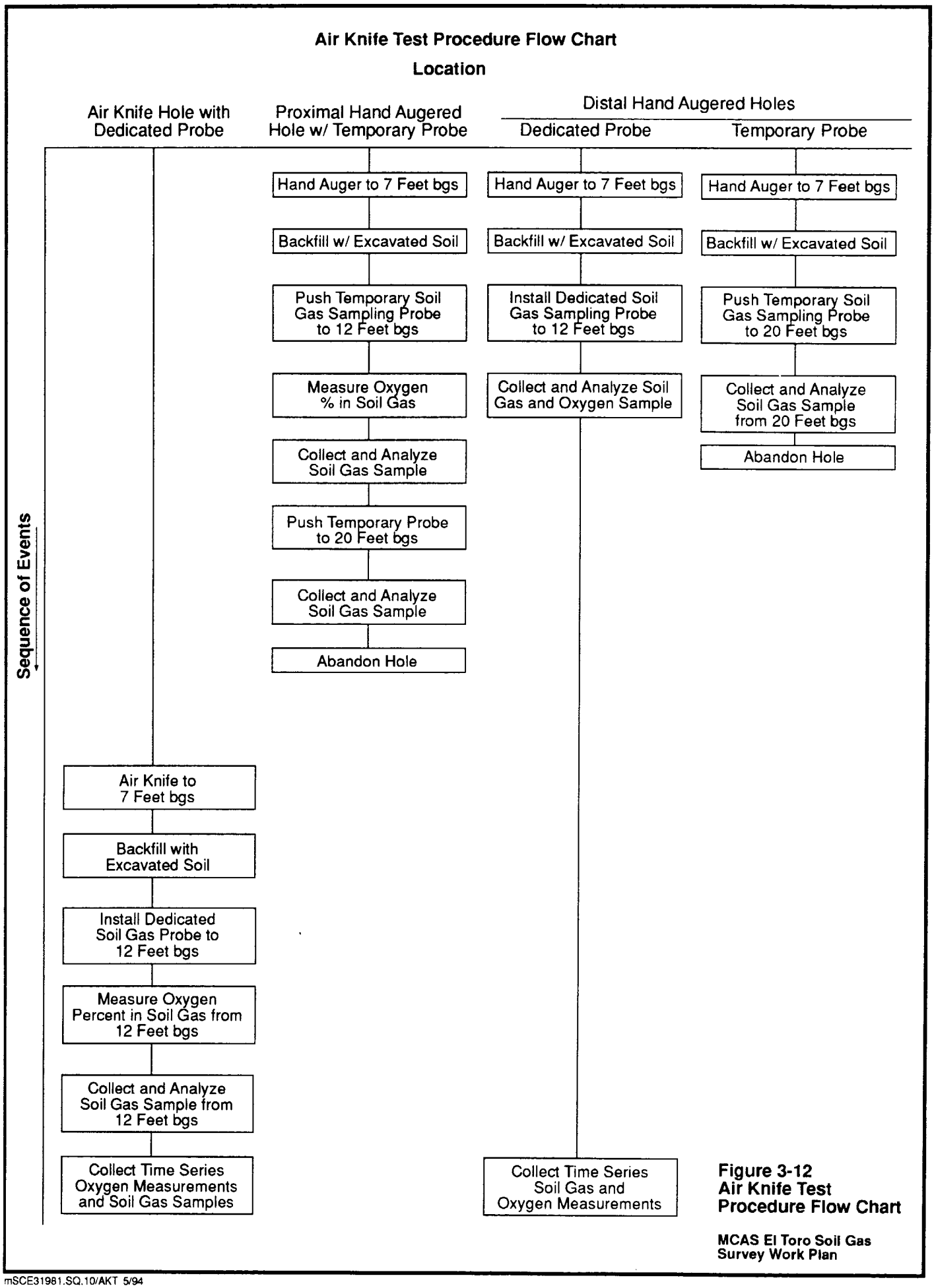

Figure 3-12
Air Knife Test Procedure Flow Chart

MCAS El Toro Soil Gas Survey Work Plan

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- Duplicates will be collected from all 12 foot soil gas samples to obtain data to evaluate the small scale temporal variability.

3.4.5 Data Evaluation

Some possible results of the air knife test and the potential actions to be taken are presented in Table 3-8.

3.5 QA/QC Procedures

The results of a soil gas survey and soil sampling are highly sensitive to procedure. Field personnel will closely follow standard operating procedures described in the SAP (Appendix A). The procedures include the probe installation, method for soil gas sampling, sample handling, and field-based equipment decontamination. Any deviations from these procedures will be documented in the field notebook and described in the technical report prepared at the conclusion of the survey.

Field QC for the soil gas sampling is detailed in Subsection 1.3.4 and for the soil screening sampling in Subsection 1.4.2 of the SAP (Appendix A).

Analytical QA/QC for the soil gas analysis and the field screening onsite soil analysis is described in the Phase II RI QAPP addendum (Appendix B). Analytical QA/QC procedures for the offsite fixed laboratory are described in the Phase II RI QAPP.

3.6 Decontamination

All downhole equipment, including the soil gas sampling probes, will be decontaminated prior to commencing work, between downhole borehole locations, and at the end ofeach field work day. Decontamination procedures are described in Section 1.5 of the SAP (Appendix A).

3.7 Investigation-Derived Waste Disposal

Investigation-derived waste will be handled in accordance with the MCAS El Toro Final Waste Management Plan (Jacobs, 1991) and amended procedures as agreed upon during RPM meetings.

Decontamination water and mobile laboratory waste water derived from the soil gas investigation will be contained, labeled, and transported to a Baker tank on the waste storage pad where the water will be treated with the onsite granular activated carbon (GAC) unit.

Soil cuttings derived from advancing probes and soil sampling will be stored in 55-gallon U.S. Department of Transportation (DOT)-approved drums. These will be stored on the waste storage pad and managed along with the Phase II investigation-derived waste.

Personal protective equipment (PPE) will be separated into a two categories, visibly contaminated and nonvisibly contaminated. The nonvisibly contaminated PPE will be disposed of with Station Garbage. The visibly contaminated PPE will be stored in 55-gallon drums and/or in appropriate roll-off bins and will be disposed with a licensed hazardous waste hauler at the end of field work.

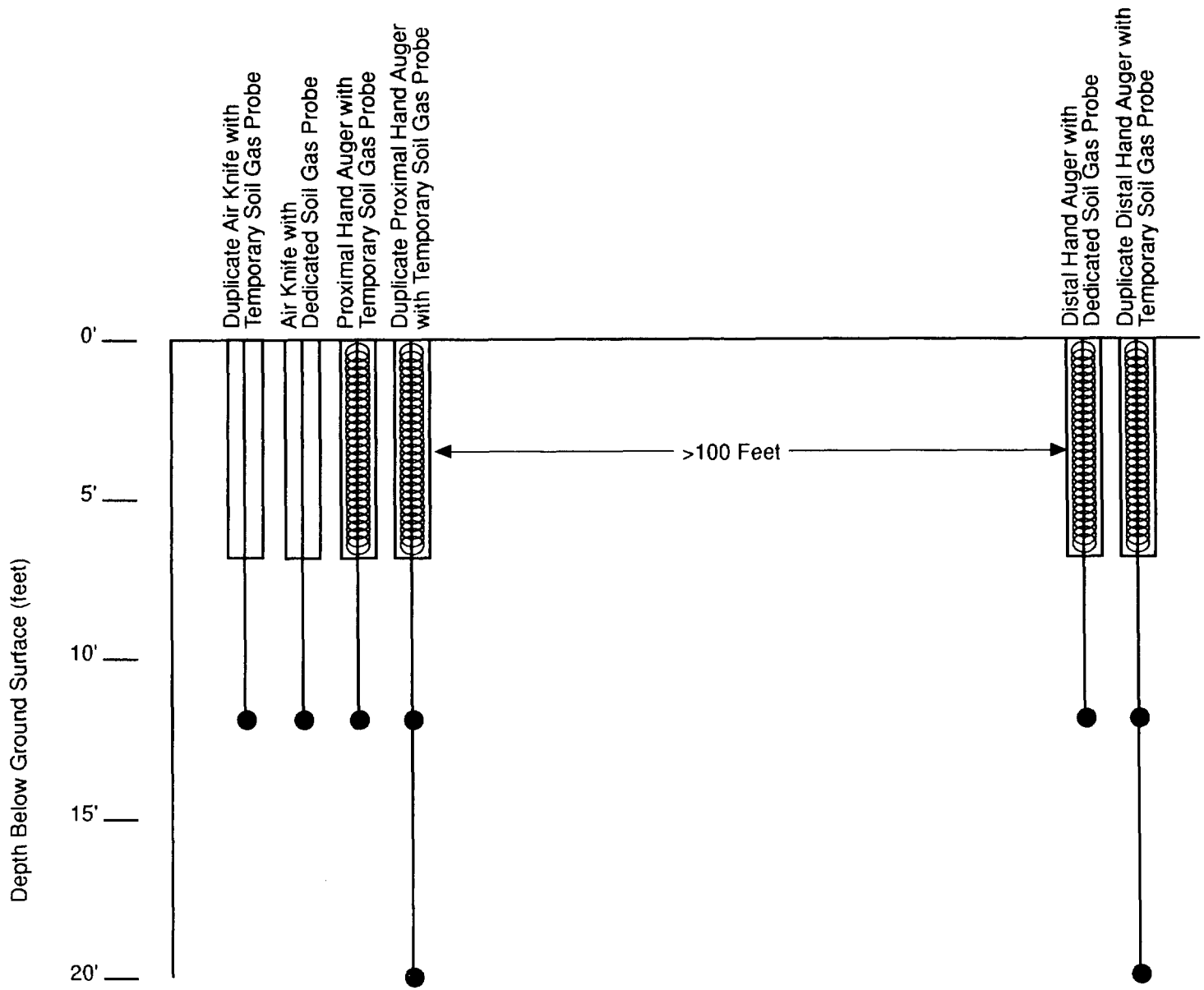

Figure 3-13
Air Knife QA/QC Test Configuration

MCAS El Toro Soil Gas Survey Work Plan

● Soil Gas Sampling Location

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Table 3-7
Number of Samples for QA/QC Air Knife Test
MCAS El Toro Soil Gas Survey Work Plan

Time	Analytes			Location							
	VOCs in Soil Gas	Oxygen	Pressure	Proximal Air Knife Hole	Duplicate Proximal Air Knife Hole	Proximal Hand Auger Hole		Duplicate Proximal Hand Auger Hole	Distal 12-foot Hand Auger Hole	Duplicate Distal Hand Auger Hole	
				12 ft bgs	12 ft bgs	12 ft bgs	20 ft bgs	12 ft bgs	12 ft bgs	12 ft bgs	20 ft bgs
Initial	X			1	1	1	1	1	1	1	1
		X		1	1	1	1	1	1	1	1
			X	NM	NM	M	NM	NM	NM	NM	NM
1-hour	X			1	1	A	A	A	1	1	A
		X		1	1	A	A	A	1	1	A
				NM	NM	A	A	A	NM	NM	A
4-hours	X			1	1	A	A	A	1	1	A
		X		1	1	A	A	A	1	1	A
				NM	NM	A	A	A	NM	NM	A
1-day	X			1	1	A	A	A	1	1	A
		X		1	1	A	A	A	1	1	A
				NM	NM	A	A	A	NM	NM	A
4-days	X			1	1	A	A	A	1	1	A
		X		1	1	A	A	A	1	1	A
				NM	NM	A	A	A	NM	NM	A

ft bgs - feet below ground surface
* Duplicate samples will be collected at Location 3 (Bee Canyon Wash).
A - Abandoned
M - Pressure will be monitored during air knife advancement
NM - Not measured

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Table 3-8
Air Knife Test Data Evaluation
MCAS El Toro Soil Gas Survey Work Plan

Potential Soil Gas Results	Potential Actions
No significant (± 50 percent) difference between the initial air knife soil gas samples and augered hole soil gas samples.	Continue to collect both the 12-foot and 20-foot samples and discontinue the time-series air knife testing.
Significant (order of magnitude) decreased/increased initial concentrations of soil gas from air knife holes in comparison to the soil gas data from the hand augered holes.	Results of the time series will be evaluated.
If the initial soil gas data results are significantly different, then time series data may indicate that the soil gas concentrations in the air knife holes recovers within a specified length of time.	Continue to use the air knife to complete utility check prior to collecting the 12- foot sample in locations where it is logistically feasible at least 4 days before soil gas sampling.
If the initial soil gas data results are significantly different than subsequent values and the time-series data indicate that the soil gas does not recover within 4 days of the test.	Discontinue the 12-foot samples. Continue to collect 20-foot samples.
Data consistently vary by more than an order of magnitude and no conclusions can be made.	Re-evaluate. May want to discontinue collection of 12-foot sample.
Potential Percent Oxygen Results	**Potential Actions**
No significant difference between oxygen before percent before air knifing (from adjacent soil gas probe in augered hole) and after air knifing (from dedicated soil gas probe in the air knife hole.	Continue to collect both the 12-foot and 20-foot soil gas samples and discontinue time-series air knife testing.
Initial oxygen percent in augered hole is significantly lower (2-3 percent) than oxygen in air knife hole. (Possible introduction of ambient air into soil gas.)	Results of time-series testing will be evaluated.
Initial oxygen percent in augered hole is significantly higher (2-3 percent) than oxygen in air knife hole. (Possible draw of soil gas from lower in vadose zone where percent oxygen may be lower).	Results of time-series testing will be evaluated.
If initial percent oxygen was significantly different (2-3 percent) between the air knife and augered hole, and the time-series data from the air knife hole re-equilibrates to initial augered hole percent oxygen.	Continue to collect both 12-foot and 20-foot samples. Maximize the amount of time between air knife utility check and soil gas sampling.
If initial percent oxygen was significantly different (2-3 percent) between the air knife and augered hole, and the time-series data show a continued variance with no trend towards re-equilibration.	Discontinue the 12-foot sample. Continue to collect 20-foot samples.

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4.0 DATA EVALUATION

This task includes data management activities, geographic information system (GIS) support for the subsurface soil and soil gas activities, and data evaluation.

During Round I, the soil gas data will be entered into the database on a daily basis as results are available. The results will be plotted and evaluated in "real time" so that any changes to the current field work and selection of Round II sampling locations can be made in a timely manner.

Data management activities include the following tasks:

- Electronic transfer of sample analyses into the MCAS El Toro RI database
- Manual data entry of Chain-of-Custody Forms for sample tracking
- Editing the database to reflect flags and detection limit changes resulting from data validation
- Manual entering of soil gas sample analyses or computer programming to read digital files, if available
- Preparation of summary reports, downloads for spreadsheets, database queries, and uploads into the GIS system

GIS activities include the following tasks:

- Loading of analytical data into the GIS database
- Digitizing of manually contoured soil gas data into the GIS database
- Preparation of up to 2 regional and 15 site-specific plots of soil gas concentrations

Graphical Software display activities may include the following tasks:

- Daily entry into database
- Preparation of 2-D and/or 3-D graphics to assess hot spots and plan new locations

The soil gas data will be evaluated using the field notes, contoured plots of soil gas concentrations for detected analytes and current understanding of the geology and source release areas to assist in identifying and defining shallow vadose zone source areas. The new conceptual model will be used to determine the following:

- Locations for the Round II soil gas probes
- Depths of soil gas samples
- Locations for soil sampling
- Soil sampling locations for SVOC, PCB, and pesticide analyses

Locations for Round II sampling will be plotted and a technical memorandum (TM) prepared describing rationale for the locations, depths, and analyses for Round II sampling. The memorandum will be submitted to the Navy and regulatory agencies. A meeting will be set up prior to the Round II sampling to obtain agreement with the Navy and regulatory agencies on the plan for Round II sampling.

5.0 REPORT PREPARATION

A TM will be prepared summarizing the results and interpretation of the soil gas survey. The TM will include:

- Description of any modifications made to the sampling and analysis methods provided in this work plan
- Soil gas concentration contour maps for analytes with elevated concentrations (greater than 1 μg/L)
- Assessment of soil gas concentrations data to aid in identifying potential vadose zone VOC source areas
- Copies of the analytical data reports, Chain-of-Custody Forms, and geologic boring logs

Drafts that will be submitted include an internal draft, Navy review draft, agency draft, and final.

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6.0 REFERENCES

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Jacobs Engineering Group Inc. Jacobs, 1993a. Marine Corps Air Station El Toro. *Phase II Remedial Investigation/Feasibility Study Draft Quality Assurance Project Plan*. CLE-C01-01F145-B8-0001.

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Jacobs, 1993c. Marine Corps Air Station El Toro. *Phase I Remedial Investigation/ Feasibility Study Draft Work Plan*. CLE-C01-01F145-S4-0006.

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1.0 FIELD METHODS AND PROCEDURES

This section describes field standard operating procedures to be followed while performing the soil gas survey at Marine Corps Air Station (MCAS) El Toro. Additional information is in the addendum to the Draft Phase II RI Quality Assurance Project Plan (QAPP).

Field activities will be conducted under the supervision of a Registered Geologist or a Professional Engineer.

1.1 Site Protocol and General Recordkeeping

Site protocol and general recordkeeping procedures include requirements for field office administration, field logbooks, photographs, access to sensitive military areas, and radio protocol.

1.1.1 Field Office Administration Records

Individual forms and field logs recordkeeping for specific procedures on the MCAS El Toro Soil Gas Survey are discussed in the appropriate subsections. Forms and records relating to Health and Safety are in the Site Health and Safety Plan (HSP); these records will be maintained onsite by the site health and safety manager. Other forms and records are discussed below.

Related Procedures - Field Office Administrative Records

- Field Logbooks (Subsection 1.1.2)
- Field Photographs (Subsection 1.1.3)

Equipment and Supplies - Field Office Administrative Records

- Various preprinted forms (See Subsection 1.8)
- Pens with indelible ink

Procedure - Field Office Administrative Records

Forms and records will be completed in indelible ink and stored in file cabinets onsite. Completed records will be copied at least once a week and the duplicates stored off-Station at the CH2M HILL Southern California office. The site manager will be responsible for maintaining and controlling forms and logs, unless noted below.

Staff sign-in forms (Form 1.1) will be initialed in the field administration office every working day. Visitor sign-in logs (Form 1.2) will be available in the field administration office. Visitors, including company and project staff not included on the staff sign-in forms, will be asked to sign these sheets. Visitors at specific field sites will be noted by the field team leader in the appropriate field logs.

Recordkeeping - Field Office Administrative Records

Records pertaining to sample custody, sample shipping, and receipt at the laboratory will be retained by the sample manager.

Equipment rental and provided services records, including receipts for materials, will be the responsibility of the equipment manager. Equipment sign-out and return sheets will also be the responsibility of the equipment manager.

Other forms and records will be retained in the field administration trailer, and will be the responsibility of the field manager. These forms include the daily staff sign-in form, visitor sign-in form, field logbooks, three-ring binders containing soil gas probe installation and soil sampling information, and miscellaneous records of progress.

Records will be copied weekly and backup copies moved to the CH2M HILL Southern California office for storage.

1.1.2 Field Logbooks

Pertinent work and sampling information will be recorded in a logbook during each day of the field effort. The field team leader on a task is responsible for completing the logbook and ensuring its custody when the logbook is outside the field administration office.

Health and safety information, including measurement of parameters made strictly for personnel protection, personnel decontamination, and notes on potential health or safety problems, will be recorded in a separate health and safety logbook.

Related Procedures - Field Logbooks

Three types of field logbooks will be used: health and safety logbooks, site logbooks, and function logbooks. Function logbooks will be kept for:

- Field Staking (Subsection 1.2.1)
- Utility Clearance (Subsection 1.2.2; documentation included in Field Staking function logbook)
- Surveying (Subsection 1.2.3)
- Soil Gas Sampling (Subsection 1.3)
- Soil Sampling (Subsection 1.4)
- Methanol Preservation of VOC Soil Samples (SAP Attachment 3)

Each field team will maintain a site logbook that documents field procedure information related to Site 24/25, including soil gas probe installation, soil gas

sampling, subsurface soil sampling, waste handling until placed in the custody of the waste manager, and decontamination of equipment.

Strict custody procedures will be maintained with the field logbooks. While being used in the field, the logbook will remain with the assigned log keeper at all times.

Equipment and Supplies - Field Logbooks

- Waterproof, bound logbooks with consecutively numbered pages
- Rubber stamp (in the field administration office)
- Pen with indelible ink

Procedure - Field Logbooks

No rules can specify precisely the content of information that must be recorded in the logbook. Each logbook will contain sufficient information that the field activity can be reconstructed without relying on the memory of the field crew. Information provided under the procedures section consists both of typical information and any additional information necessary for reconstructing the field record.

Three types of logbooks will be used: site, function, and health and safety. Site logbooks will be used for continuous activities on a site, from soil gas

probe installation through soil gas and soil sampling. Function logbooks, such as a surveyor's logbook, will be used at all sites for a common function.

When a new logbook is opened, it will be assigned a unique document control number, which will be written on the inside cover and on the top of Page 1. Each page in the book will be numbered sequentially.

The first two pages will be reserved for an index. If the logbook is a site logbook, index columns will be set up (left to right) for site identification, function, pages where the information will be found, and initials of the person who completed the work. If the logbook is a function logbook, the function column will be omitted.

Each morning, the sampling team leader will sign out (Form 1.3) the appropriate logbook(s), use the stamp (see below) at the top of the first unused page, and complete the information requested. The record for the day will be kept sequentially, beginning below the information on the stamped portion of the page. Entries will be made in indelible ink. Each entry will be initialed and dated at the bottom of the page. At the end of the day, a line will be drawn through any blank space on the page, and the author will sign and date the bottom of the final page. All corrections will consist of lined-out deletions that are initialed.

Specific information that is to be recorded for a given procedure is noted in the Recordkeeping subsection for that procedure. At the end of the day, the

entries for that day will be copied and placed in the field files in the field administration office. The logbook will be checked-in (Form 1.3) and locked in a filing cabinet until needed for the next field day.

The stamped heading for each day's work will contain the following information:

MCAS El Toro Soil Gas Survey Logbook _____
Function Log [ ] Site Log [ ] H&S Log [ ]
SCE31981._____ Date _____
Function _____ Site No. _____ Site Identification _____
Start Time _____ AM Weather _____
Log Keeper of this Logbook _____
Sampling Team Leader _____
Site Safety Coordinator _____
Driller _____
Helper _____
Helper _____
Other Personnel _____
_____
OVA: Serial Number _____ Calibration _____
HNU: Serial Number _____ Calibration _____

Recordkeeping - Field Logbooks

The logbooks will be the primary source of field information. Other records and forms (Section 1.8) will be used to sort information and have it available for field use.

1.1.3 Field Photographs

Photographs have proved to be the most accurate documentation of field worker observations. They should be taken with a camera-lens system having a perspective similar to that afforded by the naked eye. Telephotographic or wide-angle lenses should not be used. A photograph must be properly documented to provide a valid representation.

Project cameras, which print a date stamp on the print or slide, will be used for all project photographs. Personal cameras cannot be used on-Station. Photographs cannot be taken at MCAS El Toro without written authorization. When photographing in sensitive areas, an individual may be asked to be accompanied by a representative of the Station.

Related Procedures - Field Photographs

- Field Logbooks (Subsection 1.1.2)
- Access to Sensitive Military Areas (Subsection 1.1.4)

Equipment and Supplies - Field Photographs

- Camera, with date stamp
- Film
- Photography authorization form

Procedure - Field Photographs

The following procedure will be used for photographic documentation:

- Sign out a project camera from the equipment manager.

- Make a copy of the project (generic) photograph authorization form that is on the field administration office bulletin board. Carry the form at all times when in possession of a camera on-Station.

- Take the photographs. Record the required information in the field logbook (Subsection 1.1.2).

- Return the camera to the equipment manager at the end of each day.

- When a roll of film is finished, give the film to the equipment manager for development, along with the Record of Photographs Form (Form 1.4).

Recordkeeping - Field Photographs

Record the following information in the field logbook:

- Name of photographer
- Date and time

- Sequential number of the photograph
- Site identification and field task
- General direction faced and description of the subject

At the end of each day, using the information in the logbook, complete the Record of Photographs Form (Form 1.4) for the film used. The equipment manager will have the film developed and place the slides or prints in the task files in the field administration office, along with the completed Record of Photographs Forms.

1.1.4 Access to Sensitive Military Areas

Access to certain areas of the Station is restricted. These areas are primarily along and on the flight line and the more remote areas, such as those at Sites 1 and 16. The Field Manager, working through the Station Environmental Coordinator and Construction Engineer, will be responsible for obtaining access to these areas.

The procedures for obtaining access to restricted areas vary, depending on the area and the persons involved. The major considerations, however, are communication (military, site manager, and function team leader) and documentation.

Related Procedures - Sensitive Military Areas

- Field Photographs (Subsection 1.1.3)
- Radio Protocol (Subsection 1.1.5)

Equipment and Supplies - Sensitive Military Areas

Only project vehicles are allowed in certain areas of the Station; private vehicles must remain outside restricted areas.

Radios are the only special equipment that may be needed. Two types of radios are available. A military-frequency radio to be used at Site 1, the Explosive Ordnance Disposal (EOD) Range, may be obtained from the EOD Management Building. The larger-sized radios have a second channel used to contact the tower prior to crossing an active runway.

Procedure - Sensitive Military Areas

As soon as access to a restricted area will be required, notify the site manager and provide the following information:

- When access is needed
- What equipment will be used
- How many people are involved
- How long access is needed

The site manager will make the initial contacts for access and provide the function team leader with the information and protocol for access. The Team Manager will follow through with the steps needed to obtain and retain access during the work at the restricted site.

Recordkeeping - Sensitive Military Areas

Information concerning access to and operations in restricted areas will be documented in the site field book being kept for the operations. Names and telephone numbers of contacts, times, and discussions with contact persons should be recorded.

1.1.5 Radio Protocol

Each field team will have an outside communication device. Although several portable telephones may be available, two-way radio is the primary method of communicating between the field administration office and the field sites. Radios used by MCAS El Toro RI field teams will have either one or two channels. Channel 1 will be used for communications between the field administration office and a field team. Radios that are equipped with the second frequency (used to contact the MCAS El Toro tower) cannot be taken off-Station. The smaller, single-channel radios will be used for any work off-Station.

The radios are for professional use and conversations should be kept at a professional level and to a minimum. The radio frequency is public and, in theory, anyone can listen. Any highly sensitive material should be communicated to the field administration office from a telephone or in person.

Related Procedures - Radio Protocol

- Access to Sensitive Military Areas (Subsection 1.1.4)

Equipment and Supplies - Radio Protocol

- Portable radio
- Charging base for radio (left at the field office)

Procedure - Radio Protocol

Each field team will have a radio. Each day, one member of the team will sign out a radio. As soon as the team is at its first field location, the radio operator will check radio operation by calling the base. Calling involves first addressing the station called (in this instance, RI Base), then giving the assigned identification (as an example, RI-8). When you are finished transmitting and waiting for a return answer, the term "over," or literally "over to you," is used.

The sequence to call should be "RI Base, this is RI-8. Over." The answer should be "RI-8, this is RI Base. Over." At the completion of the call, the final word should be "Out," indicating that the conversation is complete.

At the end of the day, the radio is to be turned off, placed on the charger, and signed back in to the custody of the equipment manager. The radio must be turned off when it is placed on the charger or it will not be fully charged in the morning.

If a radio is checked out from a military unit for use in an area with restricted access (such as Site 1, the EOD range), treat it carefully and return it as soon as practical after use.

Recordkeeping - Radio Protocol

The sampling team leader will sign his or her name on the daily radio sign-out sheet (use Form 1.5, customized for radios) in the morning when the radio is checked out. The same person will sign again when the radio is returned at the end of the work day.

1.2 Initial Activities

Procedures that are performed only sporadically are discussed in this subsection. The procedures are field staking of sampling location, utility clearance for sampling locations, and land surveying.

1.2.1 Field Staking

"Staking" is the physical marking on the ground of each site where one or more samples will be collected. Each sample location will be staked in the field prior to moving equipment on to a site or prior to beginning any sampling. Where practical, staking will be done by driving rebar into the ground. On concrete or in traffic areas, a sample location may be staked by painting the location.

Prior permission is needed for access to restricted areas. In nonrestricted areas, it may be necessary to inform the local tenant of the reason for the staking and ask that staking markers be protected.

Preliminary staking may be completed prior to or during utility clearances. Utility clearances must be conducted at all sampling locations that use powered equipment to reach the sample depth. Final clearance and documentation in the Staking Logbook must be completed prior to beginning any sampling.

If the site has not been surveyed prior to sample collection, the location marker must be retained or replaced until the survey is complete.

Related Procedures - Field Staking

- Field Logbooks (Subsection 1.1.2)

- Field Photographs (Subsection 1.1.3)
- Access to Sensitive Military Areas (Subsection 1.1.4)
- Utility Clearance (Subsection 1.2.2)
- Land Surveying (Subsection 1.2.3)

Equipment and Supplies - Field Staking

The following equipment is required for field staking:

- MCAS El Toro utility maps
- Plate showing proposed soil gas locations
- SAP tables showing samples and designations
- Scale and tape measure
- Stakes made of 2-foot-long, 1/2-inch-diameter rebar
- Hammer and flagging (plastic survey ribbon)
- Waterproof marking pen
- Spray paint (color determined in the field)
- Compass

Procedure - Field Staking

Use Plate 1 in the Soil Gas Survey Work Plan and associated maps with enlarged portions of the Plate and the scale to locate the soil gas probe location from key landmarks, such as building corners or fences. Use the tape measure to scale the distance on the ground. If practical, scale from at least

two directions (use a compass if needed) to locate the point on the ground as closely as possible to the map location. If this is conducted at the same time as the surveying, then the surveyors can locate the points based on the digitized locations from the maps. The field engineer should then ensure that the location is appropriate before staking/marking. If not, move to an appropriate location and note the change in the field notebook.

If rebar staking can be placed at the site, place flagging on the ground and drive the rebar through it. Drive the rebar so that it is at least 5, but no more than 12, inches into the ground. Tie additional flagging to the rebar. Mark the sampling location identification on both pieces of flagging. If the rebar is in an area subject to traffic, pound the stake over at ground level. This configuration, besides being less of a hazard, may keep the stake from being pulled out of the ground.

If a rebar stake cannot be placed at the site, spray paint a small circle on the ground and cross the circle with an "X." Spray paint the location identification on the ground.

After the utility clearance (Subsection 1.2.2) has been performed, the resident officer in charge of construction (ROICC) will be notified and given a copy of the geophysical results. Arrangements must be made for the ROICC to provide field clearance and approve the location.

Recordkeeping - Field Staking

Records of field staking will be made in a function field book dedicated to that purpose. Label the field book and prepare an index at the front of the book, listing locations sequentially for cross referencing sites with pages.

Sketch the location, showing pertinent cultural or natural features and the distances from them. Note the type of staking (rebar or paint). Provide adequate information to allow the location to be restaked, if needed.

Geophysical utility clearance documentation (Subsection 1.2.2) will be recorded in the staking function logbook, along with approval by the ROICC, and the date and time of field inspection and approval to drill.

Any photographs taken shall be logged and filed as described in Subsection 1.1.3, Field Photographs.

1.2.2 Utility Clearance

Utility clearances will be made prior to collecting any sample that uses power equipment to reach the sample depth. Nonintrusive utility clearances will be completed by a subcontractor in conjunction with site field personnel.

Related Procedures - Utility Clearance

- Field Logbooks (Subsection 1.1.2)
- Sensitive Military Areas (Subsection 1.1.4)
- Staking (Subsection 1.2.1)
- Lithologic (Soils) Logging (Subsection 1.4.1)

Equipment and Supplies - Utility Clearance

- Field staking logbook, showing the location
- MCAS El Toro utility maps
- Spray paint
- Geophysical equipment (subcontractor's responsibility)
- Air Knife
- 55-gallon drums

Procedure - Nonintrusive Utility Clearance

Once the stake or the paint mark is set, the Station utilities maps of the area will be rechecked for underground utilities. Geophysical methods (through a subcontractor) will be used to help identify locations of underground lines, tanks, or other belowground items that may cause a hazard during drilling.

Nearby utilities will be marked on the ground by spray painting along the centerline of the utility. The type of utility will be marked next to the line. Forms showing the results of the geophysical survey will be completed in the field.

A copy of the Station utility map of the area and the geophysical record will be provided to the ROICC, who will inspect the area with a representative of the site manager. Soil gas probe installation will also be explored by advancing a 3-inch hole to a depth of 7 feet using an air knife, except in areas with no known utilities.

If a stake is moved for any reason, and if it is relocated 2 feet or more in any direction, or if the location has a large number of underground utilities, a replacement geophysical survey and ROICC clearance will be completed for the new location. Records will be kept for both locations, with the original and replacement locations clearly differentiated.

Procedure - Intrusive Utility Clearance - Air Knife

After the initial nonintrusive utility check has been completed, a final intrusive utility check will be conducted. This will be accomplished using an air knife technique.

The air knife is a nondestructive drilling system designed for utility clearance purposes. The air knife will be used to drill a 3- or 4-inch diameter hole to a

depth of 7 feet for the purpose of final clearance for the presence of buried utilities.

The air knife delivers compressed air under high pressure to drill soil holes. Air is delivered through a small tube attached to the side wall inside the 3-inch drill casing. The cuttings are vacuumed up through the drill casing.

After the hole has been advanced to 7 feet, the cuttings will be returned to the borehole. Remaining cuttings will be secured in a 55-gallon, labeled drum.

Recordkeeping - Utility Clearance

Field utility clearance will be documented in the field staking (function) logbook. The site identification, personnel, type of equipment used, log of the borehole (Subsection 1.3.1), and markings left at the location will be recorded. In addition, originals of geophysical records will be filed sequentially by soil gas sampling station identification in a permanent file in the field administration trailer, along with a sign-off sheet documenting that the ROICC representative has cleared the location. Working copies of the geophysical sketch will be available in a three-ring binder for taking to the field during drill-rig setup.

Documentation of the air knife utility clearance will be recorded in a separate air knife specific field notebook. The following information will be recorded:

- Station identification

- Date and time of drilling
- Depth of borehole
- Measurements away from the originally marked hole, if necessary, to move due to encountering buried utilities

1.2.3 Land Surveying

Each sampling point will be located by survey, using the State Plane Coordinate System, with northings and eastings determined to the nearest 0.1 foot. The surface elevation will be determined to the nearest 0.1 foot. The survey may be completed prior to or following sample collection.

Surveying will be performed by a qualified surveyor, working under the supervision of a licensed land surveyor. Survey equipment will be used, operated, and calibrated in accordance with the manufacturer's recommended procedures.

Related Procedures - Land Surveying

- Access to Sensitive Military Areas (Subsection 1.1.4)
- Radio Protocol (Subsection 1.1.5)
- Field Staking (Subsection 1.2.1)

Equipment and Supplies - Land Surveying

Equipment and Supplies - Land Surveying

- Standard survey equipment and supplies

Procedure - Land Surveying

Surveyors will be onsite only at selected times. Each point to be surveyed during the round will be marked on the ground and on field maps supplied to the survey crew prior to arriving at MCAS El Toro. Each point will be identified by the station identification on the map and on flagging attached to the rebar marking the sampling location.

Because surveyors will be working independent of other field crews, they will coordinate work with the site manager, who will inform them of sensitive military areas and obtain any special clearances needed while they are at MCAS El Toro.

Recordkeeping - Land Surveying

Survey field notes will be kept in a survey function logbook. Copies of the logbook will be placed in the field administration office files prior to the surveyors leaving MCAS El Toro. Calculations and other survey reduction data completed in the office will be placed in the office project files.

Surveying will be completed during more than one field session. The final survey data (sample location identification, northing, easting) after each round of sampling will consist of the listings of all sample points measured to date.

1.3 Soil Gas Sampling

Soil gas sampling will be conducted at Sites 24 and 25 during the soil gas survey. The work will be completed independently of the Phase II investigation.

1.3.1 Related Procedures

- Access to Sensitive Military Areas (Subsection 1.1.4)
- Field Staking (Subsection 1.2.1)
- Utility Clearance (Subsection 1.2.2)
- Land Surveying (Subsection 1.2.3)
- Headspace Analysis of VOCs in Soils (Subsection 1.3.2)
- Soil Sampling (Subsection 1.4)
- Backfilling of Borings (Subsection 1.4.3)
- Decontamination—Wash and Rinse Method (Subsection 1.5.1)
- Waste Handling—Personal Protective Equipment (PPE), Excess Samples, and Nonhazardous Trash (Subsection 1.6.2)

1.3.2 Equipment and Supplies

- Soil gas probes

- Installation equipment
- HNu and/or organic vapor analyzer (OVA)
- Field gas chromatograph
- Decontamination supplies

1.3.3 Procedure

Soil gas sampling will be conducted across a shallow, horizontal grid system, as shown in Plate 1 in the Soil Gas Survey Work Plan. The depth of soil gas samples will be less than 30 feet bgs due to the constraints of the probe installation technique. Each proposed soil gas sampling location will be staked and cleared for underground utilities. Soil sampling probes will driven into the soil to the desired depth.

Soil gas samples will be collected upon reaching the desired depth below ground surface (bgs). The samples will be extracted using an active sampling technique. The portable sampling system will consist of a stainless steel probe that is connected to a stainless steel sampling box by inert tubing. After reaching the desired sampling depth, the hole is sealed to isolate the probe from the atmosphere. A syringe in the sampling box is used to pull a volume of in-situ soil gas vapor from the ground through the probe and tubing. Three hundred milliliters (ml) of gas (15 purge volumes) is extracted to purge the air from the sampling system and then the gas is vented to the atmosphere. A second sample is then extracted and drawn into a pre-evacuated, self-sealing U.S. Environmental Protection Agency (EPA)-clean glass vial where it is

encapsulated at two atmospheres (15 psi) pressure. The system is then closed from the probe tip to the glass vial to prevent the loss of volatiles. Following the sample extraction, the sample vial is packaged in an airtight bag, labeled, and logged in a field notebook and Chain-of-Custody Form.

Soil gas samples will be analyzed in the field using a gas chromatograph (GC) equipped with flame-ionization detectors (FID) and electron capture detectors (ECD). Section 3.0 of the Soil Gas Survey Work Plan describes the sites where soil gas probes will be located and the analytes to be tested.

The soil gas probe will be decontaminated between locations using an Alconox wash and a tap water rinse. Syringes and adapters will be cleaned with Alconox at the end of each day and baked out overnight in the GC oven at a minimum temperature of 60° C.

After the soil gas samples have been collected from each location, the soil gas probe will be removed and the borehole abandoned according to the procedure outlined in Subsection 1.4.3.

The soil gas investigation will be conducted in compliance with the American Society for Testing and Materials (ASTM) Standard Guide for Soil Gas Monitoring in the Vadose Zone (Attachment 1).

Gas Field Screening. The types of field QC samples are field blanks, travel blanks, sample container blanks, sample probe blanks, and sample replicates. Table A-1 summarizes the field QC samples for the soil gas sampling.

Table A-1
Field Soil Gas Quality Control Samples
Soil Gas Investigation
MCAS El Toro Soil Gas Survey

Soil Gas Sample	Frequency of Collection			
	Field Control Blanks	Sample Container Blanks	Sample Probe Blanks	Field Replicates
Soil Gas Samples	5 percent	One per bottle lot	1[a]	10 percent

[a]One sample probe blank will be collected to demonstrate that the tubing used in the sampling system is inert. New tubing will be used at each soil gas sample depth and location.

Field control blanks will be used to provide an indication of the probability of leakage in the sampling system or the breakthrough of atmospheric air to the sampling device through macroporous migration pathways in the vadose zone such as soil cracks. Field control blanks of prepurified grade nitrogen or ambient air filtered through a dust and organic vapor cartridge will be obtained at the beginning of each day's sampling activities, after every 20th sample, and at the conclusion of each day's sampling. These field control samples will be labeled and analyzed in the same manner as, and will be visibly indistinguishable from, the actual field samples.

Travel blanks are the contents of a sample container handled in the same manner as those containers holding samples, except that there has been no sample inserted into the travel blank. The purpose of travel blanks is to audit

sample integrity for loss due to sample handling and transport. Since the field soil gas samples will be analyzed in an onsite laboratory, travel blanks will not be required.

Sample container blanks are obtained by sampling the contents of a clean sample container to ensure that residual contaminants are not present in the container prior to sample collection. Sample container blanks will be analyzed from one container in each bottle lot.

Sample probe blanks, consisting of carrier gas or atmospheric air contrasted to the atmospheric air blanks, will be drawn through the sampling device and recovered in the same manner as soil gas. The purpose of the sample probe blanks is to check for the presence of sample train contaminants that would impact the data. Sample probe blanks are necessary in systems where the soil gas is in contact with the drive rods. The method that will be employed uses dedicated inert tubing for each soil gas sample. Therefore, one sample probe blank will be collected to verify that the TFE Teflon tubing material does not contribute contaminants.

The entire sampling system will be purged prior to collection of each sample to displace the ambient air from the system. The sampling probe and apparatus, including tubes, valves, and injection needle, will be purged prior to each sample collection with a volume of prepurified grade nitrogen approximately 70 times the void space capacity.

Prior to collecting the soil gas sample, the sampling apparatus will be purged with in-situ soil gas. This in-situ soil gas, which is pulled into the system through the probe, will be used to purge the nitrogen air from the sampling equipment and prevent dilution of the actual sample. The gas is then vented to the atmosphere.

Field replicate samples will be recovered as separate soil gas samples collected from the same sample location and depth into multiple containers. Field replicates will be used to estimate the combined precision of sampling and analysis. The frequency of field replicate samples will be 10 percent (a replicate every 10th sample).

Chain-of-custody documentation for all samples will ensure that samples have not been altered or mishandled prior to analysis.

Documentation will be reviewed by the document control officer (field manager) on a daily basis. This will include reviewing the notebooks for sample inventories including QA/QC samples and review of field notes and chain-of-custody documentation.

1.3.4 Recordkeeping

Sample information will be recorded in the field notebook. Data collected will include the following:

- Sample identification
- Site and location
- Depth
- Method of collection
- Flow rate of soil gas withdrawal
- Vacuum pressures
- Identification of the field instrument
- Limits of detection for the field instrument
- Concentrations of selected volatile organic compounds (VOCs)

1.3.5 Headspace Analysis for VOCs in the Vadose Zone

The purpose of headspace analysis of soil gas in the field is to aid in the identification of locations in the vadose zone with contamination from VOCs. In most instances, both an OVA (a FID) and a photoionization detector (PID), sometimes called by the brand name HNu, will be available for use.

Related Procedures - Headspace Analysis for VOCs the Vadose Zone

- Soil Gas Sampling (Subsection 1.3.4)

- Waste Disposal—PPE, Excess Samples, and Nonhazardous Trash (Subsection 1.6.3)

Equipment and Supplies - Headspace Analysis for VOCs in the Vadose Zone

- OVA (FID)
- HNu (PID)

Procedure - Headspace Analysis for VOCs in the Vadose Zone

The HNu or OVA probe tip will be connected to a port from the soil gas sampling box. The reading will be recorded in the field notebook.

Prior to field use, the OVA and the HNu will be calibrated using appropriate calibration gases and documented in the same logbook used for documenting the headspace values.

Recordkeeping - Headspace Analysis for VOCs in the Vadose Zone

The information in the logbook will include:

- Station identification
- Soil Gas Probe depth and interval
- Date
- Time of collection
- Time of vapor analysis

- OVA results
- HNu results

1.4 Soil Sampling

The procedures listed in this subsection relate to logging and collecting soil samples during the soil gas survey. The borehole backfilling procedures are included in this group of procedures.

1.4.1 Lithologic (Soils) Logging

Information in this subsection refers to lithologic logging during soil sampling.

Related Procedures - Lithologic Logging

- Utility Clearance (Subsection 1.2.2)
- Headspace Analysis for VOCs in Soils (Subsection 1.4.2)

Equipment and Supplies - Lithologic Logging

- Boring log form (include with other forms)
- Pen with indelible ink
- Color chart
- Hand lens

Procedure - Lithologic Logging

Lithologic materials will be described using the Unified Soil Classification System (USCS) ASTM D 2488-84 (or the most recent version), on a standard logging form. CH2M HILL's "Standard Procedures for Logging of Soil Borings, January 1990," will be followed. A copy of the procedure is included as Attachment 2.

Recordkeeping - Lithologic Logging

Records of boring logs will be kept in both the logbook and on a Boring Log Form (Attachment 2). Data required include the station identification, the depth, sample identification number (if appropriate), the soil classification, the color, the percent gravel, sand, silt and clay, organic content, cementation, structure, and water content.

1.4.2 Soil Sampling During Soil Gas Probe Installation

This section described the procedures for collecting soil samples during the soil gas survey.

Related Procedures - Soil Sampling During Soil Gas Probe Installation

- Lithologic Logging - (Subsection 1.4.1)
- Backfilling of Borings - (Subsection 1.4.3)

Equipment and Supplies - Soil Sampling During Soil Gas Probe Installation

- Soil sampling core
- Stainless-steel sleeves
- Stainless-steel sampling spoons/implements

Procedure - Soil Sampling During Soil Gas Probe Installation

In locations where soil samples are to be collected, the soil gas probe will be removed from the hole after the soil gas sample has been collected at that depth. Soil samples will be collected by advancing a hydraulically driven 1-inch hollow-stem rod using a truck-mounted rig to the desired sample depth. Prior to collecting the soil, an open tip is exposed, and decontaminated stainless-steel sleeves are inserted into the 1-foot sampling core at the base of the drive rod. A soil core will be collected by driving the core through the desired soil layer. After the drive rod is removed from the soil, the stainless-steel liners containing the soil will be separated from the drive rod.

Soil from the middle liner will be used for the VOC analysis because the middle liner will have the least exposure to the atmosphere. Soil from this liner will be removed and placed into a 60 ml VOA vial. The sample will be preserved with methanol according to the protocol in Attachment 3. The soil will be rapidly transferred to the vial to minimize the amount of time that the soil is exposed to the atmosphere. Approximately half of the vial will be filled with soil. The cap will be placed upon the vial immediately after the proper amount of soil is placed in the vial.

At locations where additional samples are necessary due to onsite laboratory duplicates, fixed laboratory samples, fixed laboratory duplicates, or matrix spike/matrix spike duplicate (MS/MSD) samples, an additional soil core may be driven through consecutive soil layers. Duplicate samples should be collected in order of analytes. For example, soil for VOC analysis will be collected first, followed by soil for VOC duplicates, then soil for the TFH and SVOC analyses, and finally by soil for the TPH and SVOC analyses.

Field Quality Control - Soil Sampling During Soil Gas Probe Installation

Soil Field Screening. Types of QC samples that will be collected for soil samples include duplicate samples, equipment blanks, container blanks, travel blanks and MS/MSD samples. The types and frequency of each control sample is listed in Table A-2.

Container blanks are sample bottles filled with American Society for Testing and Materials (ASTM) Type II Reagent Water or equivalent organic-free water and returned to the laboratory for the identical analyses that would have been performed on the soil from that jar. Bottle lot samples will be collected from each bottle lot and for each sampling parameter.

For MS/MSD organic analyses, every sample is spiked in the laboratory with surrogate compounds and selected samples will be spiked in duplicate with selected target compound list (TCL) compounds. MS/MSDs are collected at a rate of approximately one field sample for each 20 samples (including duplicates, rinsates, equipment blanks, and source blanks). Samples suspected of moderate contamination will be preferentially chosen for

Table A-2

Field Quality Control Samples

MCAS El Toro Soil Gas Survey

Soil Sample Type	Frequency of Collection				
	Container Blank	Matrix Spike/matrix spike duplicate (MS/MSD)	Field Duplicates	Equipment Blanks	Trip Blanks
Field Screening Soil Samples	One per bottle lot	5 percent	10 percent	10 percent	NA
Fixed Laboratory Verification Soil Samples	One per bottle lot	5 percent	10 percent	10 percent	See Note

NA = not applicable, Samples will be analyzed in an onsite mobile laboratory.

Note: A trip blank will accompany each cooler for shipment to the fixed laboratory containing samples for VOC analysis. The trip blanks will be analyzed for VOCs by EPA Method 8010/8020.

laboratory QC samples, if possible. The sample will be identified as a MS/MSD sample on the sample containers and on the Chain-of-Custody Record.

MS/MSD samples will be collected as if they were duplicate samples. A double volume of either water or soil will be shipped for an identified MS/MSD sample. For soil samples, the additional material will be collected directly beneath the

standard collection area. For water, each half of the aliquot will be collected sequentially.

Duplicate samples are two samples collected independently at a sampling location during a single act of sampling. Field duplicates will be collected at a frequency of 10 percent. The samples will be blinded from the laboratory and analyzed by the same methods and for the same analytes as the soil samples.

Equipment blanks are samples collected to document the effectiveness of decontamination procedures and to verify that contamination is not introduced into the subsurface by the equipment. Equipment blank samples will be collected from the soil sampling equipment, including the sample core, stainless-steel core liners, and any utensils used to transfer the soil to the sample containers. Equipment blanks samples will be collected at a frequency of 10 percent. Only ultra-pure, organic-free water will be used for equipment blanks. The equipment blanks will be collected by passing the water over or through the equipment. The water will be collected directly into the sample containers and will be analyzed by the same methods and for the same analytes as the soil samples.

Recordkeeping - Soil Sampling During Soil Gas Probe Installation

The following information will be recorded in the field notebook:

- Sample station identification

- Sample name and depth
- Sample containers filled
- Analyses requested
- Laboratory that the samples were sent
- Method of shipment
- Date and time of collection
- Any unusual occurrences during collection

1.4.3 Backfilling of Borings

The borings will be abandoned by backfilling in a manner that prevents vertical movement of fluids along the borehole. The boring will be backfilled to meet pertinent requirements of the California Department of Water Resources, California Well Standards, Bulletins 74-81 and 74-90, Part III, Section 23.

Related Procedures - Backfilling of Borings

- Soil Gas Sampling (Subsection 1.3)
- Soil Sampling During Soil Gas Probe Installation (Subsection 1.4.3)

Equipment and Supplies - Backfilling of Borings

- Fine-grade bentonite pellets
- Potable water

- Concrete epoxy
- Asphalt patch

Procedure - Backfilling of Borings

After the soil gas and soil samples have been collected from the bottom-most depth, the probe assembly or drill rod will be removed. The remaining hole will be filled with fine-grade bentonite pellets. The pellets will be hydrated with the manufacturer-suggested amount of potable water and the surface appropriately patched. Concrete and tarmac surfaces will be patched with concrete epoxy; asphalt surfaces with asphalt patch; and soil surfaces with remaining soil from the borehole.

Recordkeeping - Backfilling of Borings

The following information will be recorded in the appropriate logbook:

- Station identification
- Measured depth of the boring
- Amount of bentonite used to fill the borehole
- Composition of the bentonite (may be recorded at the beginning of the notebook if the same brand bentonite is used for all boreholes)
- Measured amount of grout used to fill the hole

1.5 Decontamination

This section describes decontamination of all material that is reused during the soil gas field survey. It does not include personnel decontamination, which is described in the Health and Safety Plan (Appendix C of the MCAS El Toro Soil Gas Survey Work Plan).

MCAS El Toro has two constructed, concrete-lined decontamination areas with containment sumps for decontamination wastes. These pads are behind the office administration trailer. Cleaning of vehicles and equipment and any other decontamination project that requires a large amount of wash and rinse water will be done on one of these pads to facilitate the collection and treatment of decontamination solutions.

Small sampling equipment that is submersible can be washed at the sampling location. The equipment will be hand-washed, following the procedure in Subsection 1.5.1. Any decontamination procedure may be completed at the decontamination pad. All waste products developed away from the pad, however, must be contained, labeled, and transported to the decontamination pad or the waste handling facility.

1.5.1 Decontamination—Wash and Rinse Method

Equipment used for soil sampling will be decontaminated prior to and after use at each sampling probe location. This equipment includes trowels, augers, and downhole probes.

Related Procedures—Wash and Rinse Method

- Soil Gas Sampling (Subsection 1.3)
- Soil Sampling During Soil Gas Probe Installation (Subsection 1.4.2)

Equipment and Supplies—Wash and Rinse Method

- Equipment or materials to be cleaned
- Tubs or other containers for wash and rinse solution
- Alconox or other low-phosphate soap
- Bottled water (potable, deionized, and certified organic free)
- Scrub brushes
- Spray bottles
- Methyl alcohol
- Clean plastic wrap
- Sealed containers for moving waste to the decontamination area

Procedure—Wash and Rinse Method

Equipment used for soil sampling that is cleaned and reused in the field without returning to the decontamination pad will be decontaminated using the following procedure:

- The equipment will be scrubbed clean with an Alconox-type soap solution and a stiff long-bristle scrub brush. All waste solution will be containerized.

- The equipment will be rinsed over a rinsate tub with clean potable water, followed by distilled water.

- The equipment will be spray rinsed with methyl alcohol and allowed to drain and air dry.

- The equipment will be placed on a clean sheet of plastic and covered with another sheet if it is not to be used immediately.

The soil gas sampling probes and apparatus will be decontaminated internally and externally prior to each day's sample collection, and at additional intervals as judged appropriate by the sampling team. The following procedures will be used:

- Wash exterior with a laboratory cleaner
- Wipe dry with clean paper towels
- Rinse with distilled water
- Wipe dry with clean paper towels
- Flush interior of probe with laboratory cleaner
- Purge 30 seconds with 20 psi ultra pure grade air, prepurified nitrogen or filtered ambient air.

All drummed or otherwise containerized wastes from field decontamination must be appropriately labeled for transport to the waste staging area. Incidental rinsate may be placed in containers for solid or liquid waste. If Baker tanks or rolloff bins are not available at a site, specially setup 55-gallons drums may be used for field rinsate collection. Any decontamination project that requires a large amount of wash and rinse water should be moved to the decontamination pad to facilitate the collection and treatment of wash and rinse water.

Recordkeeping—Wash and Rinse Method

Decontamination will be documented in the function or site logbook, whichever is appropriate. The information will include:

- Date and time
- Sampling location where the items became contaminated
- Method of decontamination
- Person completing and witnessing the decontamination procedure
- Items decontaminated

1.6 Waste Handling

The field sampling team collecting samples at a location will be responsible for the waste generated at that location until notification is given to the Field Manager that the sealed container is ready to be moved to the Waste Storage Area. Waste movement

will be conducted by the subcontractor. The Field Manager will be responsible for classifying and disposing of solid wastes. A separate, detailed waste management plan will further describe waste management. Arrangement for transportation of solid waste from the sampling location, waste sampling, waste classification, and waste disposal will be the responsibility of the Field Manager, following the guidance in the Phase II RI Waste Management Plan.

1.6.1 Waste Handling—Cuttings from Probe Installations

Solid waste generated during drilling and sampling will be stored in rolloff bins or 55-gallon drums. The containers will be located within the exclusion zone during drilling operations.

Related Procedures—Waste Cuttings

- Intrusive Utility Check - Air Knife (Subsection 1.2.2)
- Sampling During Soil Gas Probe Installation (Subsection 1.4.3)

Equipment and Supplies—Waste Cuttings

- Waste containers supplied by the subcontractor
- Waste labels marked with indelible ink

Procedure—Waste Cuttings

Solid waste will be placed in a rolloff bin or 55-gallon drum. Storage containers will be closed and sealed when left unattended. When full (or the specific site work is complete), the container will be sealed at the site.

Each container will be affixed with a unique label that includes information identifying the site and boring(s), the depths from which the waste was produced, the date the container was first used, the date the container was last filled, and the initials of the person recording the information. The same information will be recorded, along with a description of the materials in the bound field notebook.

When the container is filled, the sampling team leader will notify the waste manager that the container is ready to be moved to the waste storage area.

Recordkeeping—Waste Cuttings

Each container of solid waste will have a unique number. Baker tanks and rolloff bins have painted or welded numbers. Records of these numbers and the source of the waste (including depths) will be kept in the field logbook. Fifty-five-gallon drums will need a permanent label attached that gives the source of the waste (including depths), dates, and the samplers' names.

1.6.2 Waste Handling—PPE, Excess Samples, and Miscellaneous Trash

Disposable PPE, including Tyvek coveralls, gloves, booties, duct tape, and plastic sheeting that comes in contact with samples, will be disposed of in a 55-gallon drum provided specifically for the disposal of PPE. It is important to keep PPE and miscellaneous trash separated. PPE will be separated into visibly contaminated and not visibly-contaminated. The not visibly-contaminated PPE will be treated as miscellaneous trash. The visibly-contaminated PPE must be treated as potentially hazardous material until proven otherwise. Miscellaneous trash collection and disposal is a normal housekeeping process that should not be mixed with the more complex and costly visibly-contaminated PPE disposal procedures.

Related Procedures—Miscellaneous Waste

- Air Knife Utility Check (Subsection 1.2.2)
- Soil Gas Sampling (Subsection 1.3.3)
- Soil Sampling during Soil Gas Probe Installation (Subsection 1.4.3)

Equipment and Supplies—Miscellaneous Waste

- Fifty-five-gallon drums with sealable lid for PPE
- Labels marked with indelible ink
- Heavy-duty trash bags with ties

Procedure—Miscellaneous Waste

A 55-gallon drum for visibly contaminated PPE disposal will be set up at any location where drilling and related equipment are used. All visibly contaminated disposable PPE will be placed in the drum immediately upon completion of use. The lid will be left on the drum when it is not being filled. When the drum is full, it will be transported to the waste staging area by the subcontractor.

Visibly contaminated PPE generated at sampling locations may be placed in heavy-duty trash bags with ties, provided the waste material is labeled at the end of each day, transported to the waste storage area, and placed in the waste PPE storage bin or area.

Miscellaneous trash that does not come into contact with samples or visibly contaminated PPE will be placed in heavy-duty trash bags that are left in the vehicle transporting the field team. At the end of each day, this trash will be placed in the waste bin at the field administration office site.

Samples not submitted for analysis will be left sealed in a plastic bag. The sample will be marked on the bag to indicate site identification, depth, date collected, and the person who collected it. These samples will be stored in specially marked 55-gallon drums in the waste storage area.

Recordkeeping—Miscellaneous Waste

The visibly contaminated PPE waste drum will be labeled to indicate the site, date, and contents (PPE) after it is set in place and prior to its use. The identification information will be recorded in the field logbook.

1.7 Sample Handling, Packaging, and Shipping

This section describes the sample containers, sample identification system, procedures for sample handling, chain-of-custody procedures, and shipping procedures. Although some of the information is duplicated in the QAPP, this section emphasizes specific procedures to be followed by the field staff.

1.7.1 Sample Containers

Sample containers will be shipped from the laboratory in sealed boxes and will be certified as having been decontaminated prior to being shipped. Where applicable, preservatives may be placed in the containers prior to them arriving at the field site.

Related Procedures—Sample Containers

- Field Logbooks (Subsection 1.1.2)
- Soil Sampling During Soil Gas Probe Installation (Subsection 1.4.3)
- Sample Numbering (Subsection 1.7.2)

- Chain of Custody (Subsection 1.7.3)
- Sample Handling in the Field (Subsection 1.7.4)
- Sample Packaging (Subsection 1.7.5)
- Sample Shipping (Subsection 1.7.6)

Equipment and Supplies—Sample Containers

- Sample containers
- Trip blanks
- Tables showing analytes by site and sample (QAPP)
- Preservatives, if not added prior to field work
- Sampling labels
- Pen with indelible ink

Procedure—Sample Containers

Before leaving for the field, the sampling team leader will obtain the proper containers and forms from the sample manager. The labels will be partially completed before moving to the field. The containers will be left closed until needed for the sample.

Trip blanks will be supplied by the laboratory conducting the analyses. The blanks will be shipped with the bottles and stored in the sample trailer. A trip blank will be transported with the sample container to and from the sample collection point and to the laboratory for analysis. Only one trip blank will be

shipped with each group of samples to be analyzed for VOCs at the fixed laboratory.

After a sample is collected, the sample container will be sealed, the label and chain of custody will be completed, and a custody seal will be placed so that the lid cannot be opened without breaking the seal.

Recordkeeping—Sample Containers

Certificates of cleanliness for glassware, including bottle lot numbers, will be cross-referenced to provide ample identification in the field logbooks. Information of whether preservatives are added at the laboratory, or by the sample manager, will be recorded in the same locations as the sample identification.

1.7.2 Sample Numbering

Sample numbers will be assigned on the basis of a code system that provides blind samples to the laboratory, with no duplication of numbers. The database used for sample management uses a 10-digit identifier; thus, the identification system must use a combination of no more than 10 numbers and letters.

Related Procedures—Sample Numbering

- Field Logbooks (Subsection 1.1.2)

- Sampling During Soil Gas Probe Installation (Subsection 1.4.3)
- PPE, Excess Samples, and Nonhazardous Trash (Subsection 6.6.3)
- Sample Containers (Subsection 1.7.1)
- Chain of Custody (Subsection 1.7.3)
- Sample Handling in the Field (Subsection 1.7.4)
- Sample Packaging (Subsection 1.7.5)
- Sample Shipping (Subsection 1.7.6)

Equipment and Supplies—Sample Numbering

- Code information from this section
- Soil gas sample location plate

Procedure—Sample Numbering

Each sample will have a location station number and sample name. For Round I, the station identification numbers will be 24_SG_001 through 24_SG_300. For Round II, the station identification numbers will be 24_SG_301 through 24_SG_500.

Sample name for soil gas samples in Round I will be as follows:

- Soil gas samples collected from 12 feet bgs: S145G1001 through S145G1300

- Soil gas samples collected from 20 feet bgs: S145G1301 through S145G1600

- Additional soil gas samples: S145G2001 through S145G2999

- QA/QC samples: S145G3001 through S145G3999

Sample name for soil gas samples in Round II will be as follows:

- Soil gas samples collected from 12 feet bgs: S145G1601 through S145G1800

- Soil gas samples collected from 20 feet bgs: S145G1801 through S145G2000

- Additional soil gas samples: S145G2001 through S145G2999 (numbers to be continued from Round I additional samples)

- QA/QC samples: S145G3001 through S145G3999 (numbers to be continued from Round I QA/QC samples)

- Onsite GC/MS soil samples: S1457301 through S1457500

- Additional onsite GC/MS soil samples: S1457501 through S1457599

- Soil QA/QC samples: S1457700 through S1457799

- Soil samples sent to the fixed laboratory: S1457600 through S1457699.

Recordkeeping—Sample Numbering

This unique sample number will be recorded in all appropriate places, including the field logbook, chain of custody, sample logbook, each sample container, and boring logs.

1.7.3 Sample Custody

Because of the potential evidentiary nature of samples, the possession of samples must be traceable from the time the samples are collected until they are introduced as evidence in enforcement proceedings. A sample is under a persons's custody if one or more of the following criteria are met:

- It is in a person's possession
- It is in a person's view after being in possession
- It was in a person's possession, then locked up to prevent tampering
- It is in a designated area

Additional information on overall chain-of-custody procedures, including those by the laboratory and a sample chain-of-custody form, is in the accompanying QAPP.

Related Procedures—Sample Custody

- Field Logbooks (Subsection 1.1.2)
- Photographs (Subsection 1.1.3)
- Soil Gas Sampling (Subsection 1.3)
- Soil Sampling During Soil Gas Probe Installation (Subsection 1.4.3)
- PPE, Excess Samples, and Nonhazardous Trash (Subsection 1.6.3)
- Sample Containers (Subsection 1.7.1)
- Sample Numbering (Subsection 1.7.2)
- Sample Handling in the Field (Subsection 1.7.4)
- Sample Packaging (Subsection 1.7.5)
- Sample Shipping (Subsection 1.7.6)

Equipment and Supplies—Sample Custody

- Sample document logbook
- Chain-of-custody records
- Custody seals
- Air bills or other bills of lading
- Pen with indelible ink

Procedure—Sample Custody

The sample manager will maintain a supply of field documents, and will be responsible for inventory of serialized documents and assignment of these documents to specific tasks and sampling team leaders. Assignments will be noted in a logbook. All unused field documents will be returned to the sample manager at the conclusion of each sampling period.

Field Custody. The field sampler is personally responsible for the care and custody of the samples collected until they are transferred to the sample manager or other responsible person. The field sampler will enter the sample information on the Chain-of-Custody Forms in the field as each sample is collected. The Site Manager will be responsible for determining whether proper custody procedures were followed and whether additional samples are required because of a question of custody.

Whenever samples are split with another party, the field sampler will note the split in the Remarks section of the Chain-of-Custody section. The note will indicate with whom the samples were split and will be signed by both the sampler and the recipient. If a representative is unavailable or refuses to sign, the sampler will note this in the Remarks section of the Chain-of-Custody Form.

Transfer of Custody. The chain of custody must move with the samples. When transferring samples, the individuals relinquishing and receiving them sign, date, and note the time on the record. The time of relinquishment and

receipt will be identical to avoid breaking the chain of custody. Notation of the bill of lading number, name of the shipping company, and signature of the shipping company agent on that bill of lading serves to keep the chain of custody intact during shipping. Any blank space will be lined out and initialed by the sample manager or other person relinquishing custody to the supplier.

Recordkeeping—Sample Custody

The Chain-of-Custody Forms will be numbered sequentially, and all Chain-of-Custody Forms used during the field activities will be accounted for. The sample logbook will list each custody form, serial number, samples associated with that form, bottle lot numbers, laboratory to which the samples were shipped, and date of shipment. In addition, information on rinsates, sample and rinsate disposition, decontamination, and any potentially important information must be in the sample logbook. The sample manager will be responsible for ensuring that this log is up-to-date and readily available for reference.

1.7.4 Sample Handling in the Field

This section describes the way samples are to be handled in the field from the time they are collected until they are received by the sample manager or are shipped by the sample team leader. The information duplicates some information in the QAPP.

Related Procedures—Sample Handling

- Field Logbooks (Subsection 1.1.2)
- Soil Gas Sampling (Subsection 1.3)
- Soil Sampling During Soil Gas Probe Installation (Subsection 1.4.3)
- PPE, Excess Samples, and Nonhazardous Trash (Subsection 1.6.3)
- Sample Containers (Subsection 1.7.1)
- Sample Numbering (Subsection 1.7.2)
- Chain of Custody (Subsection 1.7.3)
- Sample Packaging (Subsection 1.7.5)
- Sample Shipping (Subsection 1.7.6)

Equipment and Supplies—Sample Handling

- Sample containers
- Preservatives, if needed
- Labels, chain-of-custody forms, custody forms, and logbook
- Trip blanks
- Pen with indelible ink
- Plastic bags
- Ice chest (cooler), with adequate ice

Procedure—Sample Handling

The physical collection of samples is described in each section detailing the types of sampling that will be performed during the Phase II MCAS El Toro field work. Once the sample is collected, custody sealed, and labeled, it will be placed in a cooler for storage pending release to the sample manager or the shipper.

Coolers will be stored in the shade, in direct sight of the person with custody of the stored samples. The temperature will be taken a minimum of three times per day with a thermometer and ice will be added if needed. Before shipping, the samples will be repackaged and fresh ice will be added to the shipping cooler. Temperature and time of measurement will be entered into the field logbook.

Recordkeeping—Sample Handling

The Chain-of-Custody Record for a given group of samples will be kept with those samples and the cooler at all times. Field notebooks, labels, and the Chain-of-Custody Record will be completed in a timely manner.

1.7.5 Sample Packaging and Shipping

The final responsibilities of the field sample team will be to ensure that each sample is properly packaged and delivered/shipped to the appropriate onsite or offsite laboratory and that a record of that shipment is available.

Related Procedures

- Field Logbooks (Subsection 1.1.2)
- Soil Gas Sampling (Subsection 1.3)
- Soil Sampling During Soil Gas Probe Installation (Subsection 1.4.3)
- Sample Containers (Subsection 1.7.1)
- Sample Numbering (Subsection 1.7.2)
- Chain of Custody (Subsection 1.7.3)
- Sample Handling in the Field (Subsection 1.7.4)

Equipment and Supplies

- Shipping coolers
- Forms and labels
- Styrofoam packing material
- Filled sample containers
- Bubble paper or other container wrap
- Sealable plastic bags
- Strapping tape

- Bill of lading for the carrier to be used
- Custody seals
- Ice

Procedure

Samples to be sent to the offsite laboratory will be packaged and released to the transporting agent in the following manner:

- Individual sample containers will be sealed with a custody seal and labeled, as described in the Phase II RI QAPP, Section 4.0, and placed in a cooler at the sample collection location.

- Coolers will be placed in the shade during the day with adequate ice to lower the temperature of samples to 4° C.

- Samples held overnight prior to shipping will be placed in a locked refrigerator or a locked and custody-sealed cooler in a locked building under the custody of the last person signed on the accompanying custody form. The temperature will be checked and recorded when the cooler is first opened.

- Before shipment, each container within a cooler will be packaged and sealed in a separate sealable plastic bag. (Multiple container of some analyses, for example, VOCs, may be placed in a single plastic bag

as shown in the Phase II RI QAPP figures.) Phase II RI QAPP Figure 4-1 shows the process for packaging soil and sediment samples, and Phase II RI QAPP Figure 4-2 illustrates packaging for groundwater and surface water samples.

- Coolers used for shipment will be drained, dried, and lined with a plastic bag and approximately 3 inches of styrofoam "peanuts" or other packing and cushioning material. Vermiculite will not be used.

- The sample containers and ice (or reusable Blue-Ice packages) packed in sealable plastic bags will be placed on end in the cooler and arranged so that they do not touch. The voids will be filled with packing material.

- Each cooler must weigh less than 70 pounds unless other arrangements are made with the shipping agent.

- The large plastic bags will be taped closed and custody sealed.

- The Chain-of-Custody Record going to the laboratory will be reviewed and completed with the bill of lading number and the date and time the shipment was released to the shipping agent.

- The Chain-of-Custody Record will be placed in a sealable plastic bag. The bag will be custody sealed and taped to the inside of the cooler lid.

- The cooler lid will be closed and taped shut with strapping tape. A mailing label or bill of lading with the address of the laboratory and the name of the shipper will be placed on top of the container.

- At least two signed custody seals will be affixed over lid openings (front and back of cooler under strapping tape).

Recordkeeping

One copy of the Chain-of-Custody Records will be kept sequentially in a controlled custody book in the sample manager's office. Anyone using the book will check it out, using Form 1-3. Custody forms returned from the laboratory will be filed with the hard copies of laboratory analyses at CH2M HILL's office in the data management area.

1.8 Referenced Forms and Data Sheets

The standard CH2M HILL Boring Log Form is in Attachment 2. The following pages contain the other forms and information referenced in the previous portions of this section. These forms are to be used in addition to the information recorded in the bound field books. The forms are:

- Field Personnel Sign-in Log (Form 1.1)
- Visitor Sign-In Log (Form 1.2)
- Logbook Sign Out/In (Form 1.3)
- Record of Photographs (Form 1.4)
- Radio or Portable Telephone Check Out Record (Form 1.5)
- Miscellaneous Equipment Record (Form 1.6)

FORM 1.1
SOIL GAS SURVEY, MCAS EL TORO
FIELD PERSONNEL SIGN-IN LOG
WEEK BEGINNING_____, 199__

CH2M HILL NAME	INITIAL EACH DAY of the week prior to going into the field/ AT THE END OF THE DAY NOTE HOURS IN THE FIELD						
	Sat	Sun	Mon	Tues	Wed	Thur	Fri
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
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	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/

JEG NAME	INITIAL EACH DAY of the week that you are actually on-site AT THE END OF THE DAY NOTE HOURS IN THE FIELD						
	Sat	Sun	Mon	Tues	Wed	Thur	Fri
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/
	/		/	/	/	/	/

FORM 1.2
SOIL GAS SURVEY, MCAS EL TORO
VISITOR SIGN-IN LOG

Date	*Time*	*Name*	*Representing*	*Telephone*

FORM 1.3
SOIL GAS SURVEY, MCAS EL TORO
LOGBOOK SIGN OUT/IN

Logbook Site Number or Function _____ Logbook Number _____

Field Logbook Checked Out Date and Time	Field Logbook Checked In Date and Time	Signature of Responsible Sampling Team Leader

FORM 1.4
SOIL GAS SURVEY, MCAS EL TORO
RECORD OF PHOTOGRAPHS

Film Type _____ ASA Number _____

Photo No.	Date	Time	Photographer	Location	Description
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					

FORM 1.5
SOIL GAS SURVEY, MCAS EL TORO
RADIO OR PORTABLE TELEPHONE CHECK OUT RECORD

RADIO or TELEPHONE IDENTIFICATION Number _____

Radio Checked Out Date and Time	Radio Checked In Date and Time	Signature of Responsible Sampling Team Leader

FORM 1.6
SOIL GAS SURVEY, MCAS EL TORO
MISCELLANEOUS EQUIPMENT RECORD

Equipment Identification: _____ Serial Number _____

Checked Out: Date and Time	Checked In: Date and Time	Signature of Responsible Sampling Team Leader

Attachment 1

ASTM STANDARD GUIDE FOR SOIL GAS MONITORING IN THE VADOSE ZONE

Designation: D 5314 - 93

Standard Guide for Soil Gas Monitoring in the Vadose Zone[1]

This standard is issued under the fixed designation D 5314; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers information pertaining to a broad spectrum of practices and applications of soil atmosphere sampling, including sample recovery and handling, sample analysis, data interpretation, and data reporting. This guide can increase the awareness of soil gas monitoring practitioners concerning important aspects of the behavior of the soil-water-gas-contaminant system in which this monitoring is performed, as well as inform them of the variety of available techniques of each aspect of the practice. Appropriate applications of soil gas monitoring are identified, as are the purposes of the various applications. Emphasis is placed on soil gas contaminant determinations in certain application examples.

1.2 This guide suggests a variety of approaches useful to successfully monitor vadose zone contaminants with instructions that offer direction to those who generate and use soil gas data.

1.3 This guide does not recommend a standard practice to follow in all cases nor does it recommend definite courses of action. The success of any one soil gas monitoring methodology is strongly dependent upon the environment in which it is applied.

1.4 Concerns of practitioner liability or protection from or release from such liability, or both, are not addressed by this guide.

1.5 This guide is organized into the following sections and subsections that address specific segments of the practice of monitoring soil gas:

Section	
4	Summary of Practice
4.1	Basic principles, including partitioning theory, migration and emplacement processes, and contaminant degradation
4.7	Summary Procedure
5	Significance and Use
6	Approach and Procedure
6.1	Sampling Methodology
6.5	Sample Handling and Transport
6.6	Analysis of Soil Gas Samples
6.7	Data Interpretation
7	Reporting

1.6 *This guide does not purport to set standard levels of acceptable risk. Use of this guide for purposes of risk assessment is wholly the responsibility of the user.*

1.7 The values stated in either inch-pound or SI units are to be regarded separately as the standard. The values given in parentheses are for information only.

1.8 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Related to Soil, Rock, and Contained Fluids[2]

D 1356 Terminology Relating to Atmospheric Sampling and Analysis[3]

D 1357 Practice for Planning the Sampling of the Ambient Atmosphere[3]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1605 Practices for Sampling Atmospheres for Analysis of Gases and Vapors[3]

D 1914 Practice for Conversion Units and Factors Relating to Atmospheric Analysis[3]

D 2652 Definitions of Terms Relating to Activated Carbon[4]

D 2820 Test Method for C_1 Through C_5 Hydrocarbons in the Atmosphere by Gas Chromatography[3]

D 3249 Practice for General Ambient Air Analyzer Procedures[3]

D 3416 Test Method for Total Hydrocarbons, Methane, and Carbon Monoxide (Gas Chromatographic Method) in the Atmosphere[3]

D 3584 Practice for Indexing Papers and Reports on Soil and Rock for Engineering Purposes[2]

D 3614 Guide for Laboratories Engaged in Sampling and Analysis of Atmospheres and Emissions[3]

D 3670 Guide for Determination of Precision and Bias of Methods of Committee D-22[3]

D 3686 Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method)[3]

D 3687 Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method[3]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4490 Practice for Measuring the Concentration of Toxic Gases or Vapors Using Detector Tubes[3]

[1] This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved Nov. 15, 1992. Published January 1993.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 11.03.

[4] *Annual Book of ASTM Standards*, Vol 15.01.

D 4597 Practice for Sampling Workplace Atmospheres to Collect Organic Gases or Vapors with Activated Charcoal Diffusional Samplers[3]
D 4696 Guide for Pore-Liquid Sampling from the Vadose Zone[2]
D 4700 Guide for Soil Core Sampling from the Vadose Zone[2]
D 5088 Practice for the Decontamination of Field Equipment Used at Non Radioactive Waste Sites
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[5]
E 260 Practice for Packed Column Gas Chromatography[6]
E 355 Practice for Gas Chromatogaphy Terms and Relationships[6]
E 594 Practice for Testing Flame Ionization Detectors Used in Gas Chromatography[6]
E 697 Practice for Use of Electron-Capture Detectors in Gas Chromatography[6]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *capillary fringe*—the basal region of the vadose zone comprising sediments that are saturated, or nearly saturated, near the water table, gradually decreasing in water content with increasing elevation above the water table. Also see Terminology D 653.

3.1.2 *contaminant*—substances not normally found in an environment at the observed concentration.

3.1.3 *emplacement*—the establishment of contaminant residence in the vadose zone in a particular phase.

3.1.4 *free product*—liquid phase contaminants released into the environment.

3.1.5 *free vapor phase*—a condition of contaminant residence in which volatilized contaminants occur in porosity that is effective to free and open gaseous flow and exchange, such porosity generally being macroporosity.

3.1.6 *liquid phase*—contaminant residing as a liquid in vadose zone pore space, often referred to as "free product."

3.1.7 *macroporosity*—large intergranular porosity with large pore throats, including soil cracks, moldic porosity, animal burrows and other significant void space.

3.1.8 *microporosity*—intragranular porosity and microscopic intergranular porosity with submicroscopic pore throats.

3.1.9 *occluded vapor phase*—condition of contaminant residence in which volatilized contaminants occur in porosity that is ineffective to free and open gaseous flow and exchange, such porosity generally being microporosity; frequently termed dead-end pore space.

3.1.10 *partitioning*—the act of movement of contaminants from one soil residence phase to another.

3.1.11 *soil gas*—vadose zone atmosphere.

3.1.12 *solute phase*—a condition of contaminant residence in which contaminants are dissolved in ground water in either the saturated or the vadose zone.

3.1.13 *sorbed phase*—a condition of contaminant residence in which contaminants are adsorbed onto the surface of soil particles or absorbed by soil organic matter.

3.1.14 *vadose zone*—the hydrogeological region extending from the soil surface to the top of the principal water table.

4. Summary of Guide

4.1 Soil gas monitoring in the vadose zone is a method used to directly measure characteristics of the soil atmosphere that are frequently utilized as an indirect indicator of processes occurring in and below a sampling horizon. Soil gas monitoring is used as a method to suggest the presence, composition, and origin of contaminants in and below the vadose zone. Among other applications, this method is also employed in the exploration for natural resources, including petroleum, natural gas and precious metals. Soil gas monitoring is a valuable screening method for detection of volatile organic contaminants, the most abundant analytical group of ground-water contaminant compounds (**1**).[7]

4.2 *Basic Theoretical Principles*—The processes indicated by the soil gas monitoring method are partitioning, migration, emplacement and degradation. Partitioning represents a group of processes that control contaminant movement from one physical phase to another, these phases being liquid, free vapor (that is, through-flowing air (**2**)), occluded vapor (that is, locally accessible air and trapped air (**2**)), solute and sorbed. Migration refers to contaminant movement over distance with any vertical, horizontal or temporal component. Emplacement refers to establishment of contaminant residence in any phase within any residence opportunity. Degradation is the process whereby contaminants are attenuated by oxidation or reduction in the vadose zone, either through biogenic or abiogenic processes. Soil gas monitoring measures the result of the interaction of these processes in a dynamic equilibrium. Measurement of these processes in static equilibrium is unrealistic.

4.3 The following subsections provide detailed information on partitioning, migration, emplacement and degradation. Subsection 4.4 provides a summary procedure for soil gas sampling. Users of this guide who do not wish to study details of partitioning, migration, emplacement and degradation at this time may skip to 4.4.

4.3.1 Partitioning is the initial step by which contaminants begin to move away from their source. Partitioning occurs in water saturated and unsaturated environments. This group of processes is complex and difficult to quantify when considered in the vadose zone due to the unique makeup of the vadose matrix, i.e. air-filled porosity (microporous and macroporous), pore water, free product, solid-phase soil organic matter, clay and discrete inorganic soil particles. Important individual processes of partitioning are dissolution, volatilization, air-water partitioning, soil-water partitioning and soil-air partitioning (**3**).

4.3.2 Dissolution is the process whereby volatile contaminants move between the liquid phase (free product) and the solute phase (dissolved in water). At equilibrium, the product of the mole fraction of a particular compound in the liquid phase and the activity coefficient of that compound in the liquid phase is equal to the product of the mole fraction of

[5] *Annual Book of ASTM Standards*, Vol 14.02.
[6] *Annual Book of ASTM Standards*, Vol 14.01.
[7] The boldface numbers given in parentheses refer to a list of references at the end of the text.

that compound in the solute phase and the activity coefficient of that compound in the solute phase. This process is more clearly described by the following expression:

$$X^L{}_I \Gamma^L{}_I = X^W{}_I \Gamma^W{}_I \quad (1)$$

where:

$X^L{}_I$ = the mole fraction of compound (I) in the liquid (L) phase (free product),

$X^W{}_I$ = the mole fraction of compound (I) in the solute (W) phase (dissolved in water),

$\Gamma^L{}_I$ = the activity coefficient of compound (I) in the liquid (L) phase (free product), and

$\Gamma^W{}_I$ = the activity coefficient of compound (I) in the solute (W) phase (dissolved in water).

Dissolution equilibrium is therefore influenced by concentration of the subject compound in both the free product contaminant mixture and water. The most common practical application of expression Eq (1) in soil gas monitoring is in hydrocarbon detection. Simplification of Eq (1) is achieved by the following:

assume:

$$\Gamma^W{}_I = 1/S_I,$$

where:

S = the solubility of compound (I) in water

and:

$\Gamma^L{}_I = 1$, acceptable for hydrocarbons (**3**),

then:

$$X^W{}_I = X^L{}_I S_I \quad (2)$$

4.3.2.1 Dissolution equilibrium is impacted by the presence of liquid phase cosolvents, such as gasoline additives, at low concentrations in liquid phase mixtures. This change in dissolution equilibrium can enhance the solubility of certain liquid phase components in water beyond what is indicated by partitioning coefficient data generated in the laboratory. This can have significant impact on downstream concentrations of the contaminant(s) in the soil atmosphere.

4.3.2.2 The effects of temperature upon dissolution equilibrium are generally insignificant for aliphatic hydrocarbons between 15 and 50°C (**4**), the temperature range from which most soil gas samples are recovered. However, temperature effects upon dissolution equilibrium can be significant for other common families of contaminant compounds within similar temperature ranges (**5**). These effects must be considered when planning or interpreting the results of a soil gas survey.

4.3.2.3 Dissolution equilibrium is altered by changes in water salinity. Modest decreases in the solubility of contaminants in water are to be expected with increases in salinity of the solution.

4.3.2.4 The rate of dissolution is strongly dependent upon the partitioning coefficient of the particular contaminant of interest and the amount of mixing of the liquid phase and water (**3**). For example, partitioning of a particular contaminant into ground water is accelerated by frequent water level fluctuations within a contaminated capillary fringe. The downstream implications for subsequent partitioning of the contaminant from the solute to the vapor phase for eventual soil gas recovery are obvious.

4.3.3 Volatilization is the process during which volatile contaminants move between the liquid phase (free product) or solute phase and a vapor phase, either the free vapor phase or the occluded vapor phase or both. Contaminant mixtures can contain compounds with a considerable range of vapor pressures that can contribute contaminants to the soil atmosphere by volatilization. This atmosphere will exhibit a composition similar to that of the parent contaminant but lacking in those constituents with the lowest vapor pressures. The likelihood of the presence of a particular contaminant introduced into the soil atmosphere by volatilization can be estimated by considering the partial pressure of that contaminant in a vapor phase. This partial pressure is equal to the product of the mole fraction concentration of the subject component in the liquid contaminant solution, the activity coefficient of the subject component and the vapor pressure of the pure component. This concept is more clearly expressed as follows:

$$P = X_I \Gamma_I P^o \quad (3)$$

where:

P = the partial pressure of the subject contaminant compound in the vapor phase,

X_I = the mole fraction concentration of contaminant (I) in the liquid contaminant solution,

Γ_I = the activity coefficient of the subject contaminant in the liquid contaminant solution, and

P^o = the vapor pressure of the pure component.

4.3.3.1 The quantity of contaminant volatilized into a vapor phase and the rate of that process is strongly dependent upon temperature. Rate of volatilization is also controlled by the rate of transport of contaminant vapors from the liquid phase-vapor phase interface (**3**). This rate is probably higher when macroporous flow paths are available for vapor phase transport, and is promoted by a number of driving forces. These are concentration gradient, density gradient between soil atmosphere and contaminant-saturated soil atmosphere, convection currents related to temperature gradient, barometric pressure pumping and introduction of water onto the liquid phase-vapor phase interface.

4.3.4 Air-water partitioning is the process by which volatile contaminants move between the solute phase and a vapor phase, either the free vapor phase or the occluded vapor phase or both. For dilute solutions, air-water partitioning is controlled by Henry's Law, which states that the vapor pressure of a volatile compound above a dilute aqueous solution of that compound is equal to the product of the Henry's Law constant and the mole fraction of that compound in the aqueous solution. Henry's Law may be represented as:

$$P_I = kX_{I(aq)} \quad (4)$$

where:

P_I = vapor pressure of compound (I) above a dilute aqueous solution of (I),

k = the Henry's Law constant for compound (I) at a given temperature, and

$X_{I(aq)}$ = the mole fraction of the subject contaminant compound in the aqueous solution.

Care must be exercised in using Henry's Law to approximate contaminant vapor pressures because of unknowns related to the concentration of contaminants in solution and the contribution of other partitioning processes. Some available literature pertaining to soil gas surveying places emphasis on

Henry's Law constant at 25°C and atmospheric pressure as a primary controlling factor in determining the suitability of a particular volatile contaminant to the soil gas monitoring method. Such emphasis may be inappropriate when, for example, free product is the source of contaminant vapors or when contaminants have not reached ground water. Care must also be exercised in noting the units in which Henry's Law constants are expressed, as these vary from source to source. Volatile but very highly water soluble compounds behaving according to Henry's Law may not be detectable in soil gas because of their persistence for residence in the solute phase (**6**).

4.3.5 Soil-water partitioning is the process by which volatile contaminants move between the sorbed phase and the solute phase. This process is generally underestimated in its importance to the success or failure of contaminant recovery by soil gas sampling, especially when utilizing the majority of active soil gas sampling techniques generally available to field personnel.[8] There is uncertainty with respect to factors controlling soil-water partitioning, creating doubt as to the reliability of soil sorption data in most applications. Problems with soil sorption data include variability in measurement protocols, the variable nature of organic matter in soils, the effect of dissolved organic matter, unusual pH effects and the effect of salinity, among others (**3**).

4.3.5.1 The contribution of soil-water partitioning to contaminant phase residence equilibria is strongly controlled by sorbed contaminant concentration in soil, soil makeup, vadose zone pore water content, and soil porosity configuration. Important variables in soil makeup are the quantity, type and distribution of clay in soil and the quantity, type and distribution of soil organic matter. These variables impact the surface area available to sorptive processes, that is, the storage capacity of the soil for contaminants in the sorbed phase, and the pH of the sorption environment. Variations in vadose zone pore water content directly affect the storage capacity of the soil for contaminants in the solute phase. Soil porosity configuration, principally microporosity versus macroporosity, is critical to the rate of soil-water partitioning due to the contrast in surface area between micropores and macropores and the related storage capacity of this porosity for both pore water and sorbed contaminants.

4.3.6 Soil-air partitioning is the process by which volatile contaminants move between the sorbed phase and a vapor phase, either the free vapor phase or the occluded vapor phase or both. Like soil-water partitioning, this process is underestimated in its importance to the recoverability of contaminants by many soil gas sampling techniques. In vadose zone horizons with very low pore water contents, soil-air partitioning can yield vapor phase contaminant composition that differs from free product composition. In vadose zone horizons with higher pore water content, the responsibility for this compositional inconsistency is shared, largely with soil-water partitioning. In wet soil conditions, threshold soil water content values exist for trapped soil atmosphere content to become significant (**7**), suggesting that responsibility for this compositional inconsistency can be largely attributed to occluded phase residence. Additional important variables are soil clay content, type and distribution, and soil organic matter content, type and distribution. Studies have demonstrated significant impact of soil organic matter and clay content on volatile organic compound emissions from soils (**8**). Due to the strong control on vapor phase contaminant content by the soil-air partitioning process, it is unreasonable to expect soil contaminants with high affinity for sorption to be efficiently recovered by most soil gas sampling techniques.

4.4 Migration of contaminants in the vadose zone, that is, unsaturated flow, is highly complex and is controlled by soil characteristics, contaminant composition and contaminant phase (**9**). Migration through unsaturated matrix can occur through a variety of diffusion, dispersion and mass transport mechanisms which behave in a manner unique to saturated flow.

4.4.1 A major division in migratory behavior of contaminants is defined by their solubility or immiscibility in water. Contaminants are often introduced into the soil as liquid mixtures, the components of which immediately begin to partition into other phases upon soil entry. Contaminants that establish soil residence behind a migratory front change in composition with distance from their point of entry. As contaminant migration continues, pathways for individual components can become divergent, such that the composition of the liquid mixture continues to change as migration proceeds. Eventually, migration of liquid mixtures may reach ground water. This can be retarded if the contaminants partition into other phases before reaching ground water and if contaminant vapor is less dense than the uncontaminated soil atmosphere. Transport of contaminants by downward percolation of meteoric waters and upward movement of ground water accelerate the contact of contaminants with ground water. When these contaminants do reach ground water, a radically different set of migration mechanisms begins to govern contaminant transport via saturated flow. Further divergence of contaminant pathways is dependent upon the tendency of each component of the contaminant mixture to float on ground water, become dissolved in ground water or sink to an impermeable layer within the aquifer. Detailed descriptions of these phenomena are available in the literature (**10**).

4.4.2 The impact of migration processes on soil gas measurement is significant. Although it is impractical to estimate actual migration mechanisms by modelling prior to most soil gas monitoring efforts, a rudimentary knowledge of site characteristics can guide investigators to realistic interpretations of soil gas data expressing unusual or highly variable compositions. More thorough knowledge of relevant site characteristics, such as the presence or absence of barriers to vertical or horizontal migration, that is, foundations, buried pavement, or perched ground water, as well as preferential pathways for contaminant migration, that is, backfill rubble, utility vaults, storm sewers or soil cracks, can assist investigators to assess the migration impact on soil gas survey design.

4.5 The vadose zone is a highly complex soil-air-water-hydrocarbon system with abundant opportunity to store contaminants in all phases. Contaminants partition ac-

[8] See 6.2 for a discussion of active soil gas sampling techniques.

cording to their physical properties and the residence opportunity presented to them along their migratory path. This process has been described as an in-situ chromatographic-like separation of contaminants (**11**). Emplacement, or the establishment of contaminant residence, is a highly dynamic process. Contaminants move from one phase to another as changes occur in both chemical and physical equilibria. Important changes impacting phase residence change include temporal variations in moisture content, soil temperature and level of microbial activity.

4.5.1 One interesting example of disruption in equilibrium conditions is the act of sampling soil gas. Many soil gas sampling systems rely on large volume recovery of soil gas to provide a sample that is believed to be representative of the soil atmosphere in situ. Movement of this soil gas by convective flow through unsaturated soils can cause upward changes in vapor phase contaminant concentration at the expense of other phases.

4.5.2 In natural systems, temporal increases in soil moisture cause gradual increases in solute phase emplacement at the expense of other phases. It is unrealistic to attempt to characterize a static soil gas equilibrium in the vadose zone because this equilibrium is never achieved. For this reason, soil gas data sets based on specific contaminant concentrations and generated at different times are usually not comparable for the absolute values generated by each temporal sampling event. Qualitative comparison of data generated by the same soil gas method and performed at different times is permissible. Generation of a single data set by reconnaissance soil gas sampling and subsequent infilling of data to form a single data set is strongly discouraged.

4.5.3 Attempts to compensate for temporal variations in phase equilibria have been attempted by collecting samples that approximate replicates at known locations and adjusting succeeding data up or down to compensate for observed changes. This procedure is also strongly discouraged, because the number of variables affecting observed changes are too great. Moreover, the ability or willingness of most investigators to determine the most significant effects upon phase equilibria is insufficient to be of use.

4.5.4 Data sets generated by different soil gas sampling techniques may not be comparable as a direct result of differences in efficiency of recovery of contaminants from specific phases. Not only can these data sets differ in measured contaminant concentration, but they can vary substantially in composition as well.

4.6 Degradation of contaminants occurs in the vadose zone through oxidation or reduction reactions that can be biogenic or abiogenic in nature. This process can occur both aerobically and anaerobically to mitigate contaminant levels. Degradation is most often recognized in shallow, permeable soils where favorable conditions exist for oxidation of labile compounds, however other vadose environments can be conducive to degradation. Specific environmental conditions are required for degradation processes to occur. For abiogenic degradation, redox potential and soil pH can be rate controlling factors. For biodegradation, necessary environmental conditions include the presence of microorganisms capable of adaptation to the contaminant as substrate, conditions favorable to population increases of these microorganisms and migration pathways for contaminants to come in contact with these microorganisms. Most soils contain naturally occurring populations of various microorganisms that can degrade petroleum products (**12**). Contaminant biodegradation is known to occur in groundwater (**13**) and in soils (**14**) prior to contaminant partitioning into a vapor phase. Contaminant biodegradation rates for some compounds are highly variable and are controlled by a number of kinetic factors influencing the distribution of microorganisms responsible for degradation. These include aerobic versus anaerobic environments, contaminant type and temperature (**15, 16**).

4.6.1 Degradation rate can approach, equal or periodically exceed the rate of contaminant emplacement into the vadose zone, such that contaminants are not detectable by soil gas monitoring. This mechanism can result in soil gas data which are not representative of an underlying contaminated condition (**17**).

4.6.2 Labile contaminants can be degraded to compounds that may or may not be detectable in soil gas. Aerobic degradation can produce carbon dioxide which can be monitored as an indirect indicator of the presence of contaminants (**18**), or organic acids and phenols (**13**) that are not routinely detectable in active whole air soil gas samples. In alternative to whole air methods, use of an appropriate adsorption medium may facilitate recovery of such compounds for analysis by desorption and gas chromatography-mass spectroscopy. Anaerobic degradation can produce compounds including methane, ethylene, propylene, acetylene, and vinyl chloride which also can be monitored as an indirect indicator of the presence of contaminants. Caution must be used in attributing elevated levels of these compounds to biodegradation, because competitive processes can confuse the interpretation of absolute concentration values and potential sources.

4.6.3 Biodegradation of contaminants in the vadose zone can proceed naturally by adaptation of indigenous microbial populations to metabolize contaminants as primary substrate, or by introduction of foreign populations which have been preconditioned to metabolize contaminants of interest. Case histories demonstrate the absence of certain compounds in soil gas contaminant suites for which biodegradation has been named as the responsible process (**17, 19, 20**). Such cases address the attenuation or complete absence of simple aromatic hydrocarbons, some of which are halogenated, in soil gas. This phenomenon may be controlled by the availability of oxygen as has been demonstrated in the laboratory (**13**). Other compound classes can exhibit similar effects.

4.6.4 Other processes may share responsibility for the actual or apparent absence or attenuation of some contaminants in soil gas sample sets. In some cases where attenuation of contaminant concentration is attributed to degradation, combinations of high soil clay, organic matter and pore water content can reduce the recovery efficiency of certain soil gas sampling techniques for certain contaminants such that contaminant concentrations fall below detection limits. Care must be exercised in attributing a lack of contaminants in soil gas samples to degradation.

4.7 *Summary Procedure for Soil Gas Sampling*—Vadose zone monitoring methods have a set of procedures, both general and specific, that must be consistently followed in

order to provide maximum data quality and usefulness. Soil gas monitoring is no exception, with six primary procedures common to all soil gas monitoring techniques. The procedures are a planning and preparation step including definition of data quality objectives, the act of sampling soil gas in the field, handling and transporting the sample, sample analysis, interpretation of the results of analysis, and preparation of a report of findings.

4.7.1 The planning and preparation step begins with the formulation of project objectives, including purpose of the survey, appropriate application of the data to be collected and data quality objectives.

4.7.2 Data can vary in quality due to sampling methodology, sample preparation, analytical procedures, laboratory quality control, and available documentation. Quality assurance programs include all of the activities necessary to provide measurement data at a requisite precision and bias (see Practice 1357). Quality assurance objectives for soil gas monitoring are similar to those for atmospheric air monitoring. The overall quality assurance objective for measurement data is to ensure that data of known and acceptable quality are provided. In order to meet these objectives, data quality objectives should be defined for data measurements in support of the soil gas data interpretation. These are comparability, completeness, representativeness, bias and precision. The comparability of the data collected refers to the ability to interpret the results in light of previous data collection efforts. Completeness refers to the number of samples collected and analyzed compared to the planned number of samples. Representativeness is a measure of the degree to which analytical results reflect true field conditions. Field contamination and sampling intensity are two factors affecting representativeness. Bias is a generic concept of exactness related to the closeness of agreement between the average of one or more test results and an accepted reference value (see Practice E 177). The precision of a measurement process is a generic concept related to the closeness of agreement between test results obtained under prescribed like conditions from the measurement process being evaluated. Overall precision and bias targets for chemical contaminant measurements can be set at 10 % allowable deviation with 90 % confidence limits. In all of these quality assurance activities one must take into consideration that factors including geophysical conditions and definition of sampling volume in the vadose zone often have higher variability than analytical equipment calibration procedures.

4.7.3 Table 1 provides suggested quantitative limits for data quality objectives.

4.7.4 The planning and preparation step continues with the evaluation of available information already gathered for the project area. These efforts culminate in the selection of an appropriate soil gas monitoring method and a survey design which best fits the project objectives within budgetary constraints. Prior to actual field work, investigators must obtain the necessary permits and landowner permission for property access. When a survey area is pending sale, investigators should obtain written permission to conduct the survey from both the buyer and the seller. Moreover, when a soil gas survey is being performed as a service, no work should proceed on the survey without a fully executed consulting agreement between the investigator and the client for whom the survey is being conducted.

TABLE 1 Suggested Quantitative Limits for Data Quality Objectives

QA/QC Objective	Measure	Formula	Limit
Accuracy	Laboratory standard	Standard recovery	90 to 110 %
Precision	Field replicate	Relative standard deviation	< 20 %
	Laboratory replicate	Relative standard deviation	< 20 %
Representative-ness	Air blank	Bias	< 10 %
	Cross contam. blank	Bias	< 10 %
Completeness	Completion (%)	Relative compl.	> 90 %
Comparability	Prof. judgment	NA	NA

4.7.5 Actual field work consists of recovery of soil gas samples. The method selected should be based upon site specific factors and dictated by the project objectives. A detailed discussion of soil gas sampling methods is provided in 6.1.

4.7.6 As samples are being recovered, they must be handled and transported in such a way as to assure preservation prior to analysis. A detailed discussion of sampling and transport is located in 6.5.

4.7.7 The presence of contaminants is determined through analysis of the soil gas samples. This step is controlled to a large degree by the QA/QC objectives of the survey. A discussion of sample analysis is provided as 6.6.

4.7.8 Data interpretation is largely an iterative process of review of the raw soil gas data out of context, a review of the soil gas data in context of other site characteristics and the formulation of conclusions based upon all known information. A discussion of soil gas data interpretation is located in 6.7.

4.7.9 Finally, a report of findings is generated in a format that is selected to be appropriate to the requirements of the end users. Section 7 provides options that can be addressed in reporting as well as recommendations of topics that should be included in all soil gas summations.

5. Significance and Use

5.1 *Application of Soil Gas Monitoring*—Soil gas monitoring is an extremely versatile method in that it can be adapted to conform to the requirements of dissimilar industries for a wide variety of applications. A number of soil gas techniques have been utilized in the agricultural **(21)**, petroleum **(22, 23)** and minerals **(24)** industries. Certain applications have been exercised for well over 50 years. Soil gas monitoring has been utilized in research efforts, including the monitoring of underground coal gasification retorts **(25)**. Application to the environmental industry is comparably recent but very effective as a rapid and relatively inexpensive method of detecting volatile contaminants in the vadose zone. Field screening, of which soil gas monitoring is a basic component, has been demonstrated to be effective for selection of suitable and representative samples for other more costly and definitive monitoring methods **(26)**. Soil gas monitoring is useful to assess the extent of ground water contamination for certain contaminants and field environments **(27)**. Soil gas monitoring is also a viable method of monitoring subsurface contaminant discharges from underground storage tanks **(28)**. New applications of the soil gas

monitoring are periodically developed and published in the referenced literature. The method may be useful in the study of unsaturated flow. In most instances, the method can make use of very light-weight, portable and inexpensive tools made from commonly available materials. Soil gas monitoring has become a widely accepted method for locating subsequent environmental monitoring and remediation activities such as ground water monitoring wells, contaminant product recovery wells or excavations to recover contaminated soil. Soil gas monitoring has made a significant contribution to ground water monitoring and remedial planning on sites that fall under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) **(29)**. This method is highly useful at the initiation of Phase II environmental assessment action in determining the presence of volatile organic contamination of real property in a pending sale.

5.1.1 In any application, soil gas monitoring can be performed over a wide range of both spatial and temporal designs. Spatial designs include soil gas sampling in profiles or grid patterns at a single depth or multiple depths. Multiple depth sampling is particularly useful for contaminant determinations in cases with complex soil type distribution and multiple sources. Depth profiling can also be useful in the determination of the most appropriate depth(s) at which to monitor soil gas, as well as the demonstration of migration and degradation processes in the vadose zone. Temporal designs include the long-term monitoring of the vadose zone for the appearance of volatile organic contaminants from known potential sources such as underground storage tanks and solid waste landfills. Temporal designs are especially useful in monitoring the effectiveness of contaminant remediation efforts.

5.1.2 Soil gas monitoring in the vadose zone is an ideal reconnaissance tool and screening technique in most applications. However, site specific and contaminant specific limitations can cause this technique to be unsuccessful in meeting project objectives. Caveats exist in all soil gas monitoring procedures that can frustrate efforts to successfully apply the method to any application.

5.2 *Limitations*—The most significant limitation on soil gas monitoring is the inability to utilize the method as a stand alone technique. Soil gas monitoring does not provide repeatable quantitative information over time due primarily to the dynamic nature of phase equilibria in the vadose zone and secondarily to unavoidable inconsistencies in sampling practice. As a result of geologic variability in the vadose zone and the multitude of unique sampling devices currently being used in the field, quality assurance and quality control protocol, discussed in 6.4, cannot provide the rigor required as in a test method. For these reasons, soil gas data in itself cannot be used to provide definitive answers about the location or absence of buried contaminants. Moreover, the success of any soil gas monitoring method is strongly dependent upon effects related to geologic variation and moisture content in the sampling horizon as well as the physical properties of the target contaminants.

5.2.1 False negative results can occur as a direct result of the incompatibility of a specific procedure with the properties of the sampling horizon or the target contaminants, or both. Soil gas data cannot be used to establish bulk volume or the commerciality of buried petroleum, natural gas, or ore bodies.

5.2.2 With the necessary analytical procedures, soil gas can be examined for compositional anomalies, a very useful technique for multiple source problems. In some instances, contaminant occurrences are limited to single species (compounds, mercury, etc.), however more often than not the contaminant source is a mixture of organic chemicals that have a unique chemical compositional character consisting of both normally evaluated priority pollutants and non-priority pollutant chemicals that may be overlooked. By identifying and using compositional information, many problematic site situations such as degradation can be minimized by targeting the more refractory compounds associated with the contaminant occurrence. This interpretive method is impossible to model for an industry wide application due to variation in methods and technique.

5.2.3 A basic limitation of the technique is that due to the ease of procurement and use of soil gas sampling devices, there is a tendency for inexperienced personnel to oversimplify any and all aspects of the method. Investigators must consider the experience level and technical ability of personnel who acquire soil gas samples and attempt to interpret the results. Certain procedural facets are not trivial, as discussed in Section 6. The results of certain techniques tend to be affected by minor variations in procedure despite apparent adherence to a "Standard Operating Procedure."

5.2.4 Atmospheric air contamination is not a trivial problem corrected by simple device-oriented field practice. Many sampling systems recover very large volumes of "soil gas" that may actually represent a mixture of soil gas and atmospheric air. This mixing occurs through the introduction of ambient air adjacent to the sampling device and through macroporous pathways in the soil which are far from the sampling device. Some environmental investigators avoid the impact of this problem by reasoning that contaminant quantities in the soil are so great that they are detected despite atmospheric mixing. For qualitative approaches with non-rigorous quality assurance/quality control (QA/QC) objectives this mixing problem can be insignificant. For detection of compounds that exhibit only marginal partitioning preference for the free vapor phase, the mixing problem can be a fatal flaw in procedure. Moreover, contaminant concentration and composition investigations can be rendered useless by variations in the magnitude of mixing at various sample locations and depths in a survey area.

5.3 *Comments on Limitations of Soil Gas Monitoring*—Many investigators believe that soil gas monitoring is not an effective vadose zone monitoring method for certain volatile organic applications, in certain geographic regions or during certain seasons of the year, or both. The applicability of soil gas monitoring is controlled by physical and chemical properties and processes in the subsurface and not by factors that are obvious at or above the surface. For example, one common misconception is that soil gas monitoring is not effective during the winter season. The impacts upon soil gas measurement of elevated soil pore water content, reduced vadose zone temperature and the presence of frost, typical of numerous regions in winter, are obvious for many facets of most soil gas monitoring methods. Modification of standard operating procedure, such as an increase in sampling depth,

or selection of another soil gas monitoring method altogether can minimize the negative impacts of seasonal field conditions. It is important to understand that the responsibility for success or failure in soil gas monitoring can reside as much in the planning phase of a survey, including the method chosen, as in factors controlling the chemical and physical processes at work in the subsurface. Even with apparently ideal field conditions and with a carefully planned survey, soil gas monitoring can succeed or fail due to unknown factors controlling contaminant migration and emplacement. Soil gas monitoring is no different than any other measurement method, in that investigators must maximize effort in planning and implementation of procedure to maximize the likelihood of success.

6. Approach

6.1 *Sampling Methodology*—Soil gas sampling methodology has evolved over time and through practice in several industries. The equipment with which to perform this monitoring technique is highly varied, although it may be categorized into basic types (see 6.2.2). The literature provides numerous discussions about the design of some of this equipment **(10, 30, 31, 32, 33)**. The selection of a soil gas sampling method involves consideration of three primary issues. These are the type of sampling system, the methodology of application of that sampling system and the rigor of the field QA/QC protocol. Each of these issues is discussed in this guide, however, no single method or procedure is recommended to the reader due to the variation in site specific factors. As many as one hundred unique soil gas sampling systems exist that arise from variations or combinations, or both, of the many facets described in this guide. Some systems are highly versatile for numerous applications. Others are functional for more limited or specific applications. Informed investigators must assume the responsibility of selecting the technique most appropriate to the subject application, whether that technique is commercially available from contractors or equipment suppliers, or reliant upon the ingenuity of the investigator in the field utilizing commonly available materials. Success in choosing an appropriate sampling device or an entire sampling system is dependent upon the investigator's level of understanding of vadose zone processes, contaminant properties and appropriate applicability of the soil gas method.

6.1.1 The application of any of these methods must be controlled by strict adherence to a standard operating procedure. Occasional deviations as dictated by unusual field conditions should be recorded in the project field notebook. Inadvertent minor deviations in field procedure can result in misinterpretation of the data acquired.

6.2 *Sampling Systems*—Six basic sampling systems exist. These are based upon the collection of soil gas by a whole-air or sorbent method in an active or passive approach, or upon the principle of collection of a soil or water sample for subsequent sampling of a contained headspace atmosphere. Contained atmosphere methods do not yield samples representative of in situ vadose zone atmospheres.

6.2.1 Whole-air methods sample the soil atmosphere as a mixture of gases, including contaminant and non-contaminant vapors. Sorbent methods sample contaminants adsorbed onto a collection medium exposed to a whole-air sample stream. Active methods are those that obtain a soil gas sample by positioning a sampling device in the subsurface and the withdrawal of soil atmosphere through the device from the sampling horizon. Passive methods are those that obtain a soil gas sample by placing a collection device in the soil or on the soil surface, and allowing the atmosphere within the device to come into compositional equilibrium with the soil atmosphere. Four of the six basic sampling systems arise from these approaches, namely the whole air-active approach, the sorbed contaminants-active approach, the whole air-passive approach, and the sorbed contaminants-passive approach. Two additional systems exist that are based respectively upon the collection of a soil or water sample for subsequent sampling of a small volume headspace atmosphere.

6.2.2 *Whole Air-Active Approach*—This method of soil gas sample collection involves the forced movement of bulk soil atmosphere from the sampling horizon to a collection or contaminant device through a probe or other similar apparatus **(10, 34)**. Contained samples of soil atmosphere are then transported to a laboratory for analysis, or the sampling device is directly coupled to an analytical system. Whole air-active sampling is best suited to soil gas monitoring efforts where contaminant concentrations are expected to be high and the vadose zone is highly permeable to vapor. Probes exist that must utilize pre-existing holes or that can penetrate the vadose zone by driven means. These devices can be very simple and light-weight for low cost mobilization **(35)**, or they can be affixed to vehicle mounted drills or hammers useful for larger, more complex surveys at a higher cost of mobilization. The whole air-active technique can be combined with other monitoring methods such as soil monitoring for engineering purposes **(36)** in some survey environments. The success of this practice can be highly site-specific.

6.2.2.1 Ground probes can be of small to large internal volume. The development of sampling devices with smaller internal volumes equating to smaller purge volumes is a significant improvement, providing samples which are more representative of soil atmosphere, and a greater ease of equipment decontamination between usages. Sample size can vary from a few millilitres to many tens of litres depending upon the sample rate through the probe, the vapor storage capacity of the soil and the ability of the soil to deliver vapor to a probe under vacuum.

6.2.2.2 The success of the active approach is strongly dependent upon soil clay, organic matter and moisture content. Driven probes tend to destroy natural soil permeability around the body of the probe due to soil compaction concurrent with insertion. This can be a severe limitation in moist, heavy clay soils. In very dry, cemented soils, driven probes can create radial fractures that can enhance soil permeability to vapor concurrent with insertion. These fractures can communicate atmospheric air with soil atmosphere, a limiting factor for obtaining representative, large-volume soil gas samples. The effect can be so severe as to lower recovered contaminant concentrations in the soil gas sample below the limits of analytical detection. This is especially true for highly sorptive or water soluble compounds, or both. Some investigators have attributed the poor

recoveries of these compounds exclusively to other processes, that is, degradation (21, 37).

6.2.2.3 Methods requiring a pre-existing hole for probe insertion (**38**) made with a commercially available "slam bar" can provide supportable contaminant data where contaminant concentrations and soil permeability to vapor are high, however the act of making a hole with a "slam bar" and subsequent removal of the "slam bar" can encourage soil contaminant venting and lower sample representativeness. Insertion of the sampling probe into this hole further degrades representativeness by additional venting of contaminants as the probe displaces the atmosphere in the hole upon insertion. Purging of the probe prior to sampling under conditions of low soil permeability and low contaminant concentration may lower contaminant levels below the limits of analytical detection. Methods requiring a pre-existing hole for probe insertion are not recommended for soil gas sampling from soils with high clay and moisture contents.

6.2.2.4 Excellent discussions of numerous whole air-active sampling systems may be found in the literature (**10, 21, 37, 39**). Investigators must consider the caveats and limitations of the whole air-active approach when selecting a certain method for a specific application.

6.2.3 *Sorbed Contaminants-Active Approach*—The sorbed contaminants-active method of soil gas sample collection also involves the forced movement of bulk soil atmosphere from the sampling horizon through a probe or other similar apparatus, but to a collection device designed to extract and trap sample stream contaminants by adsorption (**40, 41**). This system is well suited to sites where the soil may be highly permeable to vapor and where the contaminant concentration may be lower than required for successful whole-air surveys. Sorbent devices are designed to concentrate the components of interest and remove some of the soil gas components known to interfere with sample analysis.

6.2.3.1 Contaminant trapping is accomplished by use of an adsorbent collection medium such as charcoal or a carbonized molecular sieve adsorbent (**43, 44**), as well as porous polymers, silica gel and activated alumina (**10**). This approach is especially amenable to the detection of nonpolar volatile organic compounds. Organic compounds that are reactive, oxygenated or are gaseous at room temperature are either not adsorbed by or are not efficiently desorbed (**42**) from charcoal. Sorbent collection devices are commercially available or can be specially prepared with an appropriate sorbent material that concentrates desired compounds for future analysis. Colorimetric detector tubes are available which will provide an indication of the presence of target compounds at the time of sampling. These devices are limited in application by the high concentration requirements for many compounds and the compound-specific nature of these tubes.

6.2.3.2 The effectiveness of the sorbed contaminants-active approach can be limited by high vadose zone clay and water content, reducing the ability of the soil to transmit vapor through the sorbent trap. Commercially available sorbent traps come with information suggesting maximum, minimum and optimum sampling rate through the trap. Soil characteristics can limit flow rate to a point below the minimum recommended rate, affecting the performance of the trap and the reproducibility of adjacent samples. Interaction of the sorption media with target compounds during desorption in the laboratory can form artifacts, restricting the interpretive value of the data. Some sorption media are prone to irreversible adsorption (see Definitions D 2652). Some may be affected by high soil gas relative humidity. Humidity greater than 60 % (very common for soil gas) can reduce the adsorptive capacity of activated charcoal to 50 % for some chemicals. Presence of condensed water in the sample tube will indicate a suspect sample (see Practice D 3686). Anticipation of these problems is recommended for all sorbent techniques, and a thorough quality control plan should be designed and implemented as is discussed in 6.4 of this guide.

6.2.3.3 Special sample preparation is required for samples adsorbed onto a trapping medium. This preparation step consists of the thermal or solvent desorption of the contaminants from the trapping medium. Proper practice will promote needed accuracy and precision in the determination of contaminant concentrations above specified values (see Practice D 3687).

6.2.4 *Whole Air-Passive Approach*—This method of soil gas sample collection involves the entry of bulk soil atmosphere or soil atmosphere components from a near-surface sampling horizon to a collection or containment device through a flux chamber or other similar apparatus (**30**). Enclosure devices sample vaporous emissions from a known soil surface area capped by a chamber. The volume of the chamber is continuously swept by injection of a gas of known composition, and the resultant carrier gas-contaminant mixture is collected for analysis. The rate of emission or "flux" of contaminants can be calculated if flow rate of injected gas and contaminant concentration in the sample are determined.

6.2.4.1 The whole air-passive approach is useful to some very specific applications. This method may be used, for example, to monitor contaminant emissions from soil or water to assess the health hazard risk of such emissions to the general public. Determination of the extent of contamination by volatile organic compounds has been performed with whole air-passive devices, however the application of other types of systems is far more common.

6.2.4.2 A key to successful operation of a whole air-passive system is that the system is able to recover volatile compounds as they are emitted from the vadose zone. The effects of changes in barometric pressure, soil temperature and soil moisture content are not quantifiable from site to site due to site specific variables controlling vapor phase contaminant migration and the rate of contaminant partitioning into the vapor phase. The presence of contaminants or naturally occurring organic matter floating on surface water may impact the rate of entry of certain vapor phase contaminants into the chamber.

6.2.4.3 The whole air-passive method is limited in application primarily due to the great degree of dilution of contaminants in the sample stream by injected gas. This can decrease method sensitivity by lowering contaminant concentrations to levels below the detection limits of the analysis method chosen. Further decrease in method sensitivity results from the fact that soil gas contaminant concentrations are generally lower at the surface than even at nominal depths. Soil characteristics such as high water saturation, soil

cements, clay content and organic matter content will negatively impact results of these systems by restricting the rate of contaminant flux to the chamber.

6.2.4.4 Additional limitations exist. Certain devices limit flux rates into the chamber due to aspects of design. Soil macroporosity such as desiccation cracks extending beyond the collecting device will vent soil vapors to the atmosphere that will not be collected by flux chambers unless monitoring locations are biased to include these features.

6.2.5 *Sorbed Contaminants-Passive Approach*—This method of soil gas sample collection involves the passive movement of contaminants in soil to a sorbent collection device over time. Passive samplers that have been applied to sampling soil gases of environmental concern include occupational health volatile organic compound monitors **(44)** and a sampler originally developed for detecting the presence of hydrocarbons in petroleum exploration **(33, 46)**. Both devices use charcoal as a sorbent; the former as a flat film and the latter coated on a wire. Passive samplers are housed in containers up to several inches in diameter, depending upon the design. They are placed open end down in holes that are usually less than 5 ft (1.5 m) deep, that are then backfilled **(32)**. These monitors are generally left in place from two to ten days, although certain passive collectors can be left in place for a period of 30 days or more for certain applications. For at least one device, exposure efficiency can be determined.

6.2.5.1 The sorbed contaminants-passive approach can be employed in a wide range of geological conditions. Frozen ground and high water saturation may not limit the ability of the monitors to collect contaminants **(46)**, although the composition of the contaminant suite may be impacted by related alterations in partitioning equilibria.

6.2.5.2 The sorbed contaminants-passive approach depends upon the ability of contaminants to move through the vadose zone to the passive collection device. Numerous adsorption media can be used to collect contaminants (see 6.2.4). The principle of passive-sorbent monitors relies on adsorbent reduction of the equilibrium concentration of contaminants around the monitor over time, therefore creating a concentration sink, that is, a continuous state of disequilibrium, in the vicinity of the monitor. This can encourage continued migration of contaminants toward the monitor when conditions for contaminant partitioning into the vapor phase are favorable. Migration of contaminants in the vadose zone toward a passive-sorbent device is strongly controlled by vadose zone character and the chemical and physical properties of the subject contaminants. Contaminants may move from a few feet to thousands of feet, or not at all.

6.2.5.3 Many investigators attribute the principle mechanism of contaminant migration to a passive-sorbent device to diffusion, that is, the movement of organic vapor or gas molecules from a region of high concentration to a region of low concentration as described by Fick's law (see Practice D 4597). Fick's law of diffusion states that for a constant concentration gradient, the mass of material transferred to the sampling layer can be expressed as:

$$M = \{DA(C - C_o)t\}/L \quad (5)$$

where:

M = mass of the material, ng,
D = diffusion coefficient, cm^2/min,
A = cross sectional area of diffusion cavitie(s), cm^2,
L = length of diffusion path, cm,
C = concentration at face of sampler, ng/cm^3,
C_o = concentration at adsorbing layer surface, ng/cm^3, and
t = exposure time, min.

6.2.5.4 The cross sectional area of a diffusion cavity, the length of the diffusion path and the quantity $(C - C_o)$ are impossible to accurately measure for soil gas contaminants interacting with a passive-sorbent sampler. There is some debate as to whether passive samplers measure flux or total contaminant concentration (32) in the vicinity of the trap. Due to the fact that the mass of the material transferred to the sampler by diffusion, a key measurement, cannot be determined, the debate will no doubt continue. It is reasonable to assume that a combination of processes is responsible for contaminant migration to sorbent traps, including diffusion, dispersion and mass transfer. All migration processes are impacted by partitioning equilibria.

6.2.5.5 Ambient air represents an atmospheric contaminant concentration sink that encourages a strong vertical vector of contaminant migration. This prevailing upward movement of contaminants from sources at depth results in contaminant concentration gradients throughout the vadose zone. The sorbed contaminants-passive method makes use of this contaminant flux (see 6.2.4) to collect long-term, nondisruptive samples of volatile contaminants. The method can collect contaminants which are compositionally representative of the contaminant mixture favoring the vapor phase. The quantity of volatile organic compounds trapped by these devices is proportional to the concentration gradients of contaminants present near the collection device and the affinity of the contaminant(s) for the collection medium.

6.2.5.6 As with active sampling protocols, specific issues exist affecting the function and calibration of passive monitors. Soil gas, even in the drier climates, will be at a relatively high humidity condition. This humidity can affect the collection efficiency of the adsorbent media. In soils of low permeability, contaminants commonly move very slowly. This can create a condition of near-zero contaminant concentration in the soils immediately adjacent to the monitor if the sorptive potential of the monitor is higher than that of the soil. When soil contaminant concentrations are rapidly depleted, that is, as the result of invasion of the sampling horizon by meteoric water, the passive monitor can source contaminants back to the soil.

6.2.5.7 The sorbed contaminant-passive approach to soil gas monitoring is not immune to the migration, emplacement and degradation factors affecting all soil gas monitoring techniques. It is not possible to measure the efficiency of passive-sorbent monitoring devices because the bulk volume of soil gas affected by the sorbent trap cannot be measured. Care must be taken not to contaminate the sorbent samples during installation or by backfilling with contaminated soil. Such care is comparable to potential problems for any measurement method in which a contaminated layer is penetrated.

6.2.6 *Soil Sampling for Subsequent Headspace Atmosphere or Extraction Sampling*—This method examines contaminants that are present in a headspace atmosphere

above a contained soil sample. Note well that this headspace atmosphere is not true soil gas (see 3.1.11), but is an artificial atmosphere formed above a potential contaminant source, that is, the soil sample. Contained atmosphere methods do not yield samples representative of in situ vadose zone atmospheres. Headspace atmospheres differ from in situ vadose zone atmospheres in that large percentages of vapor phase and moderate percentages of solute and sorbed phase contaminants can be lost in the act of soil sampling. This method is not generally recommended for a broad spectrum of cases due to numerous limitations and caveats. In comparison to other methods described in this guide, soil sampling for subsequent headspace atmosphere or extraction sampling can be a relatively poor method for determining many of the more volatile contaminants. Headspace atmospheres contain residual sorbed and solute phase contaminants that have partitioned to the vapor phase in the contained environment; most headspace approaches are reasonably efficient in recovery of some fraction of sorbed and solute phase contaminants. Contaminants in these phases in situ are recovered from a headspace after they have partitioned into the vapor phase. Recovery efficiency of contaminants in the vapor phase in situ ranges from moderate to poor.

6.2.6.1 Important criteria exist to consider when selecting a device that will provide suitable samples (see Guide D 4700). The equipment required is simple and readily available. Some commonly used augers are not suitable for soil sampling in support of subsequent headspace atmosphere sampling due to soil disturbance. Depths of auger investigations are limited by ground water conditions, soil characteristics and the equipment used (see Practice D 1452). Suitable procedures for some methods are described in the literature (**47, 48**). Current soil preservation practice may not apply (see Practice D 4220).

6.2.6.2 Limitations and special procedures exist for the application of soil sampling for subsequent headspace gas analysis. Filling head space with solvent can support a subsequent solvent extraction procedure. Some investigators minimize the effects of devolatilization by rapidly recovering small soil core plugs with polypropylene syringes which have been modified to accommodate recovery of soil plugs. Investigators also attempt to maximize partitioning of contaminants into the vapor phase by adding buffering solutions or sodium sulphate and phosphoric acid to the vial prior to sealing, in order to shift the activity coefficients of the subject contaminants to favor the vapor phase. Aqueous suspensions of solvent slurries of soil can be ineffective for the determination of high molecular weight labile compounds. Their persistence in soil is the result of physical entrapment in soil microporosity (**49**). Recovery efficiency of contaminants in soil headspace can be greatly enhanced by pulverization of the soil (**50**) in a ball mill or other similar apparatus. The method is biased toward recovery of contaminants in the sorbed, solute and occluded phases in situ due to the loss of pore space gas in preference to contaminants adsorbed onto the soil particles or trapped in soil micropores. Contaminant degradation, especially biodegradation, in the container is encouraged by the creation of an aerobic, moist environment during sample handling and transport prior to analysis. However, a simple method to minimize the effects of biodegradation can be achieved by storing samples, when necessary, at approximately 4°C in the dark.

6.2.6.3 Acid extraction of volatile organic compounds is widely used in geochemical exploration for petroleum and natural gas. Soil samples are placed in a closed vessel, heated and evacuated to remove vapor phase contaminants. The addition of acid to the evacuated chamber causes release of hydrocarbons believed to be bound to the soils by carbonates (**22**). Hydrocarbons are determined by analysis of resulting vessel atmospheres. Refinements to this method have been developed (**48**), however the method is designed not to determine compounds in the vapor, sorbed, or solute phases. Method sensitivity is therefore greatly reduced.

6.2.7 *Soil Pore Liquid Headspace Gas Approach*—In the vadose zone, soil gas monitoring can be accomplished in combination with soil pore liquid sampling through the use of a suction lysimeter, a pan lysimeter or a free drainage glass block sampler. The suction lysimeter installed in the vadose zone is most commonly employed for this purpose. Temporally designed surveys are ideally suited to this method.

6.2.7.1 After a lysimeter has been installed for some period of time, initial aliquots of vapor sampled from a soil pore liquid sampler will be in compositional equilibrium with solute phase contaminants when pore liquid tensions are within the operating range of the lysimeter and if pore sizes are not so great as to cause loss of hydraulic contact between the soil and the porous segment of the lysimeter. Subsequent aliquots of soil gas may compositionally resemble soil vapor in situ if soil atmosphere enters the porous segment of the sampling device. When the lysimeter cannot recover a pore liquid sample, the soil gas recovered will be compositionally similar to soil vapor in situ.

6.2.7.2 The most common effort to recover soil gas from a suction lysimeter occurs when polytetrafluoroethylene (PTFE) porous segments are employed in sampling environments with high soil moisture tensions (low moisture contents). At tensions above 60 to 80 centibars, soil pore liquid samples cannot be collected (see Guide D 4696). However, soil gas can be recovered through the porous segment and collected at the surface. This alternative sampling effort can monitor soil vapor contaminants utilizing an otherwise unsuccessful procedure until soil moisture contents increase or until an alternative soil pore liquid sampler can be installed.

6.2.7.3 This technique is limited by the relative expense and complexity of installation of the sampling devices as a primary soil gas sampling method. The completeness criterion for quality assurance is difficult to satisfy due to the inability to anticipate the performance of the soil pore liquid sampler with respect to vapor recovery. Moreover, compositional bias toward solute phase contaminants and contaminants volatilized from free product is likely in soil gas samples recovered concurrently with soil pore liquid samples.

6.3 *Methodology in Application of a Sampling Technique*—The likelihood of success of the soil gas sampling technique selected is controlled in part by the methodology in application of that sampling technique. This methodology should be guided by the objectives of the subject project and the perceived spatial and temporal array of the potential sampling targets.

6.3.1 *Grids*—Many problems suitable for soil gas monitoring are best solved by obtaining data distributed over a geographic area. Sampling in grid patterns of variable design and spacing can be a very effective way to provide data coverage over a large area for a very low cost of acquisition. Common applications of soil gas grid sampling are environmental contaminant assessments, exploration for natural resources and the siting of locations for other monitoring or exploratory techniques. Compositional analyses in conjunction with properly designed grid systems are often fundamental to successful evaluation of soil gas monitoring.

6.3.1.1 Grid spacing provides for the location of soil gas samples in grid cells. The selection of grid cell size is strongly dependent upon the relationship between project confidence level requirements and cost budget. Small survey targets and complex vadose zone geology require decreased spacing between soil gas sample locations for grid methodology to be successful. Some applications, for example, defining the boundaries of contaminated soil or ground-water contaminant plumes, may require the grid cell area to be as small as 100 to 400 ft^2 (9 to 37 m^2). Most applications to natural resource exploration monitor naturally occurring volatile compounds in soil atmospheres, requiring closely spaced grids to increase the signal to noise ratio. However, a closely spaced exploratory grid equates to a broadly spaced grid for environmental application in most situations. Common petroleum exploration grid spacing utilizes a grid cell area of approximately 250 000 ft^2 (23 000 m^2), however grid cells can range from 10 000 to 1 000 000 ft^2 (9 to 90 000 m^2) depending upon perceived reservoir target area. Widely spaced grid sample arrays are useful in reconnaissance applications such as the establishment of contaminant baselines or evaluation of the exploration potential of a geologic basin. Grid cells for such purposes can be as large as a square mile or more.

6.3.1.2 The tendency exists for investigators with constrained budgets to utilize overly large grid cell spacings. This action normally results in inadequate, over-interpreted data supporting meaningless conclusions. Care must be taken to avoid this caveat.

6.3.1.3 Grid arrays can be designed as regularly spaced and predetermined locations for soil gas sampling or they can be irregularly spaced and continually field modified. Predetermined and widely spaced grid patterns are most useful for reconnaissance work, while closely spaced, irregularly situated or field modified soil gas grid sample sites, or both, are commonly used when targeting contaminant plume boundaries, contamination from underground storage tanks or other detail work.

6.3.1.4 Multiple depth sampling, discussed in 6.3.3, when coupled with a soil gas grid sampling methodology, can provide useful data in complex geologic settings and sites with multiple contaminant sources. Computer mapping of closely spaced three-dimensional soil gas grids can provide the investigator with horizontal or vertical cross sections through the subject site, making difficult observations possible.

6.3.2 *Profiling*—Profiling is a soil gas sampling methodology useful to test a linear array for the existence of contaminants. Profiling is most often performed by sampling at closely spaced intervals in a linear array and is displayed as contaminant concentration or composition versus distance sampled on an $X - Y$ plot. Concentration data are often displayed logarithmically on the ordinant (Y) axis, while single components or ratios of compositional data are often displayed linearly on the ordinant axis.

6.3.2.1 For environmental applications such as leak detection along the length of a pipeline or monitoring of contaminant encroachment across a property boundary, soil gas samples are recovered along a profile at intervals from 25 to 100 ft (8 to 30 m) (**23**). Profiling for natural resource exploration can be performed at sample intervals from 50 to 500 ft (15 to 50 m), depending upon the application.

6.3.2.2 Profiling is useful as a corroborative tool for other monitoring or exploration methods. For example, a soil gas sample profile acquired coincident with a seismic profile can suggest primary contaminant migration pathways or the boundaries of confining layers in shallow, complex geologic settings. This technique has been demonstrated as highly effective in reducing exploratory risk prior to drilling for petroleum and natural gas, by suggesting the presence of hydrocarbon seepage coincident with structures with reservoir potential defined by the seismic method (**51**).

6.3.2.3 Soil gas profiling is also a convenient methodology effective in comparative evaluation of multiple soil gas sampling techniques. Due to variations common to the dynamic equilibrium conditions over small spatial and temporal intervals in the vadose zone (see 4.1), comparisons of multiple soil gas techniques using only one or a few soil gas samples recovered from nearly identical locations will not result in a valid comparison. However, a visual overlay of soil gas profiles resulting from the implementation of the various sampling techniques can provide a rapid and definitive comparison as to the efficiency of recovery of subject contaminants by a particular sampling system in a specific sampling environment. Similarly, comparison of profiles obtained by using the same soil gas sampling system can provide a direct measurement of system accuracy for quality control purposes.

6.3.2.4 Some investigators compare geographically coincident profiles obtained with the same sampling system at times differing by days or even years in order to generate a data correction factor in order to enhance data comparability. This practice is strongly discouraged. Factors not anticipated in this practice such as the effects of the dynamic equilibrium in the vadose zone, unavoidable changes in procedure due to personnel substitutions, contaminant movement or cultural influence on the sampling environment can have impact on results that are far more significant than the apparent correction.

6.3.3 *Multiple Depth Sampling*—Methodologies encompassing multiple depth sampling normally have one of two goals, that is, to monitor changes in soil gas contaminant fractions versus depth, and to closely follow a single sampling horizon for an entire soil gas grid or profile.

6.3.3.1 When the goal of a survey is to monitor contaminants over varying depths, some sampling systems can recover soil gas samples as probes are advanced deeper into the vadose zone. This practice is helpful in determining the optimum sampling depth for a particular site or to demonstrate the presence or absence of soil atmosphere contamination in a certain horizon. Soil gas contaminant concentrations often increase with depth as the sampling horizon

approaches contaminated ground water or other source of soil gas contaminants (52). Caution must be exercised when soil gas sampling tools are advanced to increasing depths due to the fact that cross contamination of some or all of the sampling system is unavoidable. This situation limits quality control for this type of multiple depth sampling. Attempts to eliminate cross contamination in multiple depth sampling by replacement or decontamination of sampling equipment with each new sample aliquot also result in limited quality control. Tool withdrawal and tool reinsertion result in venting of the sampling environment via an open hole. The open hole behaves as a macroporous pore space, allowing enhanced partitioning into the vapor phase and convective migration to the atmosphere. The end result is a reduction in representativeness for each subsequently recovered soil gas sample.

6.3.3.2 Multiple depth sampling can also be used to focus a sampling program into a single geologic unit or suite of units without regard to depth. This practice is helpful at sites with complex lithologic changes in the vadose zone. Samples can be recovered from lithologies with greater permeability to vapor or greater storage capacity for vapor when bias in sampling depth is necessary to accomplish project goals. This practice involves greater effort and expense than most methodologies due to the necessity to establish the presence, thickness and depth of the target horizons prior to soil gas sampling. The most common application of this methodology is the sampling of soil gas at the top of the capillary fringe.

6.3.4 *Time Variant Methodologies*—Monitoring soil gas in the vadose zone over time can suggest process rates of contaminant partitioning, emplacement, migration and degradation. Practical application of this methodology includes the monitoring of the effectiveness of remedial air-injection systems, the appearance of contaminants sourced from underground storage tanks, the encroachment of contamination onto a subject property from an abutting property and the mitigation of soil and ground-water contamination by microorganisms.

6.3.4.1 Some investigators and regulators with responsibilities at more than one location delegate seemingly simple time variant soil gas monitoring tasks to local personnel. Numerous problems with time variant monitoring can arise in the field as the result of poor system maintenance and record keeping by inexperienced or unmotivated personnel (property owners or parties responsible for contamination).

6.3.4.2 Certain maintenance problems are easily corrected, that is, cleaning bacteria and other foreign matter from detectors or replacing damaged components. Other maintenance problems can be fatal flaws in the methodology. These are principally related to ice formation in the sampling system and destruction of system integrity due to soil frost heaving.

6.3.5 *Combination of Soil Gas Monitoring With Other Vadose Zone Monitoring Techniques*—Soil gas monitoring is not a stand-alone technique. Corroborative support of this reconnaissance and screening tool by other vadose zone monitoring techniques is strongly encouraged. The possible combinations of the various vadose zone techniques with soil gas surveys are numerous. Soil gas can commonly be used as a reconnaissance tool to locate other monitoring devices such as lysimeters, neutron probes or ground water monitoring/sampling wells. Limits upon such combinations are controlled by budgetary constraints and the investigator's imagination.

6.4 *Field QA/QC*—Quality assurance and quality control procedures (QA/QC) are essential to establishing support for any interpretation of measurement data. Soil gas monitoring data requires a thorough QA/QC protocol confirming that data have been generated to satisfy the data quality objectives for the survey. This requirement is well known, however few investigators subject their soil gas data sets to the rigors of such protocol. Conclusions based upon data of unknown quality may be without merit. Justification for interpretations based upon data of unknown quality is not possible.

6.4.1 QA/QC requirements are dependent upon the data quality objectives defined in the planning phase of the survey. For example, simple contaminant audits require a less demanding QA/QC protocol than contaminant source identification. The goals of the QA/QC effort must be understood by field personnel to assure effective implementation of field QA/QC. A document control officer who is a member of the field team can provide this assurance.

6.4.2 Persons collecting descriptive data should not be varied during a soil gas survey. Soil descriptions, for example, can be somewhat subjective when estimations are made as to soil moisture or clay content. Changes in field personnel can translate into apparent changes in soil lithology that are merely functions of this subjectivity. The document control officer can review field records to discover any obvious errors related to descriptive data.

6.4.3 The results of a soil gas survey are highly sensitive to procedure. Field personnel should closely follow a standard operating procedure. This procedure should include the method(s) selected for the survey including the sampling system, means of sample collection, handling and transport of samples and field based equipment decontamination. A standard practice for equipment decontamination is essential to maximize the integrity of samples that may undergo chemical analyses (see Practice D 5088). Any deviations in the standard operating procedure should be recorded by the document control officer in a field notebook, with notes outlining the justification for the deviation. Data comparability can be severely compromised by deviations from the standard operating procedure.

6.4.4 Field based equipment decontamination can have impact on data quality. This results from the potential for cross contamination of samples due to poorly controlled field cleaning procedure or difficulties presented by the inconvenience of field decontamination. Field based equipment decontamination should not be considered a method of choice, but if unavoidable, must be performed with the data quality objectives for the survey as driving forces for procedure.

6.4.5 Bias of soil gas data describes a situation of consistently lower-than-actual or higher-than-actual soil gas contaminant concentration measurements (32). The bias of a measurement process is a generic concept related to consistent or systematic difference between a set of test results from the process and an accepted reference value of the property being measured (see Practice E 177). Bias can be imparted to

the data through sample site selection, that is, exposure of a sampling device to an environment of enhanced contaminant concentration due to a preferential contaminant migration pathway, or exposure of a sampling device to an environment devoid of contaminants due to barriers to contaminant migration. Bias may also result from malfunction of the sampling system, contaminant degradation or numerous other factors. False positive or false negative values can result, lowering the value of the soil gas data set.

6.4.6 Table 2 summarizes some common problems in soil gas monitoring that can result in biased results.

6.4.7 A sampling program must be conducted during the survey to support evaluation of both the sampling system in the field and the analytical system employed. These samples are known as QA/QC samples. The type and magnitude of QA/QC sampling depends upon the purpose of the soil gas survey and the requirements for data quality attendant to it. It is the responsibility of the investigator to determine the appropriate rigor of field QA/QC protocol. The variation in QA/QC protocol from survey to survey is controlled by the purpose and magnitude of the survey, and can vary to a great degree.

6.4.8 The types of field QA/QC samples are field blanks, travel blanks, sample container blanks, sample probe blanks and sample replicates. Other types of QA/QC samples are analytical in nature and are discussed in 6.6.

6.4.9 Field blanks are samples of ambient air or nitrogen recovered from the sampling system which are recovered to determine contamination of samples by ambient atmospheric air, or, to act as system blanks to test for contamination of the sampling system. Field blanks are used to provide an indication of the probability of leakage in the sampling system or the breakthrough of atmospheric air to the sampling device through macroporous migration pathways in the vadose zone such as soil cracks or moldic porosity. If nitrogen is employed instead of atmospheric air, field blanks can have higher contaminant levels than soil gas. This is especially true for petroleum hydrocarbons in urban environments. At least one field blank should be recovered for each ten soil gas samples, or at least one field blank per sample batch or container type (53).

6.4.10 Travel blanks are the contents of a sample container handled in the same manner as those containers holding samples, except that there has been no sample inserted into the travel blank. The purpose for travel blanks is to audit sample integrity for loss due to sample handling and transport. Travel blanks are useful when analysis is performed at an off-site laboratory. The results obtained by analysis of travel blanks can be used to indicate a potential need to modify sample handling and transport procedure. At least one travel blank should be included in each batch of samples.

TABLE 2 Summary of Possible Causes of False Positive and False Negative Values[A]

Result	Causes
False negatives, that is, falsely low values	Barriers to gaseous diffusion, such as perched water, clay lenses, impervious man-made debris, saturation of soil pores with water (as from rain), low subsurface temperatures.
	Biological or chemical degradation.
	Leakage or blockage in the sample train, improper purge procedure, loss of sample from sample container, problem with analytical system.
False positives, that is, falsely high values	Contamination in sampling train, sample container, or analytical system.
	Contribution of volatile organic contaminants from vegetation.
	Significant contamination in overlying soil.

[A] See Ref (32).

6.4.11 Sample container blanks are obtained by sampling the contents of a clean sample container to ensure that residual contaminants are not present in the container prior to sample collection. If contamination is detected in the cleaned containers, the decontamination procedure must be modified to remedy the problem. Sample container blanks should be collected and analyzed prior to each use of a sample container.

6.4.12 Sample probe blanks, consisting of carrier gas or atmospheric air contrasted to atmospheric air blanks, are drawn through the sampling device and recovered in the same manner as soil gas. The purpose for sample probe blanks is to check for the presence of sample train contaminants that would impact data quality. If contaminants are detected in sample probe blanks, the decontamination procedure must be modified to remedy this condition. Sample probe blanks should be collected and analyzed prior to each use of a probe and/or other components of the sampling system.

6.4.13 Field replicates are recovered as separate soil gas samples collected from the same sample site into multiple containers. Field replicates can be used to estimate the combined precision of sampling and analysis. The recovery of field replicates is not a common practice. When field replicates are demanded by a client or as dictated by a particular situation, field replicates should be recovered as often as is economically and practically possible, however in no instance should the number of replicates fall below ten percent of the total number of soil gas samples (53).

6.4.14 Sample spiking, or the addition of a known quantity of a known compound or mixture to the soil gas sample, is sometimes performed in the field to provide internal checks of analytical quality. Sample spiking in the field is not recommended due to measurement uncertainties in the field. Moreover, caution must be exercised with this procedure because of the potential for contaminant interaction with the known compound(s).

6.4.15 A paperwork audit is recommended at the end of each working day or at the conclusion of recovery of each batch of samples recovered. The paperwork audit should be conducted by the document control officer and include evidence of an equipment inventory, sample inventory including QA/QC samples, review of field notes and chain-of-custody documentation.

6.4.16 Chain-of-custody documentation is recommended at all times, and is mandatory for soil gas surveys when samples are transmitted to an off-site laboratory. It is recommended for soil gas surveys when sample custody is transferred to someone other than the field team leader for any reason. Chain-of-custody documentation assures that samples have not been altered or mishandled prior to analysis. This procedure is mandatory for sample handling and transport in situations where there is likely to be a cost

recovery effort or demonstration of contaminant responsibility in a court of law.

6.5 *Sample Handling and Transport*—Soil gas sampling and analysis usually involve the monitoring of contaminants at very low levels. Consideration of sample handling and transport is not trivial to this exercise.

6.5.1 The period of sample handling and transport represents the greatest opportunity for loss or gain of contaminants from or to sample containers. Loss occurs by contaminant condensation within the sampling train, sorption onto materials within the sampling train, solution into condensed water in the sampling train, chemical changes or leakage to the atmosphere through defects in the sampling apparatus or sample container. Gain of contaminants from sources other than the sampling horizon can occur through related mechanisms working in reverse. Both processes can severely limit the value of data obtained from a survey, and they must be minimized.

6.5.2 In general, the time between sample collection and analysis should be minimized. Investigators should protect samples against light and heat, and exercise precautions against leaks (see Practice D 1605).

6.5.3 *Acceptable Materials*—Investigators are responsible for selecting materials for soil gas sampling, transfer and containment that will not impact sample integrity. Containers that have parts made from porous or synthetic materials such as PTFE, rubber or many plastics are likely to retain or contribute contaminants to soil gas samples. Corrosive metals such as steel or brass become difficult to decontaminate upon corrosion due to the increased surface area of the corroded material and its enhanced sorptive capacity. Septa of any material will be responsible for measurable contaminant loss over time due to leakage. Acceptable materials can be conveniently decontaminated prior to soil gas recovery. Materials that cannot be decontaminated effectively between samples must either be replaced between samples, considered in QA/QC planning as a survey limitation or abandoned in favor of more suitable materials.

6.5.4 *Integral Systems*—Problems of sample handling and transport are minimized by integration of the sampling and analytical system. For example, a whole air-active sampling system can be coupled directly to a portable VOC (volatile organic compound) analyzer. The sample stream is fed directly to the intake port of the analyzer and passed through the detector. If there are no system malfunctions in the sample path, problems of sample degradation become trivial.

6.5.4.1 Care must be exercised with integral systems, however. The dead volume of integral systems is much higher than separate sampling and analytical systems. If the sampling system is not capable of delivering constant sample flow rates at or exceeding the requirements of the analyzer employed, data accuracy and comparability can be seriously affected. Moreover, a large sample volume is required merely to purge the sample system. In soils with moderate moisture contents or even nominal clay contents, it may not be possible to recover the volume of soil gas required to purge the system without serious negative impact to the composition of the soil gas sample recovered. Vapor phase contaminants can be lost to purge volume and atmospheric breakthrough can occur, leading toward a false negative result. Although this problem may not be apparent in seriously contaminated environments, it can become a fatal flaw at low contaminant levels.

6.5.4.2 Cross-contamination is a concern with integral systems. Many integral systems employ common elements from sample to sample, namely tubing, flow meters and analyzer components. Overcoming persistent contaminants can be difficult in integral systems, especially when high soil humidity and cold weather complicate the field effort.

6.5.5 *Transfer of Samples from Sampler to Container*—The method of transfer of samples from sampling device to containers is largely dependent upon the volume of soil gas recovered.

6.5.5.1 Small volume samples are commonly recovered by syringe for immediate injection into an analyzer or small volume container. Glass gas-tight chromatography syringes are employed when rigorous QA/QC protocol is required and samples are injected into the analyzer immediately upon recovery. These syringes must be decontaminated prior to recovery of each sample aliquot. Disposable syringes are employed when samples are to be transferred to a small volume container for transport. They are inexpensive, commercially available and convenient to use. However, disposable syringes can present a disposal problem. They should be inventoried prior to use and destroyed after use, the number destroyed equalling the number inventoried and used. Destruction includes smashing the syringe cylinder and clipping the needle.

6.5.5.2 Hand pumps are also used to transfer samples into tedlar bags or glass bulbs. Hand pumps are preferably installed behind the analyzer or container in the sample train to avoid contribution from or loss of contaminants to the hand pump. Hand pumps commonly contain petroleum-based lubricants which will contribute to the hydrocarbon content of soil gas. These devices must be placed at the end of the sample train or abandoned in favor of another tool.

6.5.5.3 Large volumes of soil gas are commonly recovered by hand or mechanical pumps installed at the end of the sample train. Large volume systems can be metered for soil gas flow rate, which is controlled by the capacity of the vadose zone sampling horizon to transmit vapor to the sampling device, the volume and configuration of the sampling system and the requirements of the analyzer or sorptive trap employed.

6.5.5.4 Small volume sampling is quite sensitive to variations in sample transfer technique. Septum coring by syringe is a common problem that restricts flow of soil gas through the needle. Coring can be corrected by decreasing the needle size and using a relatively hard septum material. Coring does not occur with side-port needles, a high-cost alternative. Needles of 25 to 27 gage seldom core septa. However, flow rates through these small gage needles are slow enough to require great care in consistency of sampling rate to minimize septum bleeding during sampling. This consistency is highly subjective and must be obtained through experience. Polypropylene disposable needles may provide opportunity for contaminant loss by sorption or gain by contribution to the soil gas sample. This can be minimized by using the polypropylene syringe to purge the sampling device prior to sampling, thereby reducing the potential for loss or gain of

contaminants to that of the sampling device. Luer-lock needles should be checked for tightness by twisting prior to each use.

6.5.5.5 Tubing is commonly used in large volume sampling. For low level detection, tubing can present a cross contamination problem if not replaced in the sampling train prior to sampling at a new location. Some particulate matter and condensate may be trapped in tubing prior to entry into the flow meter and analyzer by looping the tubing into three or four small diameter loops at a point near the sampling device. This can eliminate the need for water traps or particulate filters in the system that can contribute to system loss or gain of contaminants.

6.5.5.6 Vacuum can be employed to transfer soil gas from a sampler to a container. Evacuated glass bulbs, some containing adsorbents or absorbing liquids (see Practice D 1605), can be affixed to an in-place and purged sampling device and allowed to come to pressure equilibrium. Care must be exercised in recovery of the gas sample from a vacuum cylinder. Upon recovery, the sample is immediately subjected to negative pressure and atmospheric contamination of the sample is encouraged.

6.5.6 *Sample Collection: Containers*—A wide variety of sample containers is employed by field investigators. Container selection is based upon the physical properties of the contaminants sampled, the volume of the sample recovered, the physical properties of suspected contaminants, the sampling system employed, the anticipated sample holding time prior to analysis and the analytical method chosen. Container type for a soil gas survey should be held constant within the survey. A change in container type can impart bias to a portion of the data due to sorptive or desorptive processes related to container type.

6.5.6.1 Whole air samples can be contained in any device made of suitable materials (see 6.5.3) that conveniently satisfy survey, handling, transport and analytical requirements. Certain containers require special handling practice. The literature provides discourse on atmospheric sampling bags (**54**).

6.5.6.2 Sorbent traps are commonly self-contained. Care must be exercised to select a trapping device that is compatible with the properties of the target compounds and the technique of desorption chosen. Good practice for use of these devices, including handling and desorption procedure is required for successful implementation of sorbent traps when sampling organic compound vapors (see Practice D 3686).

6.5.6.3 Table 2 provides an inventory of sample containers, their applications, advantages and limitations (32).

6.5.6.4 Containers exist that provide for both whole-air and sorbent fractions as well as removal of sample by displacement (see Practice D 1605). Some are convenient for field use, however most are too complex or fragile to be of effective use for a field screening technique requiring rapid mobility.

6.5.6.5 Detector tubes should not be considered as a primary containment vehicle for the purpose of storage and transport of soil gas. A discussion of detector tube application is provided in 6.6.1.

6.5.6.6 Containers for soil samples to be preserved for a subsequent headspace analysis range from glass sample vials to metal cans. The choice of container for soil headspace determination is dependent upon the method of sampling chosen. For soil samples obtained by backhoe, bucket auger or other destructive technique, that is, a disturbed sample, extrusion into a sample vial is not necessary since most of the highly volatile components have already been lost through the act of soil sampling. Metal cans should be made from a material that does not rust. Coating materials and sealing waxes are likely to react with or adsorb soil contaminants, presenting limitations to the value of the data collected. Glass containers with screw threads or crimped seals are difficult to use for soil headspace methods due to the inability of investigators to consistently, thoroughly and rapidly clean the threads or crimp surfaces of all containers prior to capping.

6.5.6.7 Soil pore liquid headspace samples are whole-air or whole-air plus pore liquid samples. They may be contained in most devices suitable for whole-air containment, however investigators are cautioned to select containers from which a vapor sample can be extracted for analysis independently of the liquid present.

6.5.7 *Sample Processing*—Some investigators process soil vapor samples prior to analysis. Processing is performed in an effort to control sample degradation in containers. Efforts to check this degradation by sample processing include refrigeration, pressurization, and pasteurization. As a general practice, sample processing is strongly discouraged. Refrigeration may be somewhat effective in controlling sample degradation, however the best method is to limit or avoid soil gas sample storage whenever possible. The limited shelf life of soil gas samples is discussed in 6.5.9.

6.5.7.1 Extraction is a sample processing step used to remove soil contaminants from soil cores or other similar samples. This technique can efficiently recover contaminants from all residence phases, not just the vapor phase. As a result, the technique yields samples that are not representative of soil atmosphere contaminant suites.

6.5.8 *Sample Transport*—If samples are to be transported to an off-site laboratory for analysis, they must be properly packaged to avoid damage to sample containers. Care must be taken to keep samples from becoming overly warm or agitated during transport. Overnight air express is highly convenient if samples are properly contained, but air freight is not recommended if samples are held in containers such as gas tight syringes or tedlar bags. These containers have other limitations as discussed in 6.5.6.

6.5.9 *Sample Life*—Soil gas samples have limited shelf life even in the most effective containers. Soil gas sample life is strongly container dependent. Numerous factors limit shelf life; most involve degradation in a container. Exposure to light, heat and agitation during shipping will accelerate sample degradation. Biodegradation may occur in some sample containers if water vapor condenses in a container containing microorganisms capable of metabolizing contaminants as substrate.

6.5.9.1 The safest practice is to minimize sample storage time. This problem is greatest when off-site laboratories are engaged to analyze the samples. Prior to recovering the soil gas samples, arrangements can be made with the selected off-site testing laboratory to schedule the necessary personnel and equipment in anticipation of sample delivery.

6.5.10 *Soil Gas Archiving*—Sample archiving in anticipation of a future analytical or descriptive requirement is a common practice. Minimal effects of degradation or loss may be noted in storing certain sorbed samples. Soil gas archiving is, however, not recommended. Although dependent upon the type of container and the storage environment, the likelihood of degradation of soil gas samples is great enough to raise concern. Insertion of standard gases into an archived sample set and spiking of archived soil gas samples with standards provides a reference to determine the likelihood or extent of sample degradation.

6.6 *Analysis of Soil Gas Samples*—Soil gas analysis procedure is based upon pre-existing protocol established for the analysis of contaminants in ambient air. A common reference practice defining terms, sampling information, calibration techniques and methods for validating results may be applied to all automatic analyzers (see Practice D 3249). Basic laboratory practice common to investigators engaged in sampling and analysis of atmospheres applies to soil gas analysis. Note that air sampling protocols and soil gas sampling protocols are not equivalent; geophysical and geochemical factors as well as definition of air sample volume contribute to this lack of equivalency. This guide includes the criteria, guidelines and recommendations for analytical segments including the mode of operation of the laboratory and data validation (see Practice D 3614).

6.6.1 *Basic Analytical Approach*—Soil gas analysis is performed to identify the presence of contaminants, their type and relative concentrations. Various analytical methods are highly general, satisfying only the most rudimentary requirements of contaminant screening. Others are sophisticated, providing identification and relative concentration information for numerous chemical compounds determined to be present in a soil gas sample. The choice of basic analytical approach in soil gas analysis is driven by the purpose of the soil gas survey, quality assurance objectives and budgetary constraints placed upon investigators.

6.6.1.1 Soil gas surveying as a field screening technique can often be effective without the commitment of expenditure for highly sophisticated techniques. This survey purpose is merely to locate other, more direct, techniques. Caution is suggested when choosing highly sophisticated analytical methods for field screening by soil gas monitoring. This selection is controlled largely by the need for the analytical method chosen to be cost-effective.

6.6.1.2 Other applications of soil gas monitoring require more thorough analytical protocol. It is not possible, for example, to suggest the locations of partitioned miscible and immiscible ground-water contaminant plumes with elementary analytical systems. Moreover, the independent monitoring of multiple classes of contaminants in soil gas normally requires analytical systems with multiple detectors. Successful soil gas monitoring for petroleum exploration requires an analytical system which can separate and identify extremely similar volatile compounds occurring at very low concentration levels.

6.6.1.3 Contaminant concentrations in soil gas can vary from levels below the detection limit of the most sophisticated equipment to percent of a whole-air sample. Ideally, the analytical system chosen has enough flexibility to determine contaminants in a wide range of concentrations. Care should be taken to select an analytical system sensitive enough to avoid false negative results which can lead to invalid conclusions. Many analytical systems are not designed to perform to specifications in very high concentration environments, requiring sample dilution prior to analysis or selection of a less sensitive method.

6.6.1.4 Of primary importance to the successful analysis of soil gas is the familiarity and experience of the analyst with the analytical system chosen. The analyst must be able to independently care for and maintain the equipment as well as recognize symptoms of procedural error. The success of an analytical effort lies wholly with operator ability and experience. Excessive machine capability cannot compensate for operator inexperience.

6.6.1.5 Soil gas may be analyzed by a number of methods, including portable VOC (volatile organic compound) analyzers, gas elution chromatography, gas chromatography-mass spectroscopy, and colorimetric and color-indicating detector tubes. Infrared spectroscopy and fiber optic chemical sensors can be applied to soil gas gas analysis, however their use is currently limited and few investigators have experience with this instrumentation. In practice, gas chromatography (GC) or GC-based handheld detectors are the most widely used analytical instruments (**32**) for soil gas analysis. This guide uses numerous terms relating to various GC methods for soil gas analysis. Most of the terms should apply to other GC methods (see Practice E 355).

6.6.1.6 Portable VOC analyzers used for fugitive emission screening and industrial hygiene monitoring have been adopted for soil gas analytical purposes by numerous investigators. These devices are easily transported to and from the field, require minimal operator skill, provide immediate data and serve to eliminate many sample handling and transport steps which can result in uncertainty. Portable VOC analyzers are limited in application to very low level detection due to the absence of a concentration step. They exhibit limited selectivity and do not have the ability to separate contaminant compounds, leading to potential interference. These devices also are limited in accuracy due to the inability to calibrate for the wide variety of contaminant compounds encountered in soil gas, each compound having its own character of detector response. Portable VOC analyzers contain three types of detectors. These are the flame ionization detector (FID), the photoionization detector (PID) and the infrared (IR) detector. The literature contains a thorough treatment of these devices (**10**, **55**).

6.6.1.7 Soil gas analysis by GC is by far the most versatile and the most costly soil gas analytical method. Instrumentation can be varied to accommodate field mobility, however this is not always required. The technique provides separation of compounds in a chromatographic column, tentative identification of compounds determined to be present and a relative quantitation of compound concentration based upon comparison to a known standard. Soil gas is introduced into the GC and conveyed through a chromatographic column by a carrier gas, separating the contaminants as they pass through the column. The separation is obtained when the sample mixture in the vapor phase passes through a column containing a stationary phase possessing special adsorptive properties. As the gas stream emerges from the column, it passes through a detector, providing for measurement of a

specific sample property through the recording of detector electrical response. These responses, or peaks, are recorded as a function of time. Comparison of known standard compound response time with the response time of an unknown represented by a peak results in the tentative identification of the unknown. Comparison of the magnitude of detector response to the newly identified compound versus detector response to the same compound of known concentration, a laboratory standard, results in a relative quantitation of subject compound concentration in the sample.

6.6.1.8 Gas chromatography is essentially a physical separation technique. The degree of separation depends upon the differences in the distribution of volatile compounds, organic or inorganic, between a gaseous mobile phase and a selected stationary phase that is contained in a tube or GC column (see Practice E 260).

6.6.1.9 Numerous factors can impact the ability of the GC to determine contaminants in a soil gas sample. These include column characteristics, sample flow rate, sample temperature, the composition of the carrier gas and the type of detector employed. Instrumentation can be expanded to include multiple columns, multiple detectors, sample loops and temperature programming, all of which make an instrument more versatile, albeit at additional cost.

6.6.1.10 Simple GCs are portable analyzers with GC options. Field GCs are more advanced instruments with temperature programmable ovens and provide opportunity for multiple columns and detectors. They can be carried in mobile laboratories or established in a temporary base laboratory in the field. Research-grade instruments are normally based at off-site laboratories with strictly controlled environments. These are used when positive identification or very low detection limits are specified. The literature contains excellent comparisons of the advantages, limitations and applications of the various configurations of GCs, including instrument specifications (**10, 32, 56, 57**).

6.6.1.11 Detector tubes have been applied to safety and health atmospheric monitoring, agriculture and the chemical industry. These devices are designed to be compound specific, although this characteristic is dependent upon the contaminant compounds present in the sample drawn through the tube. Detector tubes may be used for short-term sampling (grab sampling; 1 to 10 min) or long-term sampling (dosimeter sampling; 1 to 8 h). Short-term sampling involves the movement of a given volume of gas through the tube by a mechanical pump. If the substance for which the detector tube was designed is present, the indicator chemical in the tube will change color (stain). The concentration of the gas may be estimated by either the length of the stain compared to a calibration chart or by the intensity of the color change compared to a set of standards (see Practice D 4490). Long-term sampling involves the movement of gas at a very slow rate through the tube by means of an electric pump. The use of long-term detector tube sampling for soil gas monitoring is limited to specific temporal survey designs.

6.6.1.12 Detector tubes are relatively inexpensive and provide immediate results. Their use is restricted to applications with few interfering compounds. Depending upon the contaminants present, they may be of low sensitivity and can be affected by humidity, normally high in soil gas, sample flow rate, temperature extremes (32), storage conditions and shelf life.

6.6.1.13 The literature contains excellent discourse on the detector tube apparatus, reagents, procedure accuracy and amenable compounds (see Practice D 4490).

6.6.2 *Specific Analytical Approaches*—This subsection discusses various detectors and methods that may be integrated into soil gas analytical instrumentation. For methods providing detector alternatives, the choice of an appropriate detector should be guided by knowledge of detector properties. Key properties are as follows (after Mayer, 1989 (**32**)):

6.6.2.1 *Selectivity or Specificity*—Selectivity refers to the responsiveness of the detector to the compound of interest. Detectors responding to a wide range of classes of compounds are termed universal or non-selective detectors. Those that respond to only certain classes of compounds are termed selective detectors.

6.6.2.2 *Sensitivity*—Sensitivity refers to the relationship between the detector response and the quantity of the subject compound injected. It is the smallest detectable quantity of a compound; it is usually considered to be the amount that produces a response equal to twice the baseline noise of the detector.

6.6.2.3 *Linear Dynamic Range*—Linear dynamic range is the range over which the detector response to a compound is directly proportional to the amount of compound injected. Detectors vary in the range of component concentrations over which they are linear. Wide linear dynamic range is desirable because it simplifies quantitation of samples having widely varying ranges of concentrations.

6.6.2.4 *Stability*—Stability is a factor referring to detector responsivity over time. Stability is controlled by numerous factors and is seldom quantified. The required frequency of instrument calibration is determined by detector stability.

6.6.3 Specific analytical approaches are as follows:

6.6.3.1 *Flame Ionization Detectors (FID)*—Flame ionization detectors generate electric current when gases containing carbon atoms are oxidized to carbon dioxide in a hydrogen flame and potential is applied across the flame. The magnitude of the electric current generated is termed the detector response. FIDs are responsive to hydrocarbon contaminants in soil gas and are commonly employed for this purpose. These detectors are durable for field application, and have a wide linear range and nearly uniform response to organic gas species. FIDs are generally unresponsive to inorganic gases and water vapor, common constituents in soil gas. FID performance can be evaluated independently of the chromatographic column (see Practice E 594). Although highly versatile, these detectors are not selective for halogenated compounds. They require supplies of fuel gas which require careful safety practices in handling and flame ignition.

6.6.3.2 *Photoionization Detectors (PID)*—Photoionization detectors employ ultraviolet radiation to ionize contaminant molecules. Positive ions and free electrons are formed which migrate to the detector electrode(s), resulting in an electric current that is proportional to contaminant concentration at the detector. PIDs are extremely sensitive to aromatic hydrocarbons due to the great efficiency of ionization of pi bonds under ultraviolet radiation. Efficiency of ionization of sigma bonds is lower, resulting in a higher PID detection limit for aliphatic hydrocarbons. The selectivity of

the method can be adjusted by selecting lamps of different energies, causing a change in response of contaminants with fixed ionization potentials to changing lamp energies. Tables exist of ionization potentials of compounds within classes common to soil gas contaminants (**58**). Methane has an ionization potential higher than the energies of commercially available lamps, limiting the PID to detection of compounds other than methane. PIDs are further limited by their tendency to conceal the presence of low-sensitivity compounds when high-sensitivity compounds (aromatics) are present. PID response can be impacted by condensation of water vapor in the lamp.

6.6.3.3 *Electron Capture Detectors (ECD)*—Electron capture detectors are highly sensitive to and selective for compounds with electronegative functional groups such as CFCs (chloro-fluorocarbons). The sensitivity of the detector is proportional to the number of these groups on a compound, resulting in a unique detector response to each compound. The ECD comprises a source of thermal electrons inside a reaction chamber (a radioactive source emits β radiation which ionizes the carrier gas to produce electrons). The device detects compounds with electronegative functional groups capable of reaction with thermal electrons to form negative ions. Such reactions cause a decrease in the concentration of free electrons. The detector is designed to measure changes in the concentration of these electrons inside the chamber (see Practice E 697). Calibration of the ECD is therefore linked to each compound to be determined by the detector. ECDs are also sensitive to water, oxygen and other common components of soil gas, causing potential problems in method performance. ECDs emit β radiation that should be properly vented. Operation of an ECD requires licensing under Federal regulation.

6.6.3.4 *GC/Mass Spectroscopy*—Combination of gas chromatography and mass spectroscopy results in the GC/MS method of analysis. A mass spectrometer is used to obtain a mass spectrum of each eluting compound. Positive identification of these compounds is sometimes obtained by comparison of the unknown mass spectrum to a library of known spectra. GC/MS can be extremely selective for target compounds. Use of the technique for soil gas monitoring is limited, primarily due to the cost of analyses.

6.6.3.5 *GC/Fourier Transform Infrared Spectroscopy*—This analytical method combines gas chromatography with Fourier transform infrared spectroscopy. GC/FTIR can provide a rapid identification of eluting compounds by comparison of their infrared spectra with a known spectral library. Quantitation is achieved by subsequently passing the sample through an appropriate GC detector such as the FID or ECD. This method, like GC/MS, is limited in application to soil gas monitoring by the high cost of analysis.

6.6.3.6 Other detectors are applied to soil gas analysis by GC, albeit rarely in comparison to FID, PID and ECD. They include the argon ionization detector, a non-destructive device similar in operating design to the ECD, the flame photometric detector (FPD) used to determine organic compounds containing sulfur and phosphorus, and the hot-wire (pyrolyzer) used to determine compounds containing nitrogen.

6.6.4 *Analytical QA/QC*—The validation of the analytical aspects of soil gas monitoring is fundamental to the technique. Analytical equipment and procedure must be evaluated by laboratory QA/QC, just as the sampling system, sampling plan and field procedure are evaluated by field QA/QC methods. Analytical QA/QC defines a confidence limit of performance. The utilization of well tested and uniform analytical practices is essential to the production of reliable and defensible data, the validity of which can be demonstrated at a later date through the use of written field and laboratory records (see Practice D 3614)

6.6.4.1 Most analytical QA/QC plans contain calibration steps, linearity checks, standard analyses, blank analyses, duplicate analyses and audit checks. The various analytical approaches discussed in 6.6.3 require a variety of different protocols which will satisfy the QA/QC requirements for each method. Four types of analytical QA/QC samples are required for determination of quality assurance. These are analytical reagent blanks (used to determine the potential of sample or standard contamination from a reagent), laboratory blanks (used to determine the impact potential of the laboratory atmosphere on analytical results), analytical sample replicates (used to estimate the analytical precision for samples) and analytical standard replicates (used to estimate the analytical precision for standards). Table 3 provides a summary of suggested calibration and quality control requirements for analytical systems (**10**).

6.6.4.2 The aspects of bias, precision, representativeness, completeness and comparability must be considered to evaluate analytical equipment performance, including the establishment of minimum detectable quantities of contaminant compounds, retention time drift and the linearity of instrument response. Bias and precision must be quantified in order to compare actual survey performance with goals established in the survey plan.

6.6.5 A data validation summary report is a common method of evaluating analytical system performance. A guide for determining parameters key to the data validation summary report is provided as follows.

6.6.5.1 *Bias*—For determination of bias, the percent recovery can be determined using the following formulas:

$$recovery\ reproducibility = (DCS/KCS) \cdot 100 \quad (6)$$

where:

DCS = determined concentration of standard, and
KCS = known or certified concentration of standard.

The standard deviation of all standards analyzed can be determined as follows:

$$SD = \{(sum(recovery\text{-}i - recovery\text{-}ave)^2)/(n - 1)\}^{0.5} \quad (7)$$

Finally, the range of uncertainty can be determined using the following equation:

$$\pm R = \pm t \cdot (SD)/(n^{0.5}) \quad (8)$$

where:

t = the value of Studentized t at the 90 % confidence level and $(n - 1)$ degrees of freedom.

The bias statements for data collected should be expressed as the average recovery plus or minus the range.

6.6.5.2 *Precision*—For the determination of precision, the relative standard deviation of replicates can be calculated using the following equation:

$$RSD\text{-}pair = SD/Mean \quad (9)$$

TABLE 3 Soil Gas Sampling Containers[A]

Type	Applications	Advantages	Limitations
Stainless steel canisters	Collection of samples for delayed analysis	Durability Ease of sample handling Can be re-used Sample holding time longer than that for other whole-air sample containers Sample volume measurement not required Desorption not required Allows replicate analysis	Expense Requires vacuum pump or gage Can be difficult to decontaminate
Glass bulb	Collection of samples for delayed analysis	Glass is more inert than other sample container materials Septa possible Allows replicate analyses	Easily breakable Leakage through stopcocks or septa possible Adsorption to PTFE or other parts
Bag	Collection of samples for delayed analysis Sampling of very high vapor pressure compounds for which absorption methods are unsuitable	Bulk loss of sample is readily apparent Containers are light-weight and easy to handle Sample volume measurement not required Desorption not required Allows replicate analyses	Expense Some compounds may be lost through or adsorbed to bag walls Some container materials may contaminate samples Containers cannot be easily re-used Leaks in valves
Syringe[B]	Collection of samples for on-site analysis	Ease of sample collection Does not require special equipment to introduce sample into GC Desorption not required	PTFE plungers can adsorb sample Holding time short due to leakage or absorption Sample volume smaller than for other containers
Sorbent sampler	Allows concentration of low level samples If samples are solvent-desorbed, allows analysis of liquid sample	Ease of handling Relatively long holding time	Requires precise sample volume measurements Sorbent type must be tailored to compounds to be measured; adsorption behavior of each compound for solvent used must be accounted for Requires desorption (thermal or solvent) for analysis

[A] See Ref (32).
[B] Syringes may also be used to transfer samples from the sampling device to a container for off-site analysis.

$$RSD\text{-}ave = \{\{(sum(RSD\text{-}pair))^2\}/(n-1)\}^{0.5} \quad (10)$$

where:

RSD-pair = relative standard deviation for each pair of replicates, and
RSD-avg = relative standard deviation overall.

Next, the precision can be determined as follows:

$$precision = \{(t \cdot RSD\text{-}avg)/DF\} \cdot 100 \quad (11)$$

where:

precision = the percent precision,
t = the *t* value for $n-1$ pairs of replicates, and
DF = the degrees of freedom = $(n-1)$.

Finally, mean value is reported with associated uncertainty:

$$x \pm (x \cdot t \cdot SD\text{-}ave)/(DF)^{0.5} \quad (12)$$

where:

x = reported chemical concentration, and
t = the value of *t* at the 90 % confidence level for the appropriate degrees of freedom.

6.6.5.3 *Representativeness*—Representativeness is determined by the results of the cross contamination blanks and the air blanks. The results should be presented as a bias estimate, as follows:

$$bias\ (\%) = \{(CCC - CA)/Mean\} \cdot 100 \quad (13)$$

where:

CCC = concentration in cross contamination sample,
CA = concentration in air, and
Mean = mean concentration in sample set (bias may also be expressed for a single sample by substituting sample concentration).

6.6.5.4 *Completeness*—The completeness goal is 90 % or higher. Completeness is the number of samples collected that can be validated through the procedures for bias, precision, and representativeness.

6.6.5.5 *Comparability*—Comparability is based upon professional judgment and is provided through planning steps carried out prior to initiation of field work.

6.7 *Data Interpretation*—Soil gas data interpretation is an iterative process including the examination of the raw data, selection of appropriate and useful data displays, and establishment of correlation of the data set to other vadose zone monitoring data and ground truth. Interpretation of soil gas data is not like other interpretive exercises involving measurement data, in that mathematical expressions relating soil gas contaminant concentrations to underlying soil, rock and ground-water contaminant concentrations cannot be written for most applications at a high confidence level. This is a function of a lack of site characteristics information at even the most comprehensively studied sites. Soil gas data cannot be consistently interpreted in a manner that establishes direct correlation between contaminants in a soil gas horizon and contaminants in other horizons. Processes including migration and degradation can have profound influence on the correlation of soil gas data to ground truth. Interpretive efforts excluding consideration of these influencing processes can be highly misleading. For example, the presence of contamination in an underlying horizon will not necessarily correlate to the detection of contaminants in overlying soil atmospheres, that is, the potential for a false negative resul The converse is also true, that is, the potential for a false positive result. Interpretation of GC results in the laboratory without consideration of pertinent hydrogeological informa-

tion may lead to incorrect conclusions (59). However, the detection of contaminants in soil gas does suggest the existence of a contaminant source, and increases in contaminant concentration can suggest close proximity to the source or an increased quantity of the subject contaminant in the subsurface. It is the responsibility of the interpreter to examine soil gas data in context of other site characteristics, and provide an interpretation based upon sound judgment and thorough yet practical data treatment.

6.7.1 *Manipulating Data*—Soil gas data is normally interpreted as raw data. The application of correction factors is not recommended, as it is difficult if not impossible to determine if the magnitude of the correction factor is greater than that of the variance between data populations in a survey. Moreover, the need for correction factors can indicate a flaw in survey design, sampling system performance or the objectivity of the interpreter.

6.7.2 *Defining Data Subpopulations*—Soil gas monitoring seeks to define anomalous subpopulations of data that contain measurable quantities of contaminants or unusual compositions. These populations can easily be described by their contrast to normal populations, for example, contrasting populations with and without measurable contaminants. Establishment of contaminant baselines or conditions "at background" make this contrast possible. If all soil gas samples are recovered in a contaminated area, there may be no apparent contrast.

6.7.2.1 Statistical treatment of soil gas monitoring data allows the interpreter to estimate the amount of variation noted in the survey data due to errors. This practice also permits the interpreter to evaluate the data quality objectives suggested for the survey during the planning phase. Statistical treatment of soil gas data can also be of use to define anomalous data subpopulations when the boundaries of a contaminated area are not clearly defined or if the existence of multiple populations of data (that is, contaminated and uncontaminated) within a single data set is in doubt. The literature contains discourse on statistical treatment of soil gas data (**10, 60**).

6.7.3 *Interpreting Soil Gas Data Profiles*—Soil gas data from survey profiles displayed on an $X - Y$ plot is an effective aid to data interpretation. This display is useful to examine the overall context for soil gas measurement data potentially indicating contamination. If the profile is displayed as a cross section through a grid pattern or as a linear array of sample points, the profile display can illustrate spatially significant groupings of data subpopulations.

6.7.3.1 It is quite common for concentration data to be highly variant within a contaminated area. Soil gas profiles can be used to show variation in spatially related data. This is one method of defining subpopulations of data indicating contamination or other anomalous characteristics.

6.7.3.2 Multiple data sets can be displayed on a single profile. Comparison of one data set to another on a single profile is a simple visual method to screen for suggested data subpopulations. Comparison of concentration data and compositional data (see 6.7.5) on a single profile can further resolve this problem.

6.7.4 *Mapping Soil Gas Data*—Soil gas data obtained by sampling at a single depth is often mapped to suggest the lateral extent of subsurface contamination. Map suites of soil gas data obtained from multiple depths can sometimes aid investigators in determining the depth to the contaminant source.

6.7.4.1 Numerous algorithms can be used to interpolate between data points, including linear, inverse distance squared, inverse distance cubed, splines and kriging. The various interpolation methods will yield similar results, suggesting a general pattern of contaminant distribution in soil gas. Kriging requires a probability model for each survey site mapping application for which it is employed, the derivation of which requires data which are not normally available for a given soil gas survey area.

6.7.4.2 Caveats exist in using computer mapping programs as interpretive aids. Difficulties can arise in treatment of adjacent data points differing in contaminant concentration by an order of magnitude and more due to vapor migration barriers, preferential vapor flow paths or changes in soil moisture or porosity content. It is possible to model these characteristics and input such a model into some computer mapping programs, however this introduces bias into the mapping effort. Single point soil gas contaminant concentration highs may exist due to a sample density which is insufficient to resolve the cause for the single point anomaly. Contour mapping of such data may be meaningless without the complement of other information, especially detailed knowledge of site characteristics.

6.7.5 *Analyzing the Composition of Soil Gas Contaminants*—Certain applications of soil gas monitoring require detailed analyses available from off-site bench laboratories or mobile laboratories. Determination of a number of contaminant compounds in a soil gas sample set with either of these analytical systems enables the interpreter to make a comparative analysis of the changes in soil gas contaminant composition within that sample set.

6.7.5.1 Compositional analyses can range in scope from a simple listing of the various compounds determined in each sample to thorough data treatments. Profiles of soil gas data can be constructed to illustrate the spatial relationship between two potentially different groupings of data (see 6.7.3). Crossplots of contaminant compound concentrations are highly effective in the definition of data subpopulations, and can be used to relate contaminant types to known on-site waste streams and sources in complex settings. Known as fingerprinting, this guide compares vapor composition over a known contaminant product and the known soil atmosphere composition over that product to soil gas contaminant composition in areas being investigated on the subject site. Subtle divisions in data subpopulations can be defined by crossplots of contaminant ratios. In addition to simple ratioing, computerized multivariate pattern recognition techniques such as cluster, factor and discriminant analyses can assist in the evaluation of intra-data set compositional variations and their relationship to the physical contamination issues at a site.

6.7.5.2 Soil gas data can be examined for the appearance of target compounds determined to be present in contaminant mixtures. The success of this practice, used primarily to establish the location and extent of underlying ground water contamination, relies upon selection of appropriate target compounds and the persistence of target compounds in soil vapor.

6.7.5.3 Monitoring specific compounds in soil gas data can be utilized to determine the progress of degradation or migration of contaminants in the vadose zone and in ground water. Biodegradation has been monitored by the appearance of excessive quantities of carbon dioxide in soil gas (**61**).

6.7.6 *Interpretation in Context of Other Vadose Zone Monitoring*—Soil gas monitoring is not a technique that can consistently support conclusions based upon interpretations of survey results. For this reason it is strongly recommended that other vadose zone monitoring methods be used to corroborate data obtained from a soil gas survey, especially when investigators are attempting to do more than simply audit a subject site for the presence of contaminants. Useful models of contaminant emplacement and transport in the vadose zone can be constructed by combining techniques. Examples of useful combinations are soil pore liquid and soil gas monitoring or neutron probe and soil gas monitoring.

6.7.7 *Correlation With Ground Truth*—Interpretation of soil gas data is difficult without establishing some form of ground truth with which to substantiate survey results. Ground truth can be in the form of monitoring well data, for purposes of determining the extent of contamination by a ground-water contaminant plume. Examples of other forms of ground truth usable in support of soil gas data interpretation are soil cores, the presence of contaminant odors in basements, observed floating contaminants in storm sewers or utility vaults, or other field observations.

7. Data Reporting Requirements

7.1 *Purpose of Reporting*—Of primary concern in a report of findings pertaining to a soil gas survey is that the report includes the information necessary to describe the results of that survey performed for a particular application. In many instances, certain interpretative methods or data reporting formats useful to end users for one particular application are not relevant to the needs of end users applying the information to a different application. Examples of these differing applications that require unique report subject matter are soil gas contaminant determinations for real property environmental assessments, soil gas monitoring of volatile organic contaminants from underground storage tanks and soil gas sampling as a tool useful in the exploration for natural resources. Certain applications require a thorough treatment of a significant number of factors impacting the meaning and usefulness of soil gas data interpretations. Examples of such applications include damage assessments, contaminant source identification or tests of the effectiveness of remediation. Other applications command minimum reporting requirements. An example of such an application is the monitoring of releases from underground storage tanks over time. Included in a discussion of the report objectives should be an identification of the end user category (for example, regulatory agency, land acquisition negotiations).

7.1.1 A decision must be made regarding the units expressed in reporting, that is, qualitative or quantitative. If quantitative, the appropriate expression of units in volume/volume or weight/volume must be determined. SI units are recommended for reporting of atmospheric measurement data (see Practice D 1914).

7.2 *Report Format*—Certain reporting requirements are commanded without regard to data application. In large part they are related to the QA/QC objectives, and include data comparability, representativeness, bias, precision accuracy, completeness and analytical detection limits whenever possible. At a minimum, a general discussion of the reliability of results and analytical detection limits is warranted; soil gas test data may be evaluated in the same manner as is other atmosphere test data (see Practice D 3614).

7.3 *Salient Points to be Addressed in Reporting*—The report of findings of any soil gas monitoring effort can contain discussions within any number of topics that should be selected to best suit the requirements of the end user. Selection of appropriate topics is discretionary, usually based upon a scope of work determined by prior agreement between the data provider and the data end user. Efforts to limit reporting requirements for the sake of short term time and money cost savings usually result in low-confidence level treatment of the report or an ultimate time and money cost gain, or both. Discussions that should be included when appropriate and whenever possible are provided below.

7.3.1 The purpose of the soil gas study should be stated, as well as the rationale for selection of a particular soil gas monitoring technique.

7.3.2 Selection of a particular soil gas monitoring technique is typically controlled by the chemical and physical properties of the chemical compounds of interest which are known to occur or suspected to occur on site. A discussion of the sample array in three dimensions, sampling method employed and the analytical scheme chosen in context of these properties should be provided.

7.3.3 The rationale for selection of a particular soil gas monitoring technique should always be based upon the physical properties of the vadose zone as well as the chemical and physical properties of the compounds of interest. A discussion of the impact of these vadose zone properties on survey design should be included in the report. The regional and local hydrogeologic conditions within the survey area should be described. A discussion of the regional geology should include the physiographic province, a generalized geologic column, geologic structure and general ground water occurrence. The local conditions should be described with regard to soil type(s), moisture content in the vadose zone, soil/bedrock interface, stratigraphy and lithology, ground water bearing zones, flow directions and gradients, potentiometric levels, aquifer characteristics and ground water quality.

7.3.4 If known and appropriate, the characteristics of a contaminant source or spill should be addressed. Examples of such characteristics are contaminant composition, the likelihood of single or multiple contamination events or the reaction potential (above, within and beneath the vadose zone) of multiple contaminant mixtures.

7.3.5 Every subject of every vadose zone monitoring effort has unique characteristics. Those characteristics that could impact the results of the soil gas monitoring effort should be described to provide a meaningful context in which to interpret the soil gas data.

7.3.6 There are a number of topics common to most soil gas data reporting that are useful in the majority of applications. The regional and specific site location should be identified using a site plot plan. The site plot plan could include an insert showing the regional location. A discussion

should be included regarding the physical structures at the site that may impact the location of sampling points and the migration of soil gas, for example, asphalt and concrete pads, buried pipelines and surface water impoundments. Site history must be considered, including the types of chemical compounds known or suspected to have been used at the site. These compounds should be listed with their chemical and physical properties as they relate to volatilization, solubility and other migration characteristics or soil gas recovery characteristics.

7.3.7 The site should be evaluated in the report of findings for the impact of the regional and local hydrogeologic conditions within the survey area on the results of the survey.

7.3.8 A detailed description should be given of the type of soil gas survey conducted. Details should include selection of active or passive method, whole air or passive sample collection method, sampling array, background sampling, equipment decontamination procedure employed prior to the survey, field or laboratory analytical methods and QA/QC procedures. Any unusual conditions should be noted, such as rainfall events during the course of the survey (especially when moveable soil gas chiefly originates from vadose zone microporosity), high pressure or low pressure front movement across the survey area during the course of the survey (especially when moveable soil gas chiefly originates from vadose zone macroporosity), or visual observations of contamination at sampling points.

7.3.9 If a subject property is found to be contaminated, a separate discussion of soil gas characterization of uncontaminated or non-anomalous contiguous property should be provided in the report of findings. This can be useful in highlighting naturally occurring petroleum hydrocarbons in soil and in establishing a regional baseline of contamination.

7.3.10 Data collected during the field sampling and field or laboratory analyses should be compiled in table form and be included in a preliminary or final report, preferably as appendices. Such data should include a listing of sampling and analysis dates, soil/rock description at each sampling point, depth and diameter of sampling point, quantity of soil gas purged prior to sampling, quantity of sample extracted, chromatogram and/or mass spectra for each sample and a tabulation of QA/QC samples recovered.

7.3.11 The report of findings should include a discussion of the results of the QA/QC efforts, establishing performance within limits set prior to the survey. Data validation involves review of the data collected for the purpose of isolating spurious values (32). Systematic errors or bias can be detected in this review. Suggestions should be made as to the origin of the errors or bias.

7.3.12 Results of analyses should be displayed on plan maps and should include sampling point locations, physical features, contours of equal concentrations of specific compounds or compound groups (for example, alkanes) and any necessary keys or other notes to guarantee map clarity. Cross-sections showing changes in contaminant concentration with depth and concentration profiles of more than one contaminant through several sample locations can be highly useful displays. The report should include text describing each map, cross-section or profile.

7.3.13 Whenever possible, discussion should be provided that correlates soil gas data to ground truth. The most common and widely accepted form of ground truth is data from ground water monitoring wells.

7.3.14 When appropriate, the report of findings should attempt to identify the source of the contaminants encountered in the soil gas survey.

7.3.15 The report should contain a section which discusses the conclusions drawn from the results of the soil gas study and any recommendations which seem appropriate to enhance the value of conducting such a soil gas study. Conclusions should include identification of the compounds detected, if any, an assessment of the appropriateness of the soil gas study method used, and any circumstances that may have significantly impacted the results of the investigation, such as weather conditions or equipment calibration. Recommendations should address need for establishing ground truth, extension of the study to adjacent areas of interest, the need for a different soil gas study method, actions to resolve questionable QA/QC results, or need for additional chemical analyses for contaminant identification.

7.4 *Disadvantages of Real-Time Reporting*—In actual practice, many end users request real-time reporting of soil gas data obtained from field-based laboratories. Presentation of such data presents the opportunity for misunderstanding by end users who are not familiar with the caveats presented by data not examined in light of the QA/QC program or site specific factors. Real-time reporting of soil gas data is therefore not recommended.

8. Keywords

8.1 contaminant; environmental monitoring; geochemistry; ground water; Henry's law; petroleum hydrocarbon; sampling; soil gas; unsaturated flow; vadose zone; vapor monitoring; volatile organic compound

TABLE 4 Summary of Suggested Calibration and Quality Control Requirements for Analytical Systems[A]

Type of Instrument	Detector Type	Type of Calibration/QC Test	Frequency	Gas Standard(s)	Acceptance Criteria	Corrective Action
Portable VOC (THC) Analyzer	FID	(1) Multipoint calibration (zero plus three upscale concentrations)	At start of program	Methane or other aliphatic compound	Correlation coefficient ≥ 0.995	Repeat multipoint calibration after checking calibration dilution system
		(2) Zero (span) calibration	Daily	UHP Air or N_2/Methane	Response factor agreement within ± 20 % of mean RF for multipoint calibration	(1) Repeat zero span calibration (2) If still unacceptable, repeat multipoint calibration
		(3) Control sample analysis	Daily, prior to testing	Methane	Measured concentration within ± 10 % of certified concentration	(1) Repeat zero span calibration (2) Repeat control sample analysis
		(4) Drift check	Daily, at conclusion of testing	Methane	Drift value ≤ 20 % of the input value	(1) Flag day's data as questionable (2) Repair or discontinue use of analyzer
	PID	(1) Multipoint calibration (zero plus three upscale concentrations)	At start of program	Benzene or other aromatic compound	Correlation coefficient ≥ 0.995	Repeat multipoint calibration after checking calibration dilution system
	PID	(2) Zero/span calibration	Daily	Benzene or other aromatic compound	Response factor agreement within ± 20 % of mean RF for multipoint calibration	(1) Repeat zero/span calibration (2) If still unacceptable, repeat multipoint calibration
		(3) Control sample analysis	Daily, prior to testing	Benzene or other aromatic compound	Measured concentration within ± 10 % of certified concentration	(1) Repeat zero/span calibration (2) Repeat control sample analysis
		(4) Drift check	Daily, at conclusion of testing	Benzene or other aromatic compound	Drift ≤ 20 % of the input value	(1) Flag day's data as questionable (2) Repair or discontinue use of analyzer
Portable Gas Chromatograph	FID	(1) Multipoint calibration (zero plus three upscale concentrations)	At start of program	Benzene or toluene	Correlation coefficient ≥ 0.995	Repeat multipoint calibration after checking calibration dilution system
		(2) Zero/span calibration	Daily	UHP air or N_2/methane	Response factor agreement within ± 20 % of mean RF for multipoint calibration	(1) Repeat zero/span calibration (2) If still unacceptable, repeat multipoint calibration
	FID	(3) Control sample analysis	Daily, prior to testing	Benzene	Measured concentration within ± 10 % of certified concentration	(1) Repeat zero/span calibration (2) Repeat control sample analysis
		(4) Drift check	Daily, at conclusion of testing	Benzene	Drift ≤ 20 % of the input value	(1) Flag day's data as questionable (2) Repair or discontinue use of analyzer
		(5) Retention time checks	Daily	Benzene or toluene	None	None
		(6) Analytical blanks	Daily	UHP air or N_2	Measured concentration ≤ 5 % of the instrument span value	Clean/replace system components until acceptable blank can be obtained
		(7) Sampling system blanks	Daily, plus after very high samples	Sample gas	Measured concentration ≤ 5 % of the instrument span value	Clean/replace system components until acceptable blank can be obtained
	FID	(8) Duplicate samples	10 % of sampling points, minimum	Sample gas	None; provides a measure of total sampling variability	None
		(9) Control point samples	After every ten samples or once per day, whichever is greater	Sample gas	None; provides a measure of temporal variability	None
		(10) Background samples	One sample per day	Sample gas	None; provides a measure of background concentration	None
	PID	(1) Multipoint calibration (zero plus three upscale concentrations)	At start of program	Benzene or toluene	Correlation coefficient ≥ 0.995	Repeat multipoint calibration after checking calibration dilution system
		(2) Zero span calibration	Daily	UHP air or N_2/methane	Response factor agreement within ± 20 % of mean RF for multipoint calibration	(1) Repeat zero/span calibration (2) If still unacceptable, repeat multipoint calibration

TABLE 4 *Continued*

Type of Instrument	Detector Type	Type of Calibration/QC Test	Frequency	Gas Standard(s)	Acceptance Criteria	Corrective Action
	PID	(3) Control sample analysis	Daily, prior to testing	Benzene	Measured concentration within ± 10 % of certified concentration	(1) Repeat zero/span calibration (2) Repeat control sample analysis
		(4) Drift check	Daily, at conclusion of testing	Benzene	Drift ≤ 20 % of the input value	(1) Flag day's data as questionable (2) Repair or discontinue use of analyzer
		(5) Retention time checks	Daily	Benzene or toluene	None	None
		(6) Analytical blanks	Daily	UHP air or N_2	Measured concentration ≤ 5 % of the instrument span value	Clean/replace system components until acceptable blank can be obtained
		(7) Sampling system blanks	Daily (plus after very high samples)	Sample gas	Measured concentration ≤ 5 % of the instrument span value	Clean/replace system components until acceptable blank can be obtained
		(8) Duplicate samples	10 % of sampling points, minimum	Sample gas	None; provides a measure of total sampling variability	None
	PID	(9) Control point samples	After every ten samples or once per day, whichever is greater	Sample gas	None; provides a measure of temporal variability	None
		(10) Background samples	One sample per day	Sample gas	None; provides a measure of background concentration	None
Off-site Gas Chromatograph	FID	(1) Multipoint calibration (zero plus three upscale concentrations)	1 per month	Propane/hexane	Correlation coefficient ≥ 0.995	Repeat linearity check
		(2) Single point calibration check	Daily, prior to sample analyses	Propane/hexane	Response factor agreement within ± 20 % of most recent average RFs for multipoint calibration	Repeat single point calibration
		(3) Retention time check	Daily, prior to sample analyses	Multicomponent standard	Agreement with preestablished relative retention times	Adjust GC conditions and repeat RT check
	FID	(4) Control sample analysis	Daily, prior to sample analyses	Sample gas	(1) Correct identification of 90 % of components (2) For 90 % of components, measured concentrations within ± 30 % of actual concentrations	Repeat control sample analysis
		(5) Duplicate analyses	Minimum 10 % of samples (all duplicate samples will be analyzed in duplicate)	Sample gas	CV ≤ 20 % for ten major sample components	Repeat sample analysis
		(6) Blank analysis	Daily, prior to sample analysis	UHP air or N_2	Total ≤ 20 ppbv-C	(1) Clean system (2) Repeat blank analysis
	PID	(1) Multipoint calibration (zero plus three upscale concentrations)	1 per month	Propane/hexane	Correlation coefficient ≥ 0.995	Repeat linearity check
	PID	(2) Single point calibration check	Daily, prior to sample analyses	Propane/hexane	Response factor agreement within ± 20 % of most recent average RFs for multipoint calibrations	Repeat single point calibration
		(3) Retention time check	Daily, prior to sample analyses	Multicomponent standard	Agreement with preestablished relative retention times	Adjust QC conditions and repeat RT check
		(4) Control sample analysis	Daily, prior to control sample analyses	Sample gas	(1) Correct identification of 90 % of components (2) For 90 % of components, measured concentrations within ± 30 % of actual concentrations	Repeat control sample analysis
		(5) Duplicate analyses	Minimum 10 % of samples (Duplicate samples analyzed in duplicate)	Sample gas	CV ≤ 20 % for ten major sample components	Repeat sample analysis
	PID	(6) Blank analysis	Daily, prior to sample analysis	UHP air or N_2	Total ≤ 20 ppbv-C	(1) Clean system (2) Repeat blank analysis

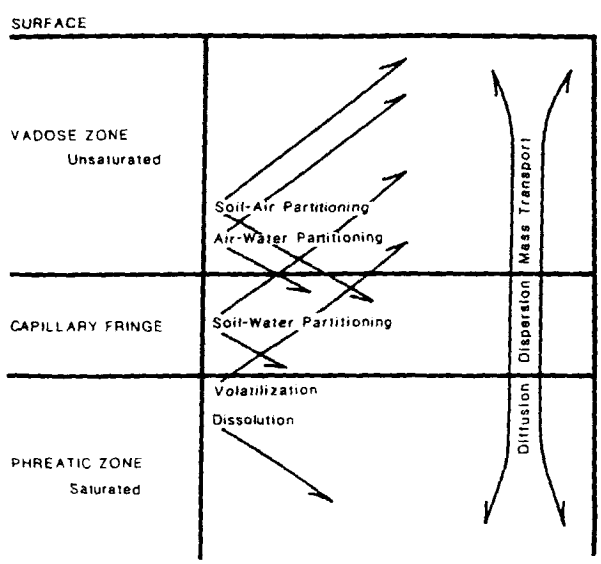
TABLE 4 *Continued*

Type of Instrument	Detector Type	Type of Calibration/QC Test	Frequency	Gas Standard(s)	Acceptance Criteria	Corrective Action
	ECD	(1) Quantitative standard	Daily, prior to sample analysis	Multicomponent standard	Response factor agreement within ± 30 % of three day rolling mean RFs for all components	Repeat calibration
		(2) Retention time check	Daily, prior to sample analyses	Multicomponent standard	None, will provide basis for comparison of FID/PID results to ECD results	None
		(3) Control sample analysis	Daily, prior to sample analyses	Sample gas	(1) Correct identification of all components (2) For 90 % of components, measured concentrations within ± 30 % of actual concentrations	Repeat control sample analysis
	ECD	(4) Duplicate analyses	Minimum of 10 % of samples (all duplicate samples analyzed in duplicate)	Sample gas	CV ≤ 20 % for ten major sample components	Repeat sample analysis
		(5) Blank analysis	Daily, prior to sample analyses	UHP air or N_2	Total ≤ 20 ppbv-C	(1) Clean system (2) Repeat blank analysis

[A] See Ref (10).

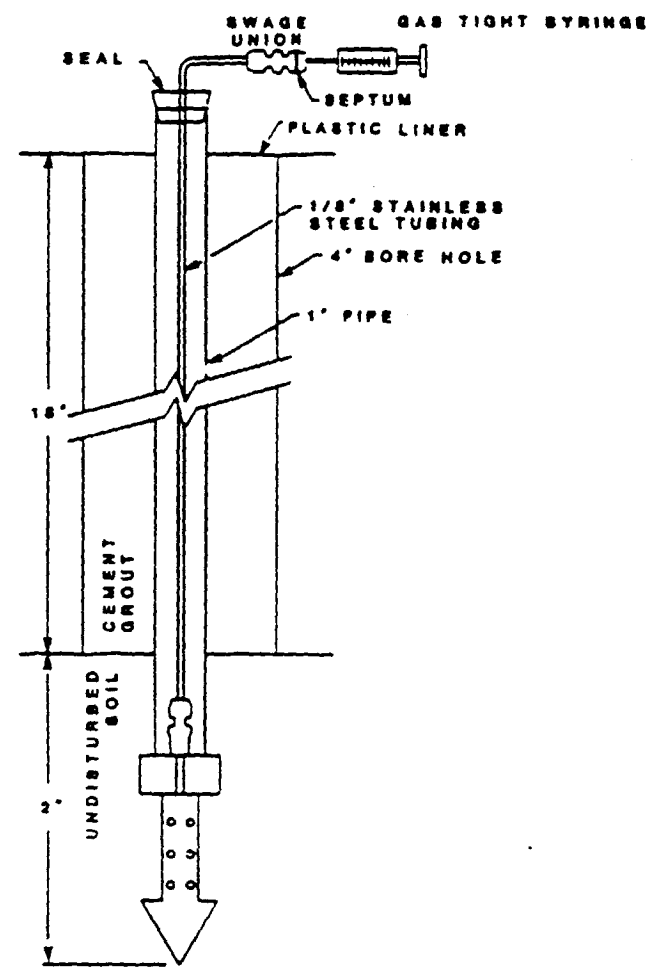
APPENDIX

(Nonmandatory Information)



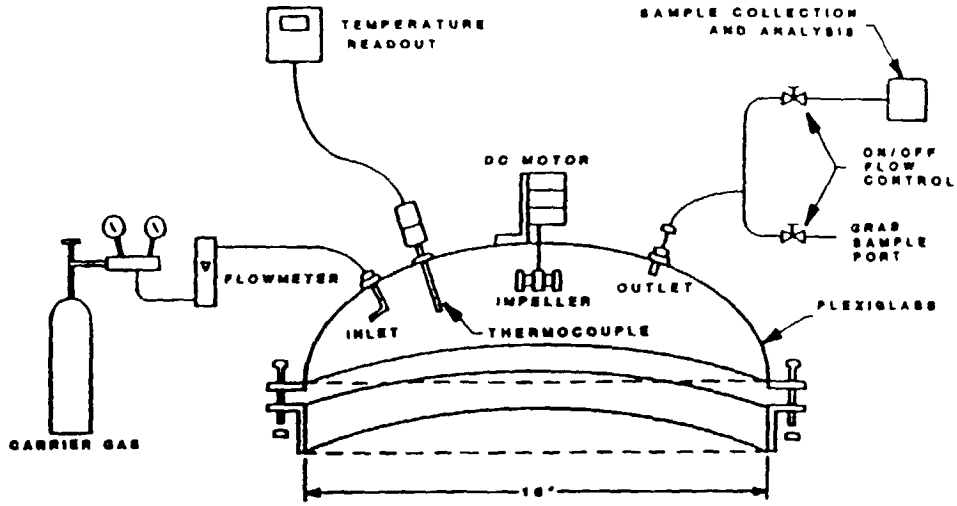
NOTE—The processes indicated by the soil gas monitoring method are partitioning, migration, emplacement and degradation. Partitioning represents a group of processes which control contaminant movement from one physical phase to another, these phases being liquid, free vapor, occluded vapor, solute and sorbed. Migration refers to contaminant movement over distance with any vertical, horizontal or temporal component. Emplacement refers to establishment of contaminant residence in any phase within any residence opportunity. Degradation is the process whereby contaminants are attenuated by oxidation or reduction in the vadose zone, either through biogenic or abiogenic processes. Soil gas monitoring measures the result of the interaction of these processes in a dynamic equilibrium.

FIG. X1.1 Arena of Soil Gas Monitoring



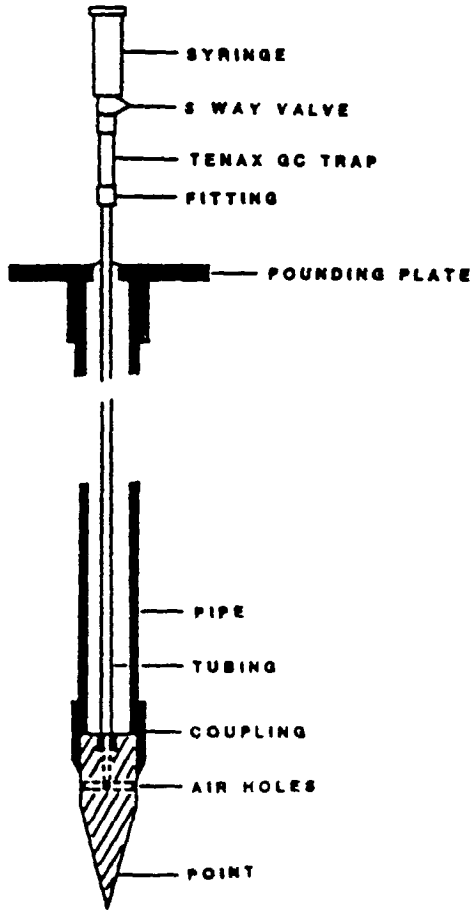
NOTE—Ground probe designed and used by Crow et al., 1985, from Ref (10)

FIG. X1.2 Example of Whole-Air Active Sampling System



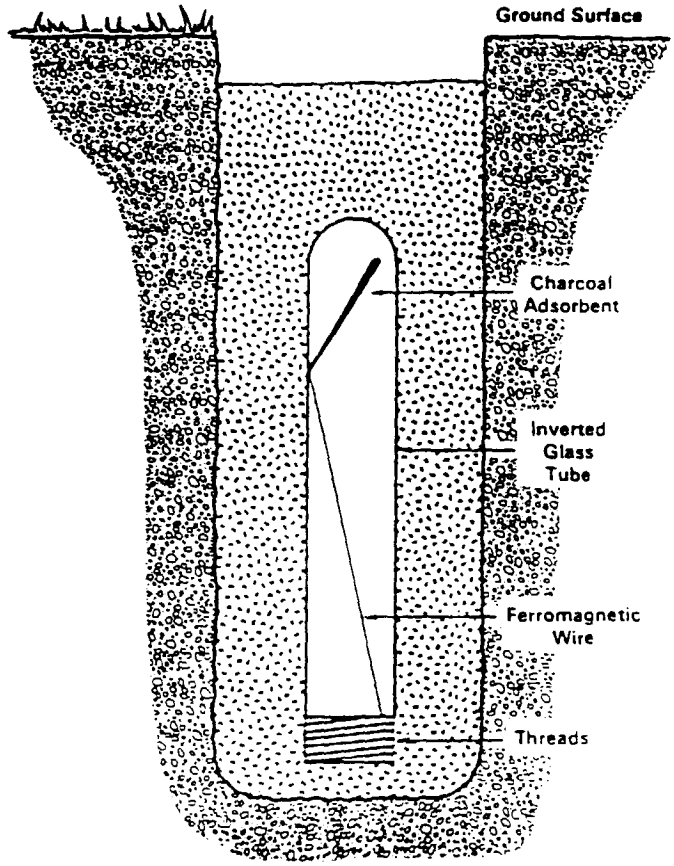
NOTE—Surface flux chamber and peripheral equipment after Eklund et al., 1984, from Ref (**10**).

FIG. X1.3 Example of Whole-Air Passive Sampling System



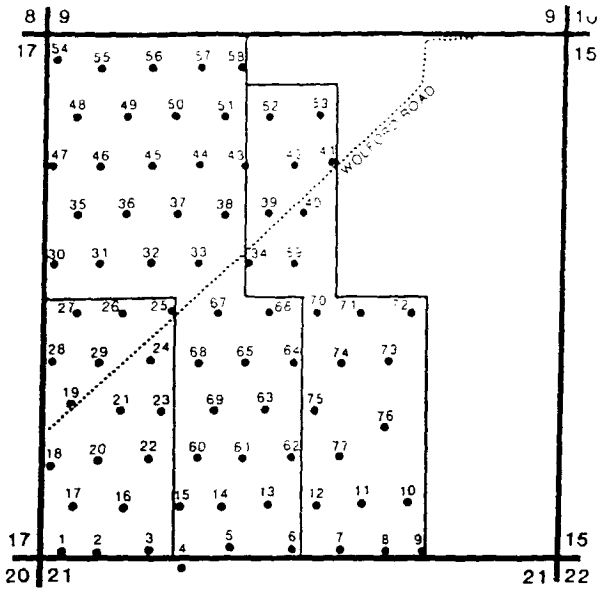
NOTE—Ground probe design used by Swallow and Gachwend, 1983, from Ref (**10**).

FIG. X1.4 Example of Sorbed Contaminant-Active System



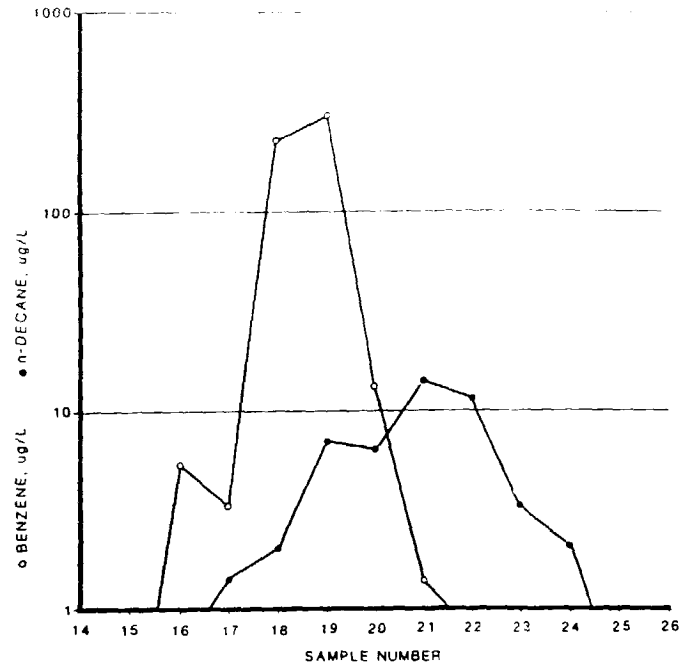
NOTE—Schematic diagram of emplacement of a sorbed contaminant-passive system (**10**).

FIG. X1.5 Example of Sorbed Contaminant-Passive System



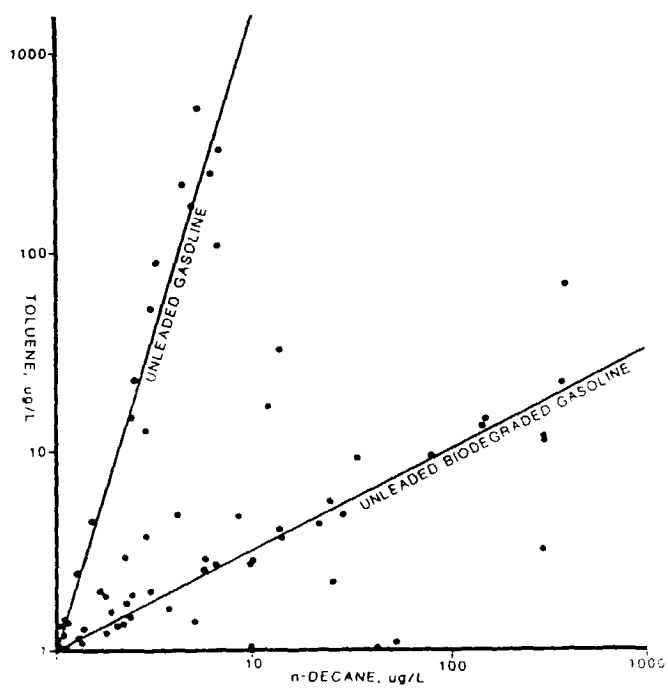
NOTE—In any application, soil gas monitoring can be performed over a wide range of spatial designs, including soil gas sampling in grid patterns at a single depth or multiple depths. This example illustrates a staggered grid pattern of samples recovered at a single depth.

FIG. X1.6 Typical Soil Gas Grid Array and Map Display



NOTE—Soil gas data from survey profiles displayed on an X – Y plot is an effective aid to data interpretation. This display is useful to examine the overall context for soil gas measurement data potentially indicating contamination. If the profile is displayed as a cross section through a grid pattern or as a linear array of sample points, the profile display can illustrate spatially significant groupings of data subpopulations.

FIG. X1.7 Typical Soil Gas Profile



NOTE—Bimodal populations of data that represent coincident contaminant occurrences (for example, soil gas contaminant vapors sourced from converging plumes of two different fuels or mixtures of gasoline and biodegraded gasoline) can be defined using compositional analyses. One technique of compositional analysis is cross-plotting as shown.

FIG. X1.8 Soil Gas Compositional Analysis by Cross Plot

Project # _____ Sample # _____

Sampled by: _____

Date Sampled: _____, 199_____ Time: _____ (AM/PM)

Sampling System (check one):

( ) Whole air-active approach
( ) Whole air-passive approach
( ) Sorbed contaminants-active approach
( ) Sorbed contaminants-passive approach
( ) Headspace or extraction approach
( ) Soil pore liquid headspace approach

Sample Type (check one):

( ) Direct field sample
( ) Field blank
( ) Travel blank
( ) Sample container blank
( ) Sample probe blank
( ) Sample replicate

Spiked? _____ with _____ cc of _____

Potential reaction products due to spiking: _____

System purge volume: _____ Volumes purged: _____ Sample volume: _____

Sorbent Device: Installed _____ (AM/PM), _____, 199_____

Recovered _____ (AM/PM), _____, 199_____

Sample container type: _____ Sample container #_____

Integral analyzer: _____ Detector: _____

Analyzer response: _____ (units) _____

Surface conditions (pavement, wet, frost, etc.) _____

Sample depth: _____ Sampling rate: _____

Sample horizon data-visual estimates:

Vadose zone make-up: ( ) Native soil+rock ( ) Fill ( ) Rock

Soil composition: Clay, _____%

Soil organic matter, _____%

Fine granular material, _____%

Coarse granular material, _____%

100 %

Moisture content of sampling horizon (qualitative):

( ) Very ( ) Dry
( ) Slightly ( ) Damp
( ) Moist
( ) Wet

Other characteristics of the sampling horizon:

( ) Free water present ( ) Probable connection to surface macropores
( ) Free product present
( ) Contaminant odors ( ) Indurated
( ) Poor perm. to vapor ( ) Soil discoloration
( ) Near slope or vent ( ) _____

_____
Investigator Signature/Date

_____
Investigator Affiliation

FIG. X1.9 Suggested Soil Gas Sample Data Sheet

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Attachment 2

CH2M HILL STANDARD PROCEDURES FOR LOGGING OF SOIL BORINGS

STANDARD PROCEDURES FOR LOGGING OF SOIL BORINGS

January 1990

CH2M HILL

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Date: January 1990

STANDARD PROCEDURES FOR LOGGING OF SOIL BORINGS

INTRODUCTION

The purpose of this document is to assist CH2M HILL staff in accurately recording and presenting all field data that are necessary to sufficiently describe, label, and package soil samples recovered from borings. Adherence to a standard format for recording data will help streamline our project efforts and ensure a consistent presentation of subsurface data.

All CH2M HILL staff members are encouraged to present their suggestions for clarification or improvements to these procedures. Please submit all suggestions or comments in writing to the Discipline Group Directors of Geotechnical Engineering or Groundwater Resources.

POLICY

This soil boring procedure must be used for all CH2M HILL projects in which soil boring techniques are used during field exploration. These procedures establish 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 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 policy document to achieve minimum acceptable standards required by CH2M HILL.

CH2M HILL Standard Form D1586, the Soil Boring Log Form, must be used on all CH2M HILL projects for field logging (see Figure 1). All heading information must be completely filled out on each log sheet, 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 instructions that follow. 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 in red, initialed, and dated on the field log.

Date: January 1990

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 completed logs 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.

HEADING INFORMATION

Project Number. Use standard region code, contract I.D. (5-digit), and appropriate point number.

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 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." It is important to tie the boring elevation to a recoverable reference point (e.g., fire hydrant, floor slab) if no other elevation data are available. Such points can be picked up later in a site survey and boring elevations can be determined. Or, if no survey is done, at least the relative boring elevation with respect to pertinent project facilities will be known.

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 (if used), and method of drilling (e.g., rotary, hollow-stem auger, air track). Information on the drilling equipment (e.g., CME 55, Mobile B61) is also entered.

Water Level and Date. Enter the depth below ground surface to the static water level in the borehole. Frequent water measurements are recommended. The information should be recorded in the Comments column. If free water is

not encountered during drilling, or cannot 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) 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, 1-S = first sample, split spoon. 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 0.1 foot of soil sample recovered from the sampler. Often, there will be some wash or caved material above the sample; do not include the wash material in the measurement.

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 is recorded as 2-3-4 and (7). The standard penetration test is 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". See the "Standard Penetration Test Procedures" subsection for additional discussion.

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

Comments. Include all pertinent observations (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

(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 following:

- The date and the time drilling began and ended each day
- The depth and size of casing and the method of installation
- The date, time, and depth of water level measurements
- 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. In general, the approach and format for classifying soils should conform 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 that are measured by laboratory tests (ASTM D 2487). It is possible, however, to estimate these values in the field with reasonable accuracy using visual-manual procedures (ASTM D 2488). Also, some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of 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 must be recorded in the Soil Description column for every soil sample collected. The format and order for soil descriptions should be as follows:

1. Soil name (synonymous with ASTM D 2488-84 Group Name) with appropriate modifiers

2. Group symbol

3. Color

4. Moisture content

5. Relative density or consistency

6. Soil structure, mineralogy, or other descriptors

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 should be identical to the ASTM D 2488-84 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 Figure 3, which are from ASTM D 2488-84.

Examples of acceptable soil names are illustrated by the following descriptions:

> 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 visual classification 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 visual classification is SANDY SILT. The gravel portion is not included in the soil 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 2488-84. 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 2488-84.

Interlayered soil should each be described starting with the predominant type. An introductory name, such as "Interlayered Sand and Silt," should be used. 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.

GROUP SYMBOL

The appropriate group symbol from ASTM D 2488-84 (see Figure 3) must be given after each soil name. The group symbol should be placed in parentheses 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 about 10 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.

COLOR

The basic color of a soil, such as brown, gray, or red, must be given. The color term can be modified, if necessary, by adjectives such as light, dark, or mottled. Especially note staining, iron staining, or mottling. This information may be useful to establish water table fluctuations or contamination. As an alternative, consider using the Munsel rock color chart designation.

MOISTURE CONTENT

The degree of moisture present in a soil sample should be defined as dry, moist, or wet. Moisture content can be estimated from the criteria listed on Table 2.

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 3 and 4.

SOIL STRUCTURE, MINERALOGY, AND OTHER DESCRIPTORS

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.

Other descriptors can be included if important for the project or for describing the sample. These include particle size, range and percentages, particular angularity, particle shape, maximum particle size, hardness of large particles, plasticity of fines, dry strength, dilatancy, toughness, reaction to HCl, and cementation.

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.

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.

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-inch O.D., with 1-3/8-inch 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-inch O.D.). A stiffer rod, such as "N" rod (2-5/8-inch 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 must state the number of blows and the fraction of 1 foot penetrated. It is important that the field logger 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 not useful. 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 scriber 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 4 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 4 for labeling and packing details.

FIELD EQUIPMENT CHECKLIST

Table 5 lists equipment and supplies that are necessary or useful for soil boring exploration.

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SFO32/010.50

Date: January 1990

Table 1
EXAMPLE SOIL DESCRIPTIONS

POORLY GRADED SAND (SP), light brown, moist, loose, fine sand size

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

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

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

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

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

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

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

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

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

LEAN CLAY WITH SAND (CL/MH), dark brownish gray, moist, stiff

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

Date: September 13, 1989

Table 2
CRITERIA FOR DESCRIBING MOISTURE CONDITION

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

Table 3
RELATIVE DENSITY OF COARSE-GRAINED SOIL
(Developed from Sowers, 1979)

Blows/Ft	Relative Density	Field Test
0-4	Very loose	Easily penetrated with ½-in. steel rod pushed by hand
5-10	Loose	Easily penetrated with ½-in. steel rod pushed by hand
11-30	Medium	Easily penetrated with ½-in. steel rod driven with 5-lb hammer
31-50	Dense	Penetrated a foot with ½-in. steel rod driven with 5-lb hammer
>50	Very dense	Penetrated only a few inches with ½-in. steel rod driven with 5-lb hammer

Table 4
CONSISTENCY OF FINE-GRAINED SOIL
(Developed from Sowers, 1979)

Blows/Ft	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)	Field Test
<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

Date: September 13, 1989

Table 5
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

CH2M HILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF

SOIL BORING LOG

PROJECT _____ LOCATION _____

ELEVATION _____ DRILLING CONTRACTOR _____

DRILLING METHOD AND EQUIPMENT _____

WATER LEVELS _____ START _____ FINISH _____ LOGGER _____

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	NUMBER AND TYPE	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION

Figure 1
SOIL BORING LOG, FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER	SHEET 1 OF 3
DEN22371.G5	BL-3	

SOIL BORING LOG

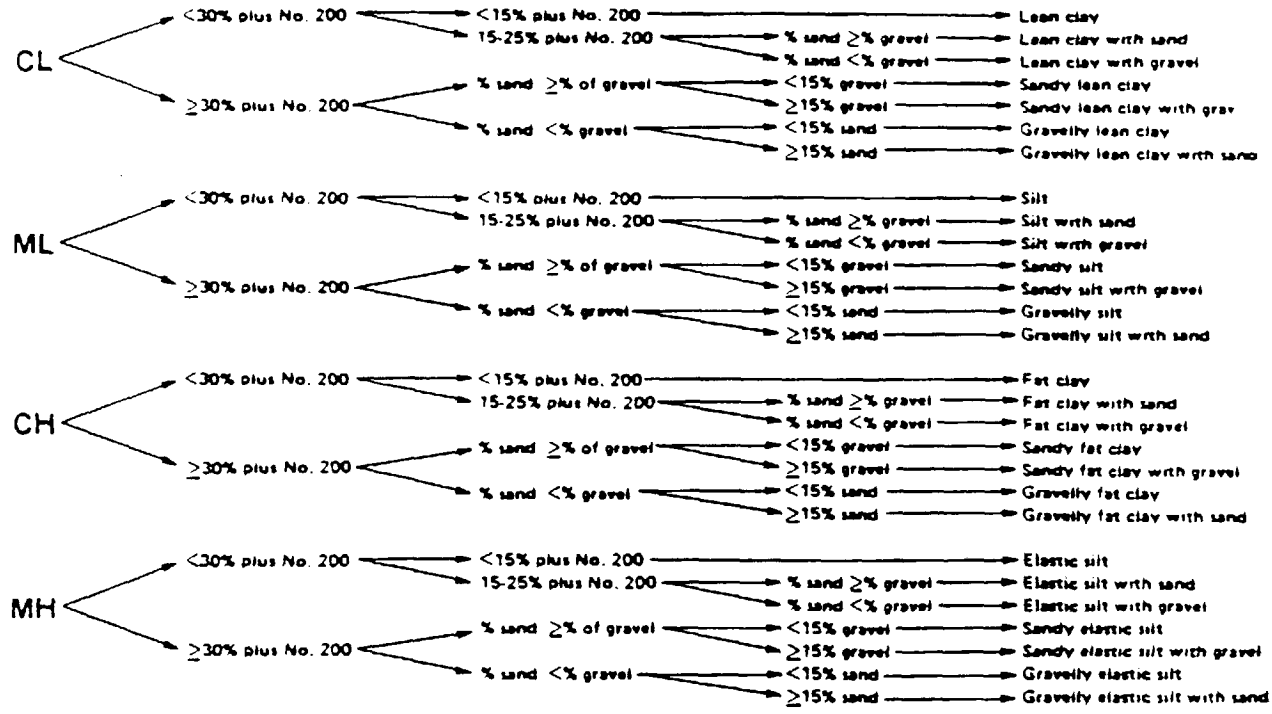
PROJECT Howard Ave Landslide LOCATION Howard & 24th Ave, Centennial, C
ELEVATION 5136 Feet DRILLING CONTRACTOR Kendall Explorations, Ashcan, Colorac
DRILLING METHOD AND EQUIPMENT 4"-inch H.S. Augers, Mobil B-61 rotary drill rig
WATER LEVELS 3.2 Feet, 8/5/89 START August 4, 1989 FINISH August 8, 1989 LOGGER J.A. Michner

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0					Surface material consist of 4 inches AC underlain by 6 inches of 3/4 inch minus base rock	Start Drilling @ 3:00
	2.5					
	4.0	1-S	1.5	2-3-4 (7)	POORLY-GRADED SAND WITH SILT, (SP-SM), fine, light brown, wet, loose	Driller notes water at 4 feet
	5.0					Driller notes very soft drilling 4 ft, dark grey, wet silty cuttings.
5	6.5	2-S	0.9	WOH/12"-1	ORGANIC SILT, (OL), very dark, gray to black, wet, very soft, strong H_2S odor, many fine roots up to about 1/4 inch	
	8.0					
	10.0	3-ST	1.3	———	ORGANIC SILT, similar to 2-S, except includes fewer roots (by volume)	
10	11.5	4-S	1.3	2-2-2 (4)	SILT, (ML), very dark gray to black, wet, soft	
						water level @ 3.2 feet on 8/5/89 @ 0730
						Driller notes rough drilling action and chatter @ 13 ft
	15.0					
15	15.5	5-S	0.5	60/6"	SILTY GRAVEL, (GM), rounded gravel up to about 1 inch maximum observed size, wet, very dense	
	20.0					Driller notes smoother, firm drilling @ 19 ft
20	21.0	6-S	1.0	12-50/6"	LEAN CLAY WITH SAND, (CL), medium to light green, moist, very stiff	some angular rock chips @ bot, top of 6-S, poss boulders or rock
	23.0					Driller notes very hard, slow grinding, smooth drilling action from 21 to 23 ft, possibly bedrock
	23.1	7-S	0	50/1"	NO RECOVERY	
					END SOIL BORING @ 23.1 FEET SEE ROCK CORE LOG FOR CONTINUATION OF BL-3	

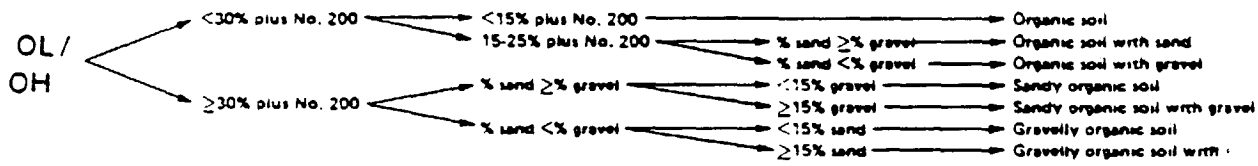
Figure 2
EXAMPLE OF COMPLETED LOG FORM

REV 11/89 FORM D1586

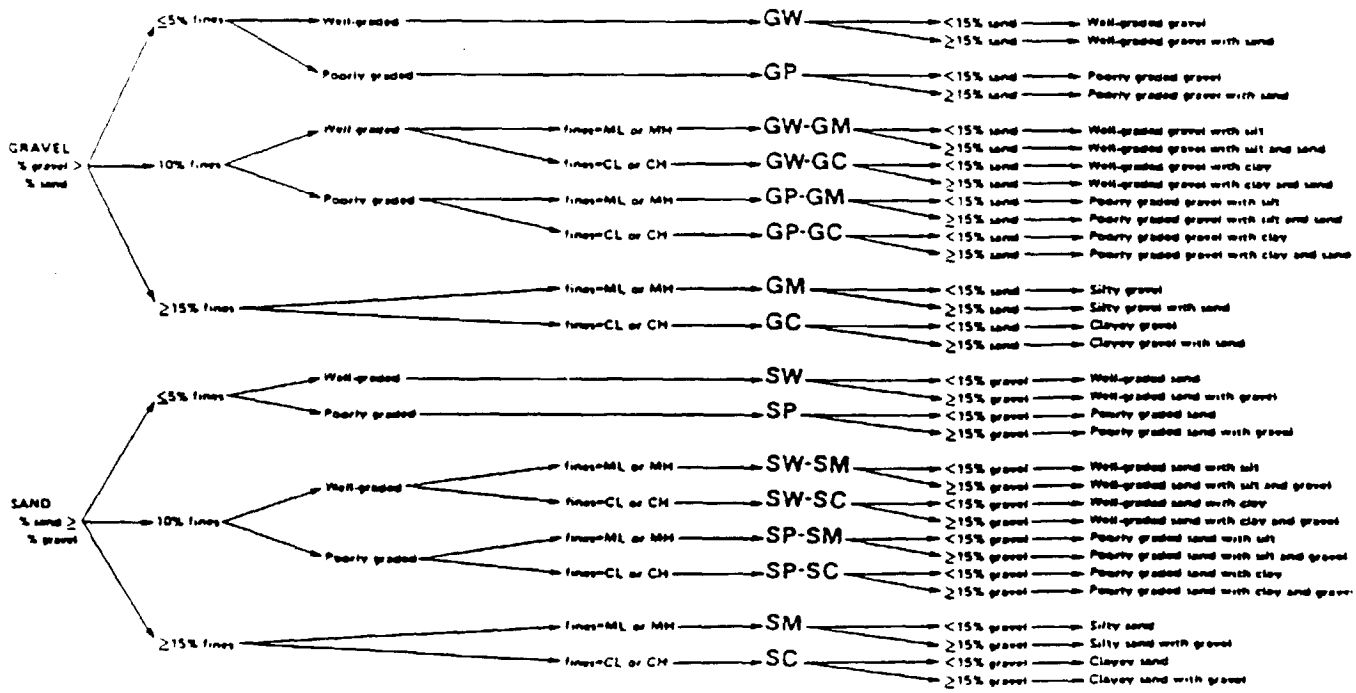
FLOW CHART FOR IDENTIFYING INORGANIC FINE–GRAINED SOIL (50% OR MORE FINES)



FLOW CHART FOR IDENTIFYING ORGANIC FINE–GRAINED SOIL (50% OR MORE FINES)

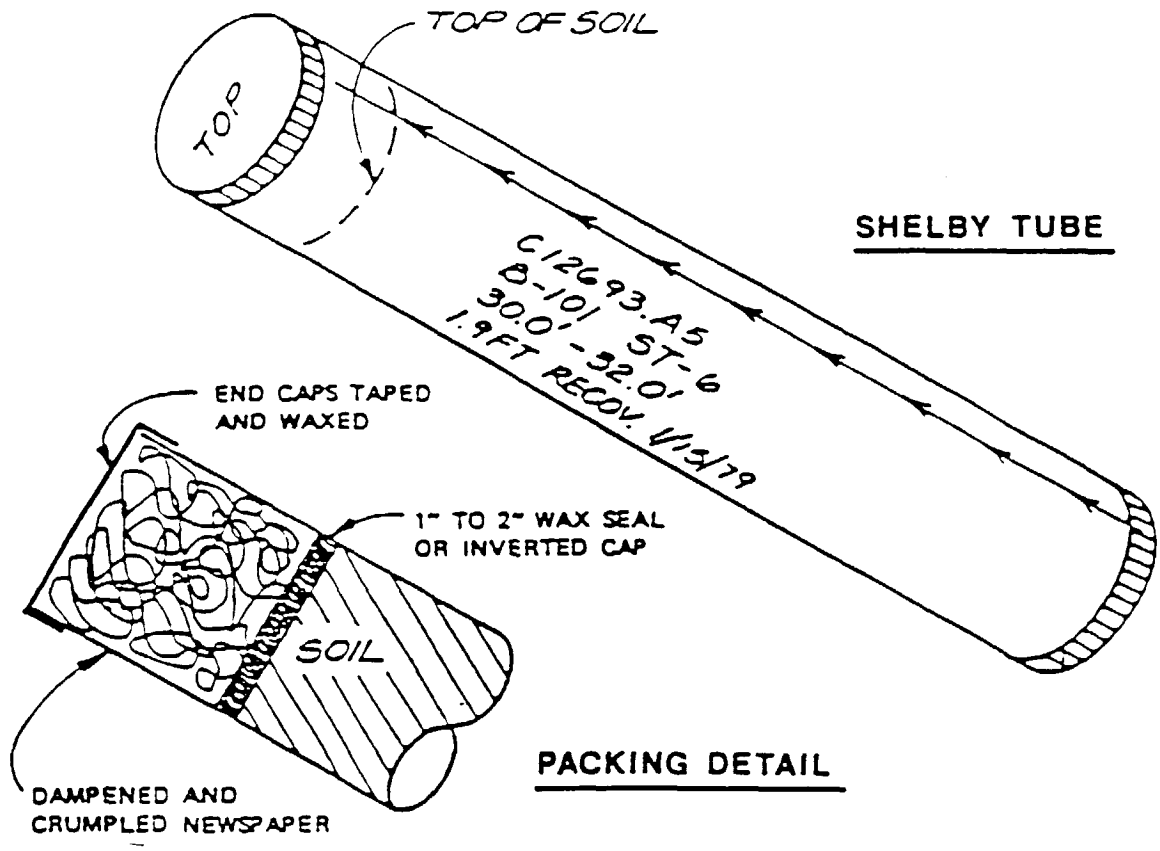


FLOW CHART FOR IDENTIFYING COARSE–GRAINED SOILS (LESS THAN 50% FINES)



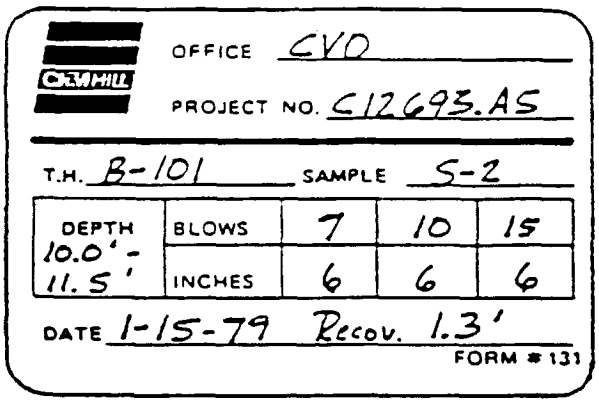
NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

Figure 3
FLOW CHARTS FOR CLASSIFICATION OF FINE–GRAINED AND COARSE–GRAINED SOILS

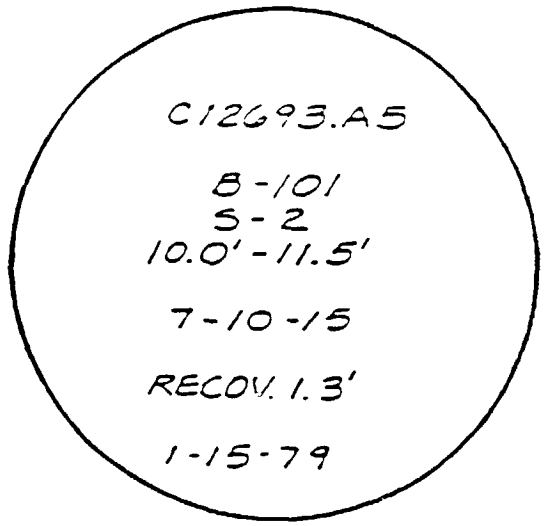


SHELBY TUBE

PACKING DETAIL



SIDE LABEL



LID

JAR SAMPLES

Figure 4
SAMPLE LABELING DETAILS

APPENDIX

Designation: D 2488 - 84[ε1]

Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)[1]

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

[ε1] NOTE—Section 18 was added editorially in January 1989

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils.

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

3. Definitions

3.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 *clay*—soil passing a No. 200 (75-μm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

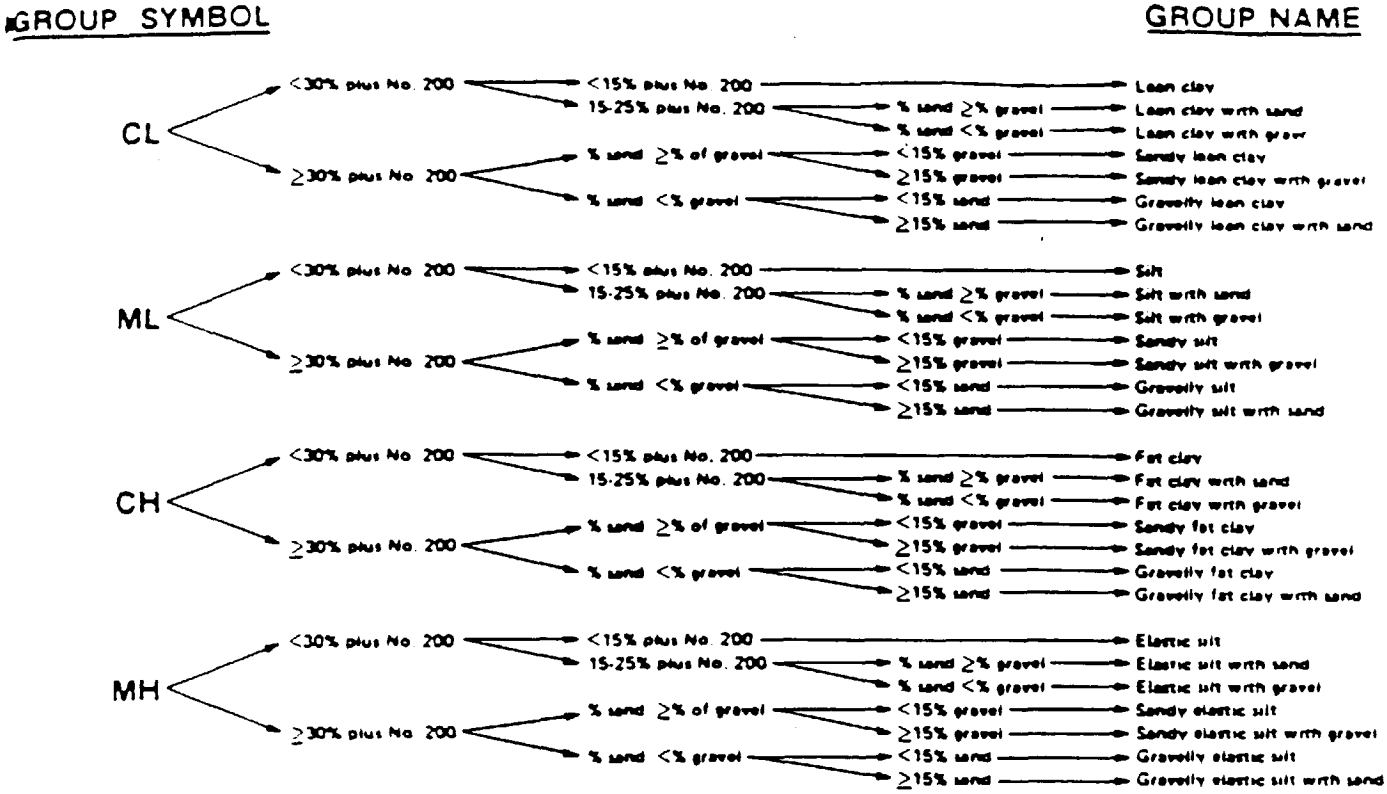
3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Oct. 3, 1984. Published December 1984. Originally published as D 2488 - 66 T. Last previous edition D 2488 - 69 (1975).

[2] *Annual Book of ASTM Standards*, Vol 04.08.



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

fine—passes a No. 40 (425-µm) sieve and is retained on a No. 200 (75-µm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D 2487).

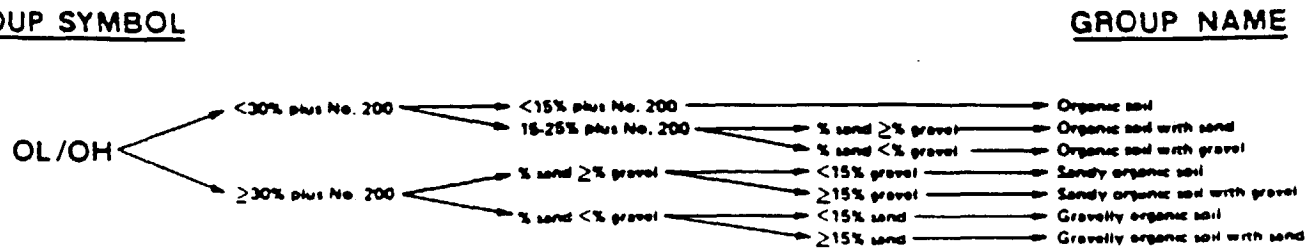
4. Summary of Practice

4.1 Using visual examination and simple manual [illegible] this practice gives standardized criteria and procedur[illegible] describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

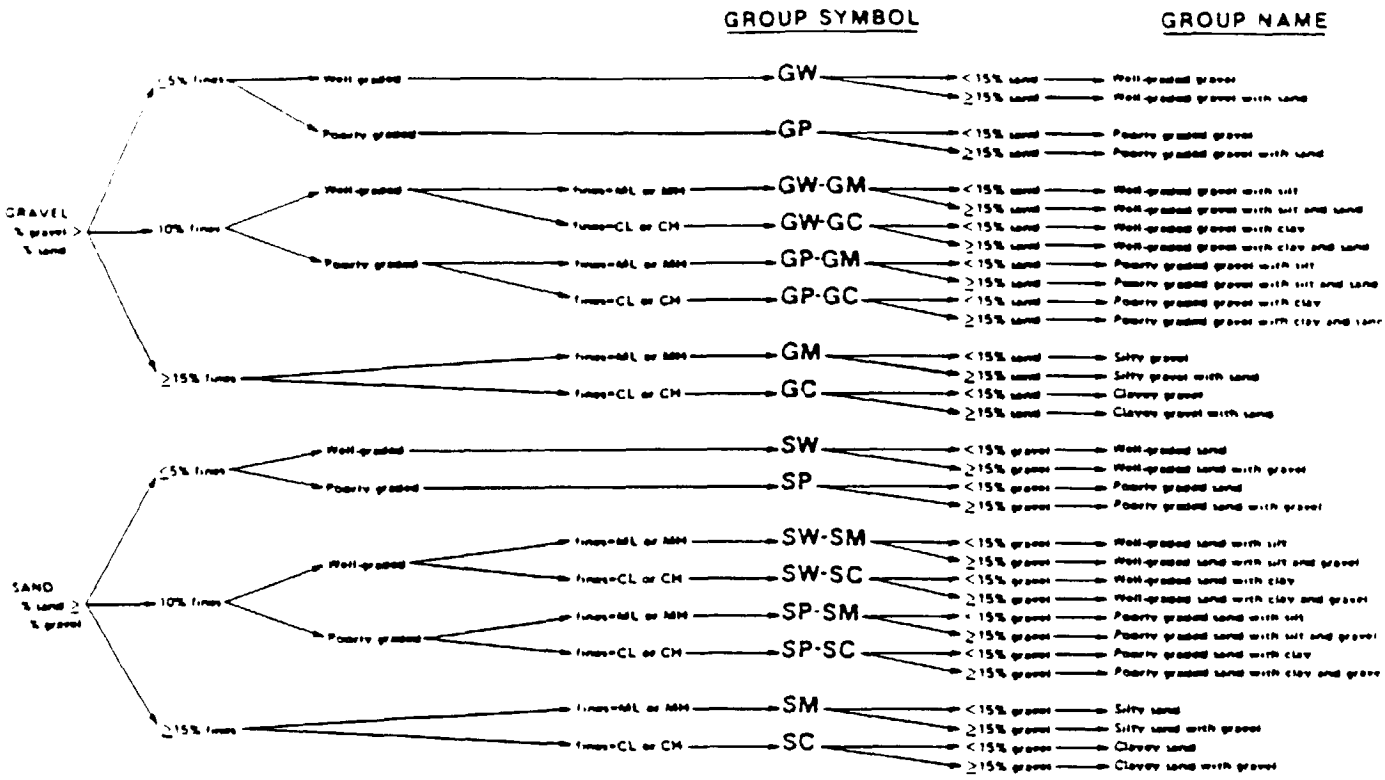
NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

symbols are required when the soil has between 5 and 12 % fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together: one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens.*

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 *N*) to three parts water (This reagent is optional for use with this practice). See Section 8.

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part

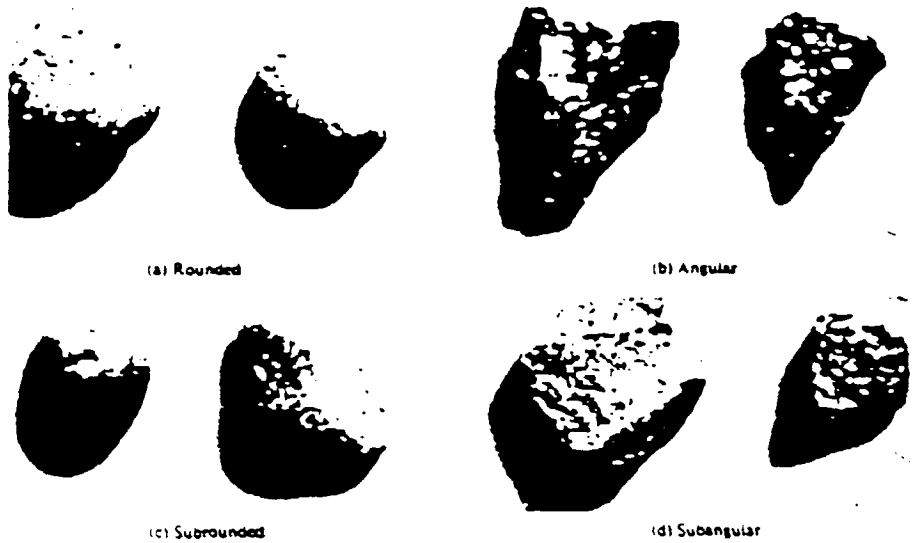


FIG. 3 Typical Angularity of Bulky Grains

concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1 1/2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that significantly larger than the particles in the soil matrix, the soil m[illegible] can be accurately described and identified in accordance w[illegible] preceeding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elo[illegible]

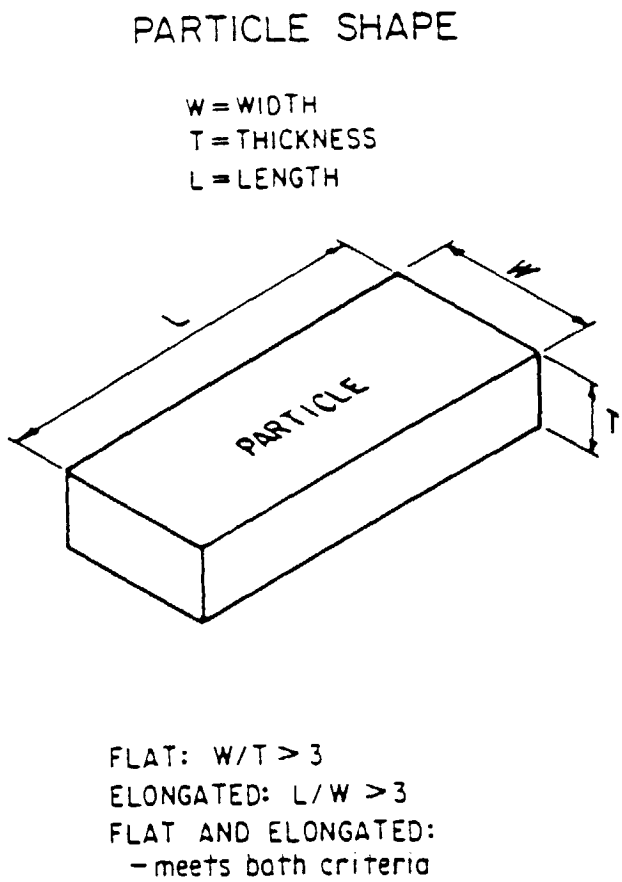


FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the critera in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.7. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 *Dry Strength:*

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy:*

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally,

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness:*

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumble at a diameter of 1/8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils*

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 *Identification of Organic Fine-Grained Soils:*

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

15. **Procedure for Identifying Coarse-Grained Soils** (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification a given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fi ay be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range
   Gravel—fine, coarse
   Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

For intact samples:

18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Index Terms

18.1 Classification, soil classification, visual classification, soil description, clay, silt, sand, gravel, organic soils.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft^3; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incororated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the

percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

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Attachment 3

METHANOL SOIL PRESERVATION PROCEDURES FOR VOCs

Attachment 3

Methanol Soil Preservation Procedures for VOCs

1.0 Sample Collection, Preservation, and Handling

1.1 Aqueous samples should be collected in triplicate (or the number of bottles directed by the laboratory) without agitation and without headspace in contaminant-free glass VOC vials with Teflon-lined septa in the caps. The Teflon liner must contact the sample. Samples must be preserved with 500 uL of 50 percent HCL at the time of collection (acid should be added to the vial prior to adding the sample). Cool samples to 4 degrees Celsius (°C) immediately after collection. Water samples must be held at 4°C and analyzed within 14 days from the date of collection.

1.2 Soil can be collected using a 30 ml plastic syringe with the end sliced off. Other methods of soil collection and methods for estimating the weight of samples can be found in Section 4.2 of the LUST and Petroleum Analytical and Quality Assurance Guidance. Samples cannot be analyzed if the amount of soil in the vial exceeds 20 grams for a 40 ml vial (therefore, 40 ml vials can only be used if a reduced sample size is being used) or 35 grams for a 60 ml vial. A sufficient number of vials (three are recommended) should be collected to provide for backup analyses in the event of breakage and to allow for screening. One vial should be collected for dry weight determination (without methanol). A methanol trip blank must accompany each batch of samples (for each site and each day that samples are collected). Excessive soil handling should be avoided.

Methanol preservation is mandatory for the Modified GRO method and must be noted on the chain of custody. Soil samples that arrive at the laboratory (more than 2 hours after collection) without methanol cannot be analyzed. Flagging data for soil samples not preserved in methanol will not be acceptable. Results from soil samples not preserved in methanol will be rejected. To avoid disturbance of soils and generation of hazardous waste, the following guidelines for sample collection should be followed:

1.2.1 Collect 25 grams of soil in empty (but tared) 60 ml VOC vials, cap them, and place them on ice. Soils may also be collected and stored on ice in the brass tube with metal end caps, the EN CORE sampler, or other equivalent sampling device. (Equivalent devices must be approved by the LUST program chemist). Collecting soils into an intermediate container such as a larger jar or a baggy and subsampling after screening has been done is not acceptable. This

practice allows excessive disturbance of the soil sample. Note: 1) Smaller sample weights may be allowed for GRO samples but a 1:1 ratio of mls methanol to grams soil should be maintained. Samplers should consult their laboratory before making any changes in the soil weight collected; 2) The use of average vial weight in lieu of taring is acceptable as long as the following criteria for quality control are followed:

1. Weigh at least 35 vials to make your estimation of the average weight of the vials.

2. Use no more than two standard deviations as your control limit for vial weights.

3. Check the weight of at least three vials from each new case to be sure that nothing has changed in the manufacturing process and that the vials are still within the control limit you have set. (If any of these vials fall outside of three standard deviations, then weigh at least 10 more vials from that case to ensure that any vial outside the deviations is an outliner.

1.2.2 After screening has been done, those vials that will be sent into the laboratory for analysis will be preserved with methanol. Add methanol only to the vials that will be analyzed by the laboratory. Methanol can be added by one of the following methods:

1.2.2.1 Using premeasured vials provided by the laboratory or a private vendor (containing 25 mls of purge and trap grade methanol), quickly open the soil vial and pour the methanol in, closing the sample vial immediately.

1.2.2.2 Transfer the methanol by syringe from a premeasured septa vial provided by the laboratory or a private vendor (containing 25 mls of purge and trap grade methanol) to the sample vial. A fresh syringe needle will be needed for each new vial to avoid cross contamination. Common laboratory glass syringes and noncoring type syringe needles should be used to perform the transfer.

1.2.2.3 Using a Teflon repeater pipet pump that attaches to a bottle of purge and trap grade methanol and delivers 25 mls of methanol. Quickly open the soil vial and depress the pump to deliver the methanol, closing the sample vial immediately. If this method is used, it is important to make sure that purge and trap grade methanol be used. The methanol in the bottle can become contaminated if stored near any source of volatile fumes. Storage and use of this apparatus must be away from petroleum products and other volatile contaminants.

Addition of methanol must be performed as soon after sample collection as possible. Samples should be returned to an iced cooler immediately after preservation. Samples may be preserved in the laboratoy <u>only if they are received at the laboratory within 2 hours of collection.</u> Sample collection time must be verifiable from the chain of custody for this option to be used. One transfer of methanol from a premeasured vial to an empty (but tared) vial should be performed. This vial will serve as the methanol trip blank. Care must be taken to be sure the vial seals properly (no sand on the threads). This can be accomplished by using a clean toothbrush or other utensil to sweep particles off the threads of the vial. Vials should be shipped in an upright position. It is suggested that vials are also placed in separate ziplock bags to avoid any problems that might occur if a vial leaks (such as the ink being removed from vial labels). Unused vials of methanol may be used at other sites at the sampler's discretion. If sampler's wish to use tared vials that already contain methanol, they are free to do so; however, all samples collected in this fashion must be analyzed by the laboratory or they will be considered hazardous waste.

Vials must not be submitted to the laboratory for analysis of any volatile parameter (GRO, PVOC, VOC) if any of the methanol has spilled in sampling. If the laboratory determines that a vial has leaked, either qualitatively such as a visible reduction of volume, or quantitatively, such as an unusually low weight, then this must be reported (in the comments section of the report). Only the vial that has leaked will be in question, not the entire cooler or shipping package.

Note: Professional judgement should be used in determining how long vials with methanol for preservation (or vials for trip blanks) can be stored. Laboratories may determine the shelf life for these vials if they wish to offer an exact time period for storage to their clients.

Shipping time should be minimized. Samples must be received by the laboratory within 4 days. For more details on soil sampling requirements (including information on safety and shipping), see Section 4.0 of the LUST and Petroleum Analytical and Quality Assurance Guidance. Sample holding time is limited to 14 days from the date of collection. For more information on VOC loss and preservation by methanol, see References 2,11, and 12.

1.3 Sample temperature must be determined upon receipt to the laboratory. If the sample was shipped in ice and solid ice is still present, report the sample as "received on ice." Exact sample temperature need not be reported for samples received on ice. If, however, the sample was cooled using "blue ice" packs, or the ice used in shipping has melted, then the temperature of a "temperature blank" must be reported. If the ice used to ship the sample has melted, the temperature of the melt water may be substituted for a temperature blank. Note: If blue ice packs are used, precooling of samples to 4°C with ice or by refrigeration is necessary.

1.4 The pH of all water samples must be determined unless sample vials containing acid for field preservation were supplied by the laborartory (this should be noted on the chain of custody). The pH measurement may be performed on leftover samples.

Source: Quality Analytical Laboratory, Inc.

Appendix B

MARINE CORPS AIR STATION EL TORO
PHASE II REMEDIAL INVESTIGATION/FEASIBILITY STUDY DRAFT QUALITY ASSURANCE PROJECT PLAN ADDENDUM

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Attachment 5 SiteWorks, Inc. TDGC/MS Methods for Field Analysis of Polychlorinated Biphenyls in Soil Matrices

1.0 PROJECT DESCRIPTION

This addendum addresses the objectives, functional activities, and specific quality assurance (QA) and quality control (QC) activities associated with the soil vapor gas study at Marine Corps Air Station El Toro. This Quality Assurance Project Plan (QAPP) is an addendum to Phase II Remedial Investigation/Feasibility Study QAPP and amends only those sections necessary to provide the specific procedures associated with the soil gas measurements and soil screenings. This addendum follows the same outline as the Phase II QAPP and, where appropriate, references Phase II QAPP and other existing guidelines. The project description is provided in the work plan.

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2.0 DATA QUALITY OBJECTIVES

The overall data quality objectives (DQOs) and the definitions of the QA parameters are as described in Phase II QAPP. This section details the specifics associated with the analytical parameters related to the soil gas survey and the associated soil screenings carried out onsite. The analyses that are sent to offsite laboratories will be per the Phase II QAPP. Table 2-1a lists specific onsite parameters of analyses, specific data uses, and relevant and applicable detection limits. Relevant detection limits are listed as dictated per regulations or user technical needs as for health risk assessment. Applicable detection limits are arrived at by consideration of analytical method limitations, as well as regulatory and technical needs. Table 2-1b further details the detection limits for the soil screening analyses by comparing regulatory, technical, and method detection limits for soil screening analyses. Table 2-1c lists method detection limits for soil gas analyses. VOCs detected during the RI and RFA field investigations in soil or groundwater, but not included in Table 2-1c are: Acetone, bromoform, bromodichloromethane, carbon disulfide, chlorobenzene, chlorodibromomethane, chloromethane, dichlorofluoromethane, styrene, 2-butanone, 2-hexanone, 4-methyl-2-pentanone, 1,1,2,2-perchloroethane, and 1,1,2-trichloro-1,2,2-trifluoroethane. Quantitative DQOs for accuracy and precision are listed in Tables 6-1a and 6-1b. As the field soil analytical methodology is relatively new, unlike offsite analyses, QC limits are based on a limited data set. The QC limits and detection limits will depend on the nature of the collected samples and will be reported based on project-specific field measurements.

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Table 2-1a
Data Uses and Detection Limits
MCAS El Toro Soil Gas Survey

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Compounds to be Analyzed	Matrix	Applicable Sites	Data Use	Data Users	Relevant Detection Limits[a]	Applicable Detection Limits[b]
Volatiles (VOCs)	Subsurface soil (onsite analysis)	24 and 25	• Refine conceptual model screening tool for further investigation • Evaluation of remedial action • Human health risk assessment • Potential impact on groundwater	• Remedial investigation team • Feasibility assessors • Risk assessors	• ARAR based • Health based • Technology based	Method detection limit (MDL)
	Subsurface soil (offsite analysis)	24 and 25	• Verification of onsite soil analysis • Refine conceptual model • Characterization of volatile organic contamination in the shallow vadose zone • Evaluation of remedial action • Human health risk assessment • Potential impact on groundwater	• Remedial investigation team • Feasibility assessors • Risk assessors	• ARAR based • Health based • Technology based	CLP
	Soil gas	24 and 25	• Screening tool for further investigation • Characterization of volatile organic contamination in the shallow vadose zone • Safety Monitoring	• Remedial investigation team	• Technology based	1 ppb
Semivolatiles (SVOCs)	Soil (onsite analysis)	24 and 25	• Refine conceptual model • ARAR comparison • Evaluation of remedial action • Potential impact on groundwater • Human health risk assessment	• Feasibility study assessors • Risk assessors	• ARAR based • Health based	MDL

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Table 2-1a
Data Uses and Detection Limits
MCAS El Toro Soil Gas Survey

Compounds to be Analyzed	Matrix	Applicable Sites	Data Use	Data Users	Relevant Detection Limits[a]	Applicable Detection Limits[b]
	Subsurface soil (offsite analysis)	24 and 25	• Verification of onsite soil analysis • Evaluation of remedial action • Refine conceptual model • Human health risk assessment • Potential impact on groundwater • ARAR comparison	• Feasibility study assessors • Risk assessors	• ARAR based • Health based	CLP
Pesticides/PCBs	Subsurface soil (onsite analysis)	24 and 25	• ARAR comparison • Evaluation of remedial action • Human health risk assessment • Refine conceptual model	• Feasibility study assessors • Risk assessors	• ARAR based • Health based	MDL
	Subsurface soil (offsite analysis)	24 and 25	• Verification of onsite soil analysis • Evaluation of remedial action • Refine conceptual model • Human health risk assessment • ARAR comparison	• Feasibility study assessors • Risk assessors	• ARAR based • Health based	CLP
Fuel Hydrocarbons	Subsurface soil (onsite analysis)	24 and 25	• ARAR comparison • Evaluation of remedial action • Human health risk assessment • Potential impact on groundwater	• Feasibility study assessors • Risk assessors • Regulators	• ARAR based • Health based	MDL
	Subsurface soil (offsite analysis)	24 and 25	• Verification of onsite soil analysis • Evaluation of remedial action • Human health risk assessment • Potential impact on groundwater • ARAR comparison	• Feasibility study assessors • Risk assessors	• ARAR based • Health based	CLP

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Table 2-1a
Data Uses and Detection Limits
MCAS El Toro Soil Gas Survey

Compounds to be Analyzed	Matrix	Applicable Sites	Data Use	Data Users	Relevant Detection Limits[a]	Applicable Detection Limits[b]
	Soil gas	24 and 25	• Screening tool for further investigation • Refine conceptual model • Characterization of petroleum contamination in the shallow vadose zone soils • Evaluation of remedial action • Human health risk assessment • Potential impact on groundwater • Safety monitoring	• Remedial investigation team	• Health based • Technology based	1 ppb

[A]For relevant ARAR and health-based limits, see Tables 2-1b,c
[b]CRDL/CRQL-EPA Contract Laboratory Program defined contract required detection/quantitation limits are provided in Attachment 1. MDL–Method detection limit, see Tables 2-1b, c.

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Table 2-1B
Detection Limits for Organic Analyses of Soil
MCAS El Toro Soil Gas Survey

Chemicals of Interest	Human Health Risk-Based Criteria (a)	Ecological Risk-Based Criteria (b)	EPA CLP Methods		GC/MS Field Screening	
			Method Detection Limit	Contract Required Detection Limit	Semiquantative[d] Method Detection Limit	Quantitative[d] Method Detection Limit
Volatile Organic Compounds (ppb)						
Benzene	2,400	235,000	--	10	1.1	0.9
2-Butanone	480,000	2,306,000	--	10	(c)	(c)
Carbon Tetrachloride	630	--	--	10	2.4	3.7
Chloroform	760	--	--	10	1.6	2.8
1,2-Dichloroethene	110,000	142,000	--	10	2.4	1.9
Ethylbenzene	360,000	1,295,000	--	10	2.7	0.3
Trichloroethene	9,300	149,000	--	10	1.7	1.5
Tetrachloroethene	5,500	--	--	10	3.6	2.5
Xylene (o,m,p)	98,000	1,000,000	--	10	2.8	2.3
Polynuclear Aromatic Hydrocarbons (ppm)						
Benzo(a)anthracene	0.42	26	0.096	0.33	0.30	0.44
Benzo(a)pyrene	0.042	0.01	0.187	0.33	0.36	0.50
Benzo(b)fluoranthene	0.42	533	0.259	0.33	0.36	0.50
Benzo(k)fluoranthene	0.42	960	0.199	0.33	0.36	0.50
Dibenzo(a)anthracene	0.042	--	0.107	0.33	(c)	(c)
Indeno(1,2,3-cdpyrene	0.42	960	0.09	0.33	(c)	(c)
Polychlorinated Biphenyls (ppm)						
PCB-1248	--	--	--	--	(c)	(c)

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Table 2-1B
Detection Limits for Organic Analyses of Soil
MCAS El Toro Soil Gas Survey

Chemicals of Interest	Human Health Risk-Based Criteria (a)	Ecological Risk-Based Criteria (b)	EPA CLP Methods		GC/MS Field Screening	
			Method Detection Limit	Contract Required Detection Limit	Semiquantative[d] Method Detection Limit	Quantitative[d] Method Detection Limit
PCB-1254	--	--	--	--	(c)	(c)
PCB-1260	--	--	--	--	(c)	(c)
Total PCBs	0.040	67	0.018	0.160	2.8	2.6
Pesticides (ppb)						
Dieldrin	19	510	1.495	16	72	157
4′ 4′ DDT	900	3,000	1.943	16	60	31

(a) Criteria based on a residential scenario.
(b) Criteria listed is most conservative of criteria derived for vertebrates, invertebrates, or plants.
(c) Can not be analyzed by this method.
(d) The differences between semiquantitative and quantitative methods are described in Section 6 and Attachment 1.
-- Not established

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Table 2-1c
Analytes for Soil Gas Analysis
MCAS El Toro Soil Gas Survey

Analytes	Method Detection Limit Goal[a] (ug/L)
1,2-dichloroethylene (1,2-DCE)	1.0
Trichloroethylene (TCE)	1.0
Tetrachloroethylene (PCE)	1.0
1,1,1-trichloroethane (1,1,1-TCA)	1.0
1,1,2-trichloroethane (1,1,2-TCA)	1.0
1,1-dichloroethane (1,1-DCA)	1.0
Methylene Chloride (dichloromethane)	1.0
1,1-dichloroethylene (1,1-DCE)	1.0
carbon tetracholoride (CT)	1.0
Chloroform (CF)	1.0
1,2-dichloroethane (1,2-DCA)	1.0
1,2-dichloropropane	1.0
Benzene	1.0
Ethylbenzene	1.0
Toluene	1.0
Meta- and para-xylene	1.0
Ortho-xylene	1.0
Total Fuel Hydrocarbons (TFH)-Diesel/Gasolene	Qualitative Fingerprint

[a]Actual detection limits may be different depending on sample size, instrument performance, and matrix effects.

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3.0 PROJECT ORGANIZATION

Figure 3-1 is an organizational chart of the field personnel. Table 3-1 lists personnel responsibilities/authority and lines of communication.

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FIGURE 3-1
PROJECT ORGANIZATION

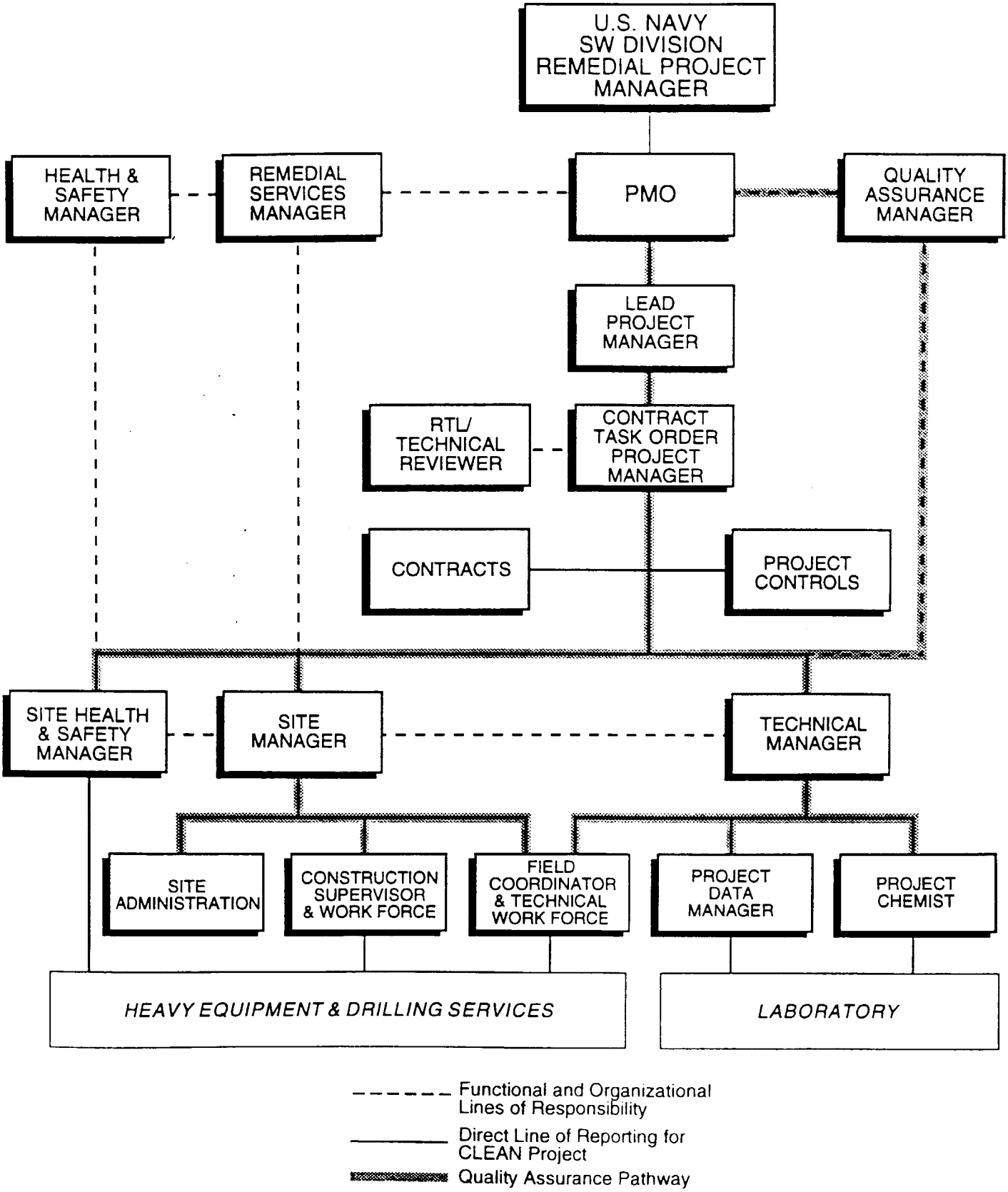

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
Page 1 of 7

Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Remedial Project Manager Andy Piszkin	Code 0181 Navy SW Division	• Project Management from client perspective • Fulfills scope of work • Oversight of cost and schedule • Is lead interface with Agencies	• Direct to Code 0181 Navy SW Division • Direct to PjM • Direct to Agencies
Environmental Health and Safety Manager Dave Smith	Corporate Director Environmental Health and Safety Terry Briggs	• Monitors implementation of Corporate Health and Safety Program • Provides Health and Safety direction guidance and training to the PjM, PMO, and Site Health and Safety Managers • Assigns Site Health and Safety Managers • Approves project Health and Safety Plans • Performs program and project health and safety audits and approves corrective actions	• Direct to PM • Direct to QAM • Direct to Corporate, Director Environmental Health and Safety • Direct to Project Managers • Direct to Site Health and Safety Manager
Remedial Services Manager Mike McClure	Senior VP Construction Maintenance Division Greg Landry	• Monitors implementation of Corporate Construction Management Program • Provides Construction Management direction, guidance, and training to the PjM, PMO, and Site Managers • Assigns Site Managers • Performs Project Site Management Audits and approves corrective actions	• Direct to PM • Direct to QAM • Direct to Senior VP Construction Maintenance Division • Direct to Project Managers • Direct to Site Manager
Quality Assurance Manager Dan Longpre	QA Director Kris Barrett	• Implements the QAMP and actions to document and correct any situation that negatively affects the quality of data or documentation • Stops work, if necessary • Provides QA direction, guidance, and training to the PM, PMO, and auditors • Fosters TQM atmosphere • Develops and maintains QAMP • Reviews and approves CTO QAPPs and CQAPPs • Interfaces with Program Manager, PMO, and Navy on status of the QAMP, quality issues, and corrective action • Reviews and approves modification of SOPs to meet Program needs • Performs Program and project QA audits and approves corrective action plans • Maintains QA audit database and disseminates lessons learned	• Direct to PM • Direct to QA Director • Direct to Navy Quality Management • Direct DPMs • Direct to MTPQC • Direct to Project Managers

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
Page 2 of 7

Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Lead Project Manager John Dolegowski	Deputy Program Manager - Operations Raoul Portillo	• Implements QAMP, QAPP, and CQAPP and other planning document specifications • Attends Lead Project Manager and other PMO meetings to assist in development of Program goals, mechanisms to accomplish goals, and to disseminate lessons learned from all Program work • Acts as focal point with Base Command for all CTO work activities on a Base • Serves as a CTO Project Manager on at least one CTO on Base • Ensures lessons learned are disseminated and consistency of approach amongst all CTOs on a Base • Monitors status of all work conducted and assists CTO Project Managers in resolving problems and ensuring that quality, cost and schedule objectives are met	• Direct to Navy RPM • Direct to DPM Operations • Direct to DPM Project Services • Direct to QAM • Direct to MTPQC
CTO Project Manager John Dolegowski	Deputy Program Manager - Operations Raoul Portillo	• Executes all phases of a specific project and efficiently applies the full resources of the CLEAN I Team • Manages all technical, quality, financial and administrative aspects of the project • Fosters a TQM environment among project personnel • Ensures all technical and administrative SOPs are identified and implemented for consistent completion of work tasks • Identifies and completes planning documents appropriate to work assignments • Approves and maintains qualification records for all project personnel • Orients and trains all project personnel, as required, to complete work assignments • Ensures and verifies that the project team completes all work tasks and QA/QC requirements of planning documents • Logs all variances to planning documents and ensures timely follow-up and approval by the Navy • Ensures that regular QC inspection of work activities is assigned and documented in the Quality Control Inspection Report • Maintains appropriate logbooks to provide complete documentation and defensibility of all project work	• Direct to Lead Project Manager • Direct to Navy RPM • Direct to DPM Operations • Direct to DPM Project Services • Direct to QAM • Direct to MTPQC

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
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Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Review Team Leader/ Technical Reviewer Mike Bitner	Manager Technical Planning and Quality Control Anu Sood	• Leads and coordinates other personnel, and performs technical review of deliverables • Interfaces with MTPQC, project team, and Navy technical branch on technical requirements and coordinates with PjM to implement appropriate actions • Verifies deliverables meet SOW, consistency, agency requirements, sound content, and state-of-the-art technology • Approves and signs deliverables for distribution • Monitors the results of peer, independent, and Navy reveiw of deliverables and comments on project technical performance to asses trends and identify corrective actions	• Direct to MTPQC • Direct to CTO Project Manager • Direct to Navy Remedial Technical Manager • Direct to Project Technical Manager
Contract Administration Manager Karen Freeman	Deputy Program Manager Project Services Margaret Bell	• Provides Project Manager with Federal Contracts (FAR) guidance • Solicits, selects, and awards subcontracts • Administers subcontracts • Coordinates invoice approval and payment	• Direct to DPM Project Services • Direct to Contracts Manager • Direct to CTO Project Manager • Direct to Subcontractors
Project Controls Manager John Green	Manager Project Controls Bob Michell	• Provides Project Manager with cost/schedule guidance • Conducts project tracking • Monitors and schedules reports on cost/schedule status • Conducts estimating and trending • Prepares monthly progress reports to Navy • Assigns Site Managers • Performs Project Site Management Audits and approves corrective actions	• Direct to DPM Project Services • Direct to Manager Project Controls • Direct to CTO Project Manager
Site Health and Safety Manager Carl Wilson	Environmental Health and Safety Manager Dave Smith	• Provides Project Manager with Health and Safety guidance • Prepares Health and Safety Plans • Conducts personnel Health and Safety training and quidance to subcontractors • Reviews and audits field activities to ensure compliance	• Direct to Environmental Health and Safety Manager • Direct to CTO Project Manager • Direct to Technical Manager • Direct to Site Manager • Direct to Subcontractors

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
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Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Site Manager Mark Schnell	Remedial Services Manager Mike McClure	• Organizes and maintains field office, supporting guidance/planning materials, SOPs, records/filing system and control of logbooks • Implements field activities and coordinates field personnel • Coordinates with the Project Manager on the assignment and implementation of "first level" QC inspection of field work activities • Reviews and approves "first level" Quality Control Inspection Reports and conducts regular spot inspections of work activities • Acts as focal point with Technical Manager for coordinating audits by the QAM and reviewing, evaluating, and resolving non-conforming items and other quality issues • Monitors subcontractor performance • Develops and monitors the execution of detailed work schedules • Supervises work and personnel to comply with Jacobs, federal, state and local regulations • Implements all relevant Health and Safety requirements • Coordinates emergency procedure training • Oversees Government property in the field • Maintains client relations and reports	• Direct to Remedial Services Manager • Direct to CTO Project Manager • Direct with client at field level (RPM, ROICC) • Direct with QAM • Direct to H&S Manager • Direct to Technical Manager
Technical Manager John Lovenburg	CTO Project Manager TBD Raoul Portillo	• Acts as focal point for all technical issues on the project • Coordinates the development of the technical approach and design parameters of the project based on the Navy Scope of Work • Identifies project technical staff qualifications and skill level requirements; selects team • Orients and trains project technical personnel in their assigned work tasks • Oversees development of project planning documents to implement the Scope of Work and technical approach • Identifies subcontractor requirements and conducts or coordinates with Contracts Management Group the technical evaluation of bidder capabilities for award of project services • Ensures that all Standard Operating Procedures appropriate to work tasks are used by project personnel • Coordinates with Site Manager on the implementation of planning documents and monitors performanc	• Direct to Lead Project Manager • Direct to Navy RPM • Direct to DPM Operations • Direct to DPM Project Services • Direct to QAM • Direct to MTPQC

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
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Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Technical Manager Lovenburg (Continued)	CTO Project Manager TBD	• Coordinates with Project Manager on the assignment and implementation of "first level" QC inspection of office work • Reviews and approves office "first level" Quality Control Inspection Reports and conducts regular spot inspections of work • Acts as focal point with Site Manager to coordinate audits by the QAM and to review, evaluate, and resolve nonconforming items and other quality issues • Reviews and evaluates project documentation for completeness and defensibility of work • Monitors laboratory analysis data reduction and data management processes to ensure valid, useful data are provided to meet project objectives • Oversees interpretation and reporting of data in deliverables to meet project objectives	
Construction Supervisor Mark Schnell	Site Manager TBD	• Supervises subcontractors and coordinates daily field activities to accomplish scope of work • Oversees subcontractors in compliance with standard construction practices • Conducts or coordinates "first level" QC inspection as assigned by Site Manager • Oversees the maintenance or conducts project logbook documentation of work activities to ensure that documentation is clear, complete, and defensible • Ensures work sites are clean and restored, as appropriate, at end of work • Provides status report to Technical and Site Managers on work progress and field team and subcontractor time, equipment, and supplies used and/or expended • Ensures that Site Manager receives all project logbook documentation of work activities for inclusion in project files	• Direct Site Manager • Direct Field Coordinator • Direct to Contracts Manager • Direct to Technical Manager • Direct to Site Health and Safety Manager

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
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Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Field Coordinator Bill Avolio	Technical Manager and Site Manager TBD	• Supervises the field teams or leads a field team in implementing planning document work tasks assigned by Technical and Site Managers • Ensures that all appropriate logbooks, equipment, and supplies are checked out, calibrated, maintained, accounted, and returned to proper storage, as applicable • Ensures that schedule is maintained to accomplish work assignments • Ensures that standard operating procedures are followed by field team • Supervises subcontractors on technical issues • Ensures that schedule is maintained to accomplish work assignments • Conducts or coordinates "first level" QC inspection as assigned by Technical and Sites Manager • Implements C inspection and /or audit corrective actions • Oversees the maintenance or conducts project logbook documentation of work activities to ensure that documentation is clear, complete, and defensible • Ensures work sites are clean and restored, as appropriate, at end of work • Provides status report to Technical and Site managers on work progress and field team and subcontractor time, equipment, and supplies used and/or expended • Ensures that Site Manager receives all project logbook documentation of work activities for inclusion in project files	• Direct to Technical Manager • Direct to Site Manager • Direct to Construction Supervisor • Direct to Site Health and Safety Manager • Direct to Field Subcontractors
Project Data Manager Manaj Desai	Technical Manager TBD	• Coordinates submission of electronic data with the Project Chemist and subcontract laboratories • Coordinates all field and laboratory data deliverables • Develops project's main database infrastructure and manages the database • Analyzes, designs, and implements the project's field sample data tracking system • Directs and verifies the technical quality of field sample data entry procedures, electronic chain-of-custody forms and sample label generation, and field database exports to other software packages • Conducts in-house training in software environments tools • Implements data security and archival procedures for both paper and electronic data forms	• Direct to Technical Manager • Direct to Project Chemist • Direct to Laboratory and Validation Subcontractors

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Table 3-1

Personnel Responsibilities/ Authority and Lines of Communication
Page 7 of 7

Position/Key Personal	Line Manager	Primary Responsibilities/Authority	Principal Lines of Communication
Project Chemist Artemis Antipas	Technical Manager TBD	• Coordinates certification of analytical results from laboratory with the Project Data Manager • Acts as technical resource to resolve questions concerning analytical results • Verifies that laboratory analysis requests are consistent with project requirements • Evaluates and verifies that all Sample Delivery Groups meet project requirements	• Direct to Technical Manager • Direct to Project Data Manager • Direct to Laboratory and Validation Subcontractors
Drilling Subcontractor TBD	Construction Supervisor TBD	• Provides drilling equipment and qualified operators • Provides groundwater monitoring well supplies, installation, and development • Provides borehole abandonment • Provides waste transportation and disposal	• Direct to Construction Supervisor • Direct to Field Coordinator • Direct to Site Manager • Direct to Technical Manager • Direct to Contracts Manager
Laboratory Subcontractors TBD	Project Data Manager and Project Chemist TBD	• Provides sample collection preservation and storage guidance • Provides sample collection containers • Conducts soil and groundwater sample analysis and reports results	• Direct to Project Data Manager • Direct to Project Chemist • Direct to Technical Manager • Direct to Contracts Manager
Soil Gas Subcontractors	Site Manager and Project Chemist	• Collect soil gas samples • Analyze soil gas samples	• Direct to Project Data Manager • Direct to Project Chemist • Direct to Technical Manager • Direct to Contracts Manager
On-site Laboratory Subcontractors	Site Manager and Project Chemist	• Analyze soil samples	• Direct to Project Data Manager • Direct to Project Chemist • Direct to Technical Manager • Direct to Contracts Manager
Nondestructive Drilling Subcontractors	Site Manager	• Drill holes for utility clearance	• Direct to Project Data Manager • Direct to Project Chemist • Direct to Technical Manager • Direct to Contracts Manager
Concrete Coring Subcontractor	Site Manager	• Core through concrete	• Direct to Project Data Manager • Direct to Project Chemist • Direct to Technical Manager • Direct to Contracts Manager

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4.0 SAMPLE COLLECTION AND QUALITY CONTROL

Sample collection and quality control are detailed in the sampling and analysis plan.

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5.0 SAMPLE CUSTODY

Sample custody will be as described in Phase II QAPP.

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6.0 ANALYTICAL AND QUALITY CONTROL PROCEDURES

6.1 Analytical Procedures

Soil gas volatile organics analyses will be carried out in the field by gas chromatography (GC). The methodology will be based on EPA SW846 8010 and 8020 methodology. The field laboratory QAPP standard operating procedures for Target Environmental are given in Attachments 1 and 2. These procedures will be further detailed on a project-specific basis after the laboratory has been contracted.

Onsite soil sample analyses for organics will be per TD-GC/MS. See Attachment 3 for onsite laboratory vendor QAPP. TD-GC/MS methodology for polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) is given in Attachments 4 and 5. The methodology for volatiles and semivolatiles will be equivalent to PCBs and will be detailed upon contracting the laboratory. The methodology in Attachment 1 describes the quantitative and semiquantitative methods. The difference between the quantitative and semiquantitative is not expected to be significant in terms of accuracy and precision (the authors have indicated approximately 10 to 20 percent difference). The quantitative and semiquantitative methods identify the specific compounds in the same manner. As the semiquantitative method provides significantly higher output, the semiquantitative approach is expected to be used in the field. At least five (out of 40) of the soil samples sent for offsite fixed laboratory confirmation will be analyzed using the quantitative method. The final selection will depend on the initial field analyses after the laboratory has been contracted.

6.2 Calibration Procedures

Calibration procedures have been detailed in Attachment 1.

6.3 Quality Control Procedures

QC procedures for field analyses are shown in Tables 6-1a and 6-1b for volatiles and semivolatiles. The tables also list Contract Laboratory Program and RCRA QC procedures for comparison.

Table 6-1a
QC Requirements for Offsite Laboratory and Field Laboratory VOC Organics Analysis

Requirement	CLP SOW OLM01.8	Quantitative TDGC/MS	RCRA 8240, 8260	Screening TDGC/MS	8010/8020 Modified for Soil Gas GC/ECD/FID
Tuning Frequency Criteria	50 ng BFB 12 hrs See Method	FC-77 Daily See QAPP	50 ng BFB 12 hrs See Method	FC-77 Daily See QAPP	NA
Initial Calibration Maximum %RSD Minimum RRF	5 standards <20.5% 0.01-0.50	5 standards <30%	5 standards CCC <30% SPCC >0.25-0.30	5 standards <40%	3 standards linear regression $r \geq 0.99$
Continuing Calibration Frequency Maximum %D Minimum RRF 1S Area	12 hrs ±25.0% 0.01-1.50 NS	Begin, end of day ±30%	12 hrs CCC±25% SPCC >0.250-0.300 -50+100% of last CC	Begin, end of day ±40% ± 0.4 log units	Begin, end of day Area + 20% of second initial calibration standard
QC Check Sample/LCS Frequency Criteria	Each SDG QC limits	Each SDG ±30%	If MS % recovery not in QC limits QC limits	Depends on DQO ±40%	Same as continuing calibration standard Begin, end of day Area + 20% of second initial calibration standard
Method Blank Frequency Criteria	12 hrs <CRQL	Daily <MDL	12 hrs In control	Daily <MDL	Daily < Reporting Limit (1.0 µg/L)
Spikes Frequency % Recovery	Matrix spike 5% or 1/SDG QC limits	Blank spike and MS/MSD(1) 5% or 1/SDG 80-120%	Matrix spike 5% QC limits	Blank spike and MS/MSD(1) 5% or 1/SDG Depends on DQO	NA
Duplicates Frequency Precision	MS duplicate 5% or 1/SDG RPD Limits	Triplicate 5% <30%	MS duplicate or sample duplicate 5% SD Limits	Triplicate 5% <40%	Replicates 10% + 20%
Sample Analysis Holding Time Internal Standards Criteria	10 days, receipt 3 @50 ug/L Area -50 +100% RT ±sec	10 days, receipt 3 @6.25 ug/L Area -50+100%; RT ±	14 days 3-4 @ 50 ug/L NS	10 days, receipt 1 @ 6.25 ug/L Area -50 +100%; RT±30 sec depends on DQO	10 days, receipt NA
Surrogate Criteria	3 @ 50 ug/L See Method RRT ±0.06	30 sec depends on DQO	3 @ 50 ug/L See Method RRT ±0.06	NA	
Analyte ID	Ions >10% ±20%		Ions >10% ±20%		NA ± 0.05 - 0.12 min

Notes:
- CC = Continuing calibration
- CRQL = Contract required quantitation limit
- MS = Matrix spike
- MSD = Matrix spike duplicate
- %D = Percent difference
- % RSD = % relative standard deviation
- SD = Standard deviation
- SPCC = System performance check compounds
- CCC = Calibration check compounds
- LCS = Laboratory control standard
- NS = Not specified
- RPD = Relative percent difference
- RRT = Relative percent difference
- SDG = Sample delivery group
- NA = Not applicable

CLP SOW and RCRA QA procedures added for comparison purposes only

(1) The subcontractor will be requested to analyze MS/MSD samples. It is not yet known if the TD GC/MS can analyze MS/MSD samples.

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Table 6-1b
Requirements for Laboratory and Field SVOCs
Organics, Pesticides and PCBs Analysis
MCAS El Toro Soil Gas Survey

Requirement	CLP SOW OLM01.8	Quantitative TDGC/MS	RCRA 8270	Screening TDGC/MS
Tuning Frequency Criteria	50 ng DFTPP 12 hrs See Method	FC-77 Daily See QAPP	50 ng DFTPP See Method	FC-77 12 hrs daily See QAPP
Initial Calibration Maximum %RSD Minimum RRF	5 standards <20.5% 0.01-1.30	5 standards <30%	5 standards CCC <30% SPCC >0.050	5 standards <40%
Continuing Calibration Frequency Maximum %D Minimum RRF 1S Area	 12 hrs ±25.0% 0.01-1.30 NS	 Begin/end day ±30% ±0.4 log units	 12 hrs CCC±30% SPCC >0.0.01-1.30 -50+100% of last CC	 Begin/end of day ±40% ± 0.4 log units
QC Check Sample/LCS Frequency Criteria	 Each SDG QC limits	 Each SDG ±30%	 If MS % recovery not in QC limits QC limits	 Depends on DQO ±30%
Method Blank Frequency Criteria	 1 per batch <CRQL	 Daily <MDL	 1 per batch In control	 Daily <MDL
Spikes Frequency % Recovery	Matrix spike 5% or 1/SDG QC limits	Blank spike and MS/MSD(1) 5% or 1/SDG 80-120%	Matrix spike 5% QC limits	Blank spike and MS/MSD(1) depends on DQO 80 to 120%
Duplicates Frequency Precision	MS duplicate 5% or 1/SDG RPD Limits	Triplicate 5% OR 1/sdg <30%	MS or sample dup 5% SD Limits	Triplicate depends on DQO <40%
Sample Analysis Holding Time Water Extraction Soil Extraction Analysis Internal Standards Criteria	 5 days 10 days 35 days from ext. 6 @ 20 ug/L Area -50/100%; RT ±30 sec	 7 days 7 days 30 days from ext. 3 @ 25 ng Area -50/100%; RT ±30 sec	 7 days 14 days 40 days from ext. 6 @ 40 ug/L NS	 7 days from ext. 1 depends on method Area -50/100% RT ±30 sec
Surrogate Criteria Analyte ID	8 @ 100-150 ug/L See Method RRT ±0.06 Ions>10%±20%	Depends on DQO RRT ±0.06 Ions >10% ±20%	6 W 100-200 ug/L See Method RRT ±0.06 Ions >10% ±20%	Depends on DQO RRT ±0.06 Depends on method

Notes:
- CC = Continuing calibration
- CRQL = Contract required quantitation limit
- MS = Matrix spike
- MSD = Matrix spike duplicate
- %D = Percent difference
- % RSD = % relative standard deviation
- SD = Standard deviation
- SPCC = System performance check compounds
- CCC = Calibration check compounds
- LCS = Laboratory control standard
- NS = Not specified
- RPD = Relative percent difference
- RRT = Relative percent difference
- SDG = Sample delivery group
- NA = Not applicable

CLP SOW and RCRA are added for comparison only

(1) The subcontractor will be requested to analyze MS/MSD samples. It is not yet known if the TD GC/MS can analyze MS/MSD samples.

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7.0 DATA QUALITY MANAGEMENT

7.1 Data Reduction, Validation, and Reporting

Data reduction will be per laboratory standard operating procedures (Attachment 1). The data will be reviewed by the onsite laboratory team, as well as a chemist outside the laboratory team. The data services will include the following aspects of the analytical system:

- Calibration procedures
- Accuracy and precision measurements
- Blank measurements
- Compound identification
- Instrument tuning
- Standards measurement

Laboratory deliverables will include electronic diskettes, as well as hard copies. Specific formats will be detailed after contracting of laboratory.

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8.0 QUALITY ASSURANCE OVERSIGHT

Quality assurance oversight will be as discussed in Phase II QAPP.

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Attachment 1

QUALITY ASSURANCE PLAN FOR SOIL GAS SERVICES

A site-specific QAPP for soil gas services will be prepared by the soil gas subcontractor. The site-specific QAPP will be inserted here.

Attachment 2

TARGET ENVIRONMENTAL SOIL GAS STANDARD OPERATING PROCEDURES (SOPs) FOR OPERATING LABORATORY GC

Version 1.1
Revision date: 01/07/93
Approved _____

S.O.P. OPERATING LABORATORY GC

I. Start up of GC (Check gases in cylinder room)

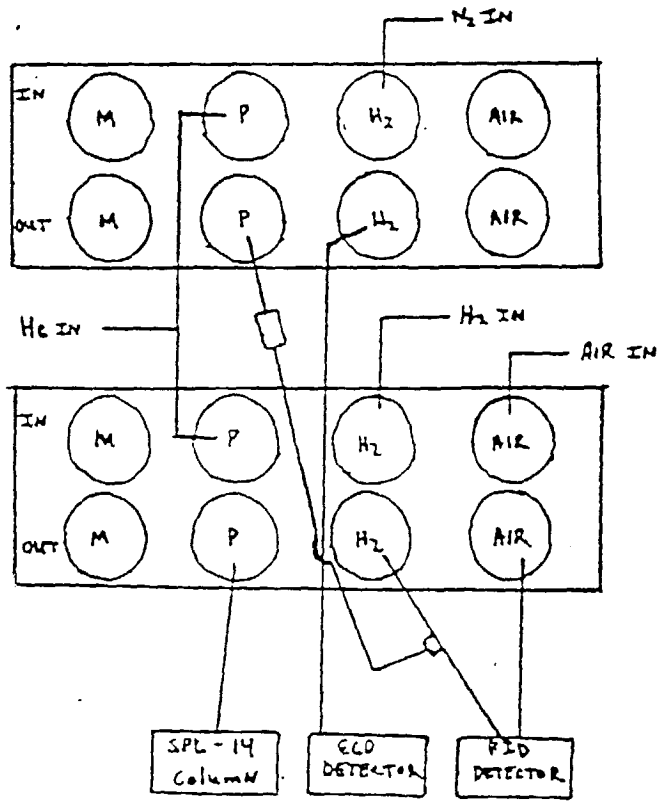
A. Turn on gases by turning main valve to tank and small black knob of regulator. To avoid damage of valves, do not open past resistance.

1. Check gauges on regulators for amount of gas in each tank. The range should be ≈500 psi to 2200 psi. Change tank at 300 psi.

2. The N_2, He, and H_2 regulators should be delivering 80 psi. The Air regulator should be delivering 60 psi.

3. Check top and bottom flow control boxes to see if appropriate gauges are responding (see plumbing diagram).

PLUMBING DIAGRAM PREFERRED WAY
(FID & ECD)
BACK VIEW OF FLOW CONTROL BOXES



4. Snoop for leaks.

5. Measure and adjust if necessary the following gas flows:

Column = 10 mL/min	ECD make up = 40μL/min
Split = 10 mL/min	ECD vent = 50μL/min
Purge = 20 mL/min	H_2 and Air @ .5kg cm^2

B. Light FID

1. Turn hydrogen knob so that it reads 0.8 Kg/cm^2.
2. Press ignite button on bottom flow control box and at the same time light the FID with the ignition wand by placing it in front of the hole in the FID cap.
3. Turn hydrogen down so that it reads 0.5 Kg/cm^2.
4. Check for H_2O vapor by holding a shiny metal object in front of the hole in FID cap.

C. Turn on GC and CR4A (with system disk in Drive 1).

1. Check GC key pad for "CITP XX".
2. Press start once on GC key pad.

D. Inspect GC

1. Change septa every other day (do not over tighten).
2. White switch at the top of the SPL-14 control panel should be in "analysis remote" position and green light above should be off.
3. On FID Electrometer Panel:
   a. Polarity = INJ1
   b. Range 1
   c. FID white button press in ("ON" position)
4. On ECD Electrometer Panel:
   a. Range = 0
   b. Current = 1
   c. ECD white button in
5. Heater (green button next to power on/off switch) pressed on
6. Measure flows on SPL-14 panel
   a. Split vent ≈ 10 mL/min
   b. Purge vent ≈ 20 mL/min
   c. ECD vent ≈ 50 to 55 mL/min on left side of GC

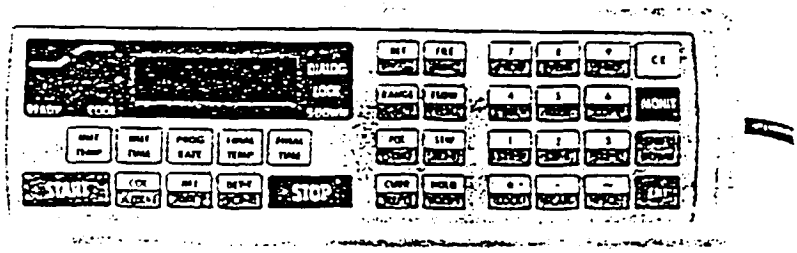
   NOTE: Total ECD vent should not exceed 60 mL/min.
7. Inspect headspace sampler HSS-2B if present
   a. Alignment
   b. Red LED light is out

c. Syringe and needle assembly

E. Temperature programs (GC key pad)

1. Injector temperature = 100°C
   * Press "INJ 1 0 0 ENT"
2. Detector temperature = 300°C
   * Press "DET-T 3 0 0 ENT"
3. For FID analysis only:
   a. Press "INIT TEMP 3 5 ENT"
   b. Press "INIT TIME 0 ENT"
   c. Press "PROG RATE 1 0 ENT"
   d. Press "FINAL TEMP 1 0 0 ENT"
   e. Press "PROG RATE 4 0 ENT"
   f. Press "FINAL TEMP 1 3 0 ENT"
   g. Press "FINAL TIME 2 ENT"
   h. Press "COL INIT TEMP ENT" (This command resets PROG RATE, FINAL TEMP, FINAL TIME to first level.)
   i. Press "MONIT INIT TEMP"
4. For FID and ECD or ECD only:
   a. Press "INIT TEMP 3 5 ENT"
   b. Press "INIT TIME 2 ENT"
   c. Press "PROG RATE 1 0 ENT"
   d. Press "FINAL TEMP 1 1 5 ENT"
   e. Press "FINAL TIME 0 ENT"
   f. Press "PROG RATE 4 0 ENT"
   g. Press "FINAL TEMP 1 4 5 ENT"
   h. Press "FINAL TIME 0 ENT"
   i. Press "COL INIT TEMP ENT" (This command takes you back to initial temp.)
   j. Press "MONIT INIT TEMP"

GC KEY PAD



F. Programming CR4A Chromatopac using CR4A keyboard

1. Press "Set" (F-8)
   a. Select Choice 1 (ENTER) (Setting date, time, & channel)
   b. Year/Month/Day (ENTER)
   c. Time (ENTER)
   d. CH.?
      (1) 1 = FID only
      (2) 2 = ECD only
      (3) 3 = Both FID and ECD *Preferred

```
*** BASIC SETTING ***

 Move cursor to choice or Select NO., then press [↵]
 Select NO.?

  1: Initial set --- Date/Time ,Channel ,Printer
  2: Communication with GC/LC
  3: Load analysis conditions after changing the disk
  4: BASIC Program --- Load,Make,Edit
  5: Auto starting BASIC program --- Make,Edit
  6: Text Files --- Make,Edit,Print
  7: Make,Edit Analysis Files (disk only: to use load by [FILE])
  8: Communication port parameter
  9: Reset Printer (error,page,color ribbon)
 10: [Reserved]
 11: ** EXIT **
```

```
*** INITIAL SETTING ***  for system disk only

  Year/Month/Day                    92/12/22
  Hour:Minutes:Seconds              22:20:29
  Text mode  J:Japanese             E
             E:English
  Channel    1:CH1                  3
             2:CH2
             3:Both
  Printer    0:None                 1
             1:Thermal
             2:Thermal transfer
             3:Color
  Hard copy size  1:Half size       2
                  2:Normal size
                  3:Double size
  Page length (cm)                  0
  Plot width  1:A4(21cm)            2
              2:B4(26cm)
```

NOTE: If HSS is present you may skip step F.2.

2. Press "Set" (F-8) (Establishing link between GC & CR4A)
   a. Select Choice 2 (ENTER)
   b. Port: 1 (ENTER)
      (Result: GC will beep and display "Link OK")
      If no link is established within 15 seconds, turn off the GC and the CR4A and try again. Turn on the GC first.)

```
*** BASIC SETTING ***

 Move cursor to choice or Select NO., then press [↵]
 Select NO.?

  1: Initial set --- Date/Time ,Channel ,Printer
  2: Communication with GC/LC                Port No. :1
  3: Load analysis conditions after changing the disk
  4: BASIC Program --- Load,Make,Edit
  5: Auto starting BASIC program --- Make,Edit
  6: Text Files --- Make,Edit,Print
  7: Make,Edit Analysis Files (disk only: to use load by [FILE])
  8: Communication port parameter
  9: Reset Printer (error,page,color ribbon)
 10: [Reserved]
 11: ** EXIT **
```

3. Saving chromatograms and data

a. For FID only, Press "ANAL" (F-6) and follow the steps listed below.

```
** RE-ANALYSIS , CALIBRATION **

  Move cursor to choice or Select NO., then press [↵]
  Select NO.?  5

    1: Manipulation on CRT --- of last chromatogram
    2: Manipulation on CRT --- of any chromatogram on disk
    3: Re-calculation (without chromatogram) --------- REPEAT
    4: Re-calculation (with chromatogram) ------------ REPEAT ,1
    5: Preset to save N subsequent chromatograms ----- A.SAVE
    6: Reanalysis (File specification required) ------ ANAL
    7: Assign background chromatogram for real-time -- ANAL C
    8: Reset item No.5(A.SAVE) and No.7(ANAL C) ------ ANAL S
    9: Subtraction of chromatogram (chrm.A-chrm.B) --- ANAL "A","B"
   10: Calibration
   11: Exit

Channel No. ? 1
Initial chromatogram No. ? 2:MMMM.C01
How many analyses ? 99
------------------------------------------------------------------------
   ▲D: Delete  ▲I: Insert  ▲X: Cancel
```

```
** RE-ANALYSIS , CALIBRATION **

  Move cursor to choice or Select NO., then press [↵]
  Select NO.?  5

    1: Manipulation on CRT --- of last chromatogram
    2: Manipulation on CRT --- of any chromatogram on disk
    3: Re-calculation (without chromatogram) --------- REPEAT
    4: Re-calculation (with chromatogram) ------------ REPEAT ,1
    5: Preset to save N subsequent chromatograms ----- A.SAVE
    6: Reanalysis (File specification required) ------ ANAL
    7: Assign background chromatogram for real-time -- ANAL C
    8: Reset item No.5(A.SAVE) and No.7(ANAL C) ------ ANAL S
    9: Subtraction of chromatogram (chrm.A-chrm.B) --- ANAL "A","B"
   10: Calibration
   11: Exit

Channel No. ? 2
Initial chromatogram No. ? 1:@CHRM2.C00
How many analyses ? 1
------------------------------------------------------------------------
   ▲D: Delete  ▲I: Insert  ▲X: Cancel
```

b. For DUAL or ECD only, Press "ANAL" (F-6) and follow the steps listed below.

```
** RE-ANALYSIS , CALIBRATION **

  Move cursor to choice or Select NO., then press [↵]
  Select NO.?  5

    1: Manipulation on CRT --- of last chromatogram
    2: Manipulation on CRT --- of any chromatogram on disk
    3: Re-calculation (without chromatogram) --------- REPEAT
    4: Re-calculation (with chromatogram) ------------ REPEAT ,1
    5: Preset to save N subsequent chromatograms ----- A.SAVE
    6: Reanalysis (File specification required) ------ ANAL
    7: Assign background chromatogram for real-time -- ANAL C
    8: Reset item No.5(A.SAVE) and No.7(ANAL C) ------ ANAL S
    9: Subtraction of chromatogram (chrm.A-chrm.B) --- ANAL "A","B"
   10: Calibration
   11: Exit

Channel No. ? 1
Initial chromatogram No. ? 2:MMMMF.C01
How many analyses ? 99
-------------------------------------------------------------------
   ▲D: Delete  ▲I: Insert  ▲X: Cancel

** RE-ANALYSIS , CALIBRATION **

  Move cursor to choice or Select NO., then press [↵]
  Select NO.?  5

    1: Manipulation on CRT --- of last chromatogram
    2: Manipulation on CRT --- of any chromatogram on disk
    3: Re-calculation (without chromatogram) --------- REPEAT
    4: Re-calculation (with chromatogram) ------------ REPEAT ,1
    5: Preset to save N subsequent chromatograms ----- A.SAVE
    6: Reanalysis (File specification required) ------ ANAL
    7: Assign background chromatogram for real-time -- ANAL C
    8: Reset item No.5(A.SAVE) and No.7(ANAL C) ------ ANAL S
    9: Subtraction of chromatogram (chrm.A-chrm.B) --- ANAL "A","B"
   10: Calibration
   11: Exit

Channel No. ? 2
Initial chromatogram No. ? 2:MMMME.C01
How many analyses ? 99
-------------------------------------------------------------------
   ▲D: Delete  ▲I: Insert  ▲X: Cancel
```

4. Press CH 1 "FILE" (F-2) (Selecting analysis file for FID)
   a. Select Choice 1 (ENTER).

```
** Channel No.1 Analysis File **  FILE-1

 Move cursor to choice or Select NO., then press [↵]
 Select NO.?

  1: Load from disk
  2: Display current file and Edit
  3: Make new file or Load from disk & display
  4: List parameters on printer (without option parameters)
  5: List all parameters on printer
  6: Exit
```

   b. Press "HELP" for file names
   c. Choice FID file (1:FILE-1)

```
** Channel No.1 Analysis File **
File name ?

 1:@FILE1.          1:@FILE2.          1:FILE-1.
 1:FILE-2.          1:FILE-3.          1:FILE-4.
```

   d. Press CH 1 "FILE" (F-2)
   e. Select Choice 2 (ENTER).

```
[HELP]:Disk Directory   ^P:Previous file    ^A:ABORT
    ↵:Enter        ^D:Delete        ^I:Insert        ^X:Cancel
** Channel No.1 Analysis File **  FILE-1

 Move cursor to choice or Select NO., then press [↵]
 Select NO.?

  1: Load from disk
  2: Display current file and Edit
  3: Make new file or Load from disk & display
  4: List parameters on printer (without option parameters)
  5: List all parameters on printer
  6: Exit
```

   f. Make appropriate changes to file (highlighted items on next page)
   g. Exit and save.

MCLP - #

(RANGE=1.800uL) .

SSING PARAMETERS

TH (sec)	5	SLOPE (uV/min)	50
FT (uV/min)	50	MIN.AREA (Count)	50
DBL (min)	0	STOP.TM (min)	12
TEN (2^X mV)	1	SPEED (mm/min)	10
ETHOD (0~8)	4	W/B (0:WINDOW 1:BAND)	1
INDOW (%)	5	SPL.WT	100
IS.WT	1	CALIB POINTS (1~8)	3

Due to New FID Source

9/8/97

IME PROGRAM

0.01 ZERO

EVENT PROGRAM

0.01 START 2

IDENTIFICATION TABLE

IDNO	Name	Time	Band	Conc	Factor(1)	Factor(2)
1	ACETONE	1.17	0.05	~~1.1~~ 1.12	0.0357897	-0.864447
				~~1.96~~ 2.01		
				~~5.76~~ 5.88		
2	MTBE	1.73	0.05	~~1.76~~ 1.71	0.0204661	-0.00841326
				~~3.13~~ 3.04		
				~~9.19~~ 8.92		
3	MEK	1.84	0.05	~~1.39~~ 1.41	0.0309488	0.072964
				~~2.48~~ 2.51		
				~~7.28~~ 7.37		
4	BENZENE	2.82	0.05	~~1.51~~ 1.51	0.0133889	-0.256246
				~~2.7~~ 2.69		
				~~7.9~~ 7.90		
5	TOLUENE	4.79	0.05	~~1.8~~ 1.78	0.0187175	-0.322966
				~~3.21~~ 3.18		
				~~9.42~~ 9.32		
6	CHLOROBEN	6.36	0.05	~~2.24~~ 2.18	0.0541178	-0.501512
				~~4~~ 3.59		
				~~11.7~~ 11.39		
7	ETHYLBEN	6.78	0.05	~~2.12~~ 1.0	0.0252052	-0.187662
				~~3.78~~ 2.0		
				~~11.1~~ 10.0		
8	M&P-XYLENE	6.97	0.05	~~4.26~~ 4.03	0.0303873	-0.503153
				~~7.59~~ 7.20		
				~~22.3~~ 21.09		
9	O-XYLENE	7.42	0.05	~~2.18~~ 1.99	0.0311271	-0.323452
				~~3.88~~ 3.55		
				~~11.4~~ 10.40		

OPTION PARAMETERS

PLOT ZERO POSIT (%FS)	10	PLOT CHROMAT (N/Y/REV)	0
X,Y MARKERS(X/Y)	3	MARKER INTERVAL(cm)	2
PLOT START TIME (min)	0	PLOT STOP TIME (min)	12
PLOT LENGTH (cm)	20	BASELINE DRAW	1
PEAK TOP COMMENTS	10	2-CHANNEL PLOT	0
MEM SAMPLING (msec)	500	MAX No. of PEAKS	200
MAX No. of SLICES	0	IDENT (0=AB 1=RR 2=MS)	0
QUANTITATE (0=AR 1=HI)	0	CALIB (0=SP 1=LS 2=ML)	1
2-CH CALC (0=NO. 1~4)	0		

PRINT FORMAT

DATE & TIME	1	NOTES	2
CHROMATOGRAM	3	CALCULATION REPORT	4
GROUP DATA (IDNO)	0	GROUP DATA (NAME)	0
PEAK TIME INFO	0	ANALYSIS FILE	0

5. Press CH 2 "FILE" (F-4) (Selecting analysis file for ECD)
   a. Select choice 1 (ENTER)

```
** Channel No.2 Analysis File ** 1:@FILE2.

Move cursor to choice or Select NO., then press [↵]
Select NO.?

 1: Load from disk
 2: Display current file and Edit
 3: Make new file or Load from disk & display
 4: List parameters on printer (without option parameters)
 5: List all parameters on printer
 6: Exit
```

   b. Press "HELP" for file names
   c. Choose ECD file (1:@FILE2)

```
** Channel No.2 Analysis File **
File name ?

 1:@FILE1.          1:@FILE2.          1:FILE-1.
 1:FILE-2.          1:FILE-3.          1:FILE-4.
```

   d. Press CH 2 "FILE" (F-4)
   e. Select Choice 2 (ENTER)

```
** Channel No.2 Analysis File ** 1:@FILE2.

Move cursor to choice or Select NO., then press [↵]
Select NO.?

 1: Load from disk
 2: Display current file and Edit
 3: Make new file or Load from disk & display
 4: List parameters on printer (without option parameters)
 5: List all parameters on printer
 6: Exit
```

   f. Make appropriate changes to file (highlighted on next two pages)
   g. Exit and save

** ANALYSIS FILE ** 1:@FILE2.

(ECD) MCLP - #

ATTN: 6 (ECD RANGE=0. 500UL)

PROCESSING PARAMETERS

WIDTH (sec)	5	SLOPE (uV/min)	5000
DRIFT (uV/min)	5000	MIN.AREA (Count)	500
T.DBL (min)	0	STOP.TM (min)	12
ATTEN (2^X mV)	6	SPEED (mm/min)	10
METHOD (0~8)	4	W/B (0:WINDOW 1:BAND)	1
WINDOW (%)	5	SPL.WT	100
IS.WT	1	CALIB POINTS (1~5)	3

TIME PROGRAM

0.01 ZERO
2.05 SLOPE=1000
2.5 SLOPE=5000

IDENTIFICATION TABLE

IDNO	Name	Time	Band	Conc	Factor(1)	Factor(2)
1	TCFM	1.13	0.1	0.16 0.32 4.78	5.16886E-7	-0.570056
2	11DCE	1.41	0.05	0.4 0.79 11.86	4.16303E-5	-0.485739
3	CH2CL2	1.69	0.05	0.26 0.52 7.74	0.000250769	-0.203794
4	t12DCE	1.92	0.05	0.46 0.92 13.76	0.000421122	-0.481052
5	11DCA	2.22	0.05	0.47 0.93 14.01	0.000931201	-0.919806
6	C12DCE	2.74	0.05	0.59 1.18 17.7	0.000706149	-0.528538
7	CHLOROFORM	3.01	0.05	0.05 0.1 1.44	4.23225E-6	-0.0669976
8	111TCA	3.25	0.1	0.05 0.09 1.38	1.5722E-6	-0.0650797
9	CARBON TET	3.47	0.12	0.23 0.45 6.8	6.7356E-7	-0.483456
10	TCE	4.35	0.12	0.04 0.09 1.34	3.94285E-6	-0.0725843
11	112TCA	6.39	0.05	0.08 0.16 2.4	0.00002984	-0.0890249
12	PCE	6.68	0.12	0.06 0.12 1.73	1.36808E-6	-0.0873469
13	TECA	9.69	0.05	0.05 0.09 1.36	5.58056E-6	-0.036885

OPTION PARAMETERS

PLOT ZERO POSIT (%FS)	20	PLOT CHROMAT (N/Y/REV)	0
X,Y MARKERS(X/Y)	3	MARKER INTERVAL(cm)	2
PLOT START TIME (min)	0	PLOT STOP TIME (min)	12
PLOT LENGTH (cm)	20	BASELINE DRAW	1
PEAK TOP COMMENTS	10	2-CHANNEL PLOT	0
MEM SAMPLING (msec)	500	MAX No. of PEAKS	200
MAX No. of SLICES	0	IDENT (0=AB 1=RR 2=MS)	0
QUANTITATE (0=AR 1=HI)	0	CALIB (0=SP 1=LS 2=ML)	1
2-CH CALC (0=NO. 1~4)	0		

PRINT FORMAT

DATE & TIME	1	NOTES	2
CHROMATOGRAM	3	CALCULATION REPORT	4
GROUP DATA (IDNO)	0	GROUP DATA (NAME)	0
PEAK TIME INFO	0	ANALYSIS FILE	0
CALIBRATION DATA	5		

G. Initialize Data Disk

1. Press "Exit" to clear CR4A screen
2. For precautionary measures take out system disk from Drive 1
3. Insert Data Disk into Drive 2
4. Type command: IDISK "2:CLEAN (ENTER)
5. "Data on drive 2 will be destroyed: continue? (y/n)". Press "Y" (ENTER).
6. When cursor reappears on screen and disk drive light goes out, IDISK complete (≈ 2 min.)

H. Monitor baselines until they stabilize

1. Press "MONIT" (F-5)

```
CH 1 1:FILE-1 READY                 406.79min     645uV ATTEN= 1 SPEED= 10.0
          404.0                 406.0

CH 2 1:@FILE2 READY                 406.78min   10011uV ATTEN= 6 SPEED= 10.0
          404.0                 406.0

92/12/23 02:55:03        P:PLOT START X:CHANGE SET CH  [MONIT]:PAGING
[EXIT]   S:S.TEST   Z:ZERO   F:FREE          ↑↓:ATTEN    ↔:SPEED
```

II. Standard Preparation

Note: Remove volume from each vial respectively.

A. From Tedlar bag of FID stock standard carefully and precisely:

1. Take 130 µL of stock standard and inject into 30 mL nonevacuated vial and label
2. Take 232 µL of stock standard and inject into 30 mL nonevacuated vial and label
3. Take 680 µL of stock standard and inject into 30 mL nonevacuated vial and label

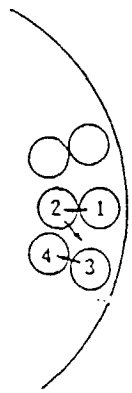
B. From Tedlar bag of ECD stock standard carefully and precisely:

1. Take 1000 µL of stock standard and inject into 30 mL vial that was filled with N_2 and equilibrated to atmospheric pressure and label
2. Take 2000 µL of stock standard and inject into 30 mL vial that was filled with N_2 and equilibrated to atmospheric pressure and label
3. Using ECD transfer needle assembly, insert one end into ECD stock Tedlar bag and place a 30 mL evacuated vial on the other end of the transfer needle. Wait 10 seconds then remove 30 mL vial and label.

III. Load carousel and record in runlog book (Analysis order)

For DUAL analysis:
3 ECD Standards
3 FID Standards
1 N_2 Blank
10 Samples
1 N_2 Blank
10 Samples
1 N_2 Blank
1 ECD Check Standard
1 FID Check Standard
Repeat for every 10th sample analyzed

For FID Analysis only:
3 FID Standards
1 N_2 Blank
10 Samples
1 N_2 Blank
10 Samples
1 N_2 Blank
1 FID Check Standard
Repeat for every 10th sample analyzed



Turn table

IV. Start up of GC HSS System

A. Basic program for HSS (Headspace sampler)

1. Press "Set" (F-8)

2. Choice 4

```
*** BASIC SETTING ***

  Move cursor to choice or Select NO., then press [↵]
  Select NO.?

    1: Initial set --- Date/Time ,Channel ,Printer
    2: Communication with GC/LC
    3: Load analysis conditions after changing the disk
    4: BASIC Program --- Load,Make,Edit
    5: Auto starting BASIC program --- Make,Edit
    6: Text Files --- Make,Edit,Print
    7: Make,Edit Analysis Files (disk only: to use load by [FILE])
    8: Communication port parameter
    9: Reset Printer (error,page,color ribbon)
   10: [Reserved]
   11: ** EXIT **
```

3. Has the program already been loaded ? (1:Yes 2:No) 2

4.
```
BASIC Program file
File name ?

1:HCOPY.B11        1:HSS-2B.B11        1:HSS-2B.J11
1:REPO.V3          1:TARGET.           1:TARGET.STD
1:2CHREP.0         1:CH1LR.STD
```

5. Exit

6. Save to the disk ? (1:Save 2:No) 2

7. Press "RUN" (F-9)

***** HSS-2B V1.1 BASIC PROGRAM START ******
NOW SETTING HSS SEQUENCE PROGRAM. WAIT A MINUTE.

If this doesn't appear in 50 seconds, turn off GC and CR4A and start again.

8. Single mode Choice 1

```
*** SET MENU ***  [DETECTOR--FID]
1  SINGLE MODE
2  MULTI MODE
3  MANUAL MODE
4  TEST MODE
5  DETECTOR
6  END

WHICH ITEM No.? 1
```

9. If FID only use Method 7

```
*** ANALYSIS PARAMETER MENU ***  [DETECTOR-FID]

1  VIAL TEMP        60
2  COND.TIME        4
3  FINAL S.No.      4
4  No. of REPEATS   1
5  COL.INI.TEMP     35
6     INI.TIME      0
7     P.RATE        10
8     FIN.TEMP      100
9     FIN.TIME      0
10 INJ.TEMP         100
11 DET.TEMP         300
12 DET.POL          1
13 DET.RANGE        1
*  14 ANAL.TIME     16
SELECT DESIRED OPTION  (0: NEXT STEP)?
```

10. If FID and ECD or ECD only use Method 8

*** ANALYSIS PARAMETER MENU *** [DETECTOR--FID]

1	VIAL TEMP	60
2	COND.TIME	4
3	FINAL S.No.	4
4	No. of REPEATS	1
5	COL.INI.TEMP	35
6	INI.TIME	2
7	P.RATE	10
8	FIN.TEMP	115
9	FIN.TIME	0
10	INJ.TEMP	100
11	DET.TEMP	300
12	DET.POL	1
13	DET.RANGE	1
* 14	ANAL.TIME	19

SELECT DESIRED OPTION (0: NEXT STEP)?

11. Make sure Data Disk is out of Drive 2 and press 0 return: next step

12. DISPLAY/SET C-R4A PARAMETERS ? (Y:YES / N:NO)
? N

13. PARAMETER SETTING COMPLETED.
CHECK SAMPLE ARRANGEMENT ON TURNTABLE.

INPUT Y TO START HSS SEQUENCE .
? Y

14. Once sequence starts and the analysis parameter menu is displayed on the CR4A screen. Press in Data Disk into Drive 2. Press F-12 to copy the screen (analysis parameters).

15. Press "MONIT" (F-5) to check for the baselines μV's
Ch 1 FID = 300 μV
Ch 2 ECD = 10,000 μV

16. Before first injection, verify settings on GC keyboard. (ie. Method 7 or 8 temp. programs)

V. Calibration of GC

A. I.D. compounds (Refer to FID and ECD chromatograms)
B. Press (F-2)
   1. Select "Choice 2" (ENTER)
   2. Go to I.D. table and press 0
      NOTE: Never delete I.D. table
   3. Update retention times
   4. Exit and save
C. Press (F-6) "ANAL"
   1. Choice 10 CALIBRATION
   2. Select appropriate channel, 1 or 2
   3. Choice 1 "Start calibration"
   4. Number of groups to analyze = 1
D. Press (F-6) "ANAL"
   1. Choice 6 "Re-analyze"
   2. Press "HELP" for file name of chromatogram
   3. Re-analyze first standard
E. Re-analyze second and third standards
   1. Calibration done
   2. Check to see if Factor 1's are positive numbers.

NOTE: If calibrating ECD also, repeat procedures for CH 2 using ECD standards.

VI. Following analysis of repeats and between analysis days, condition columns (The more time the system has to condition, the better it will perform.)

A. Press "COL INIT TEMP 2 0 0 ENT"
B. Press "DET-T 3 4 5 ENT"

WARNING: TO AVOID DESTRUCTION OF COLUMNS ($1,000) HELIUM MUST ALWAYS BE FLOWING THROUGH GC WHILE GC IS "ON". TO AVOID DAMAGE TO ECD CELL ($2,000), NITROGEN MUST ALWAYS BE FLOWING WHILE GC IS "ON". HELIUM MUST ALWAYS BE FLOWING THROUGH GC WHILE TRAVELING.

VII. QA/QC Procedures (QA/QC forms Appendix 2)

A. Linear regression check on calculator (acceptable limit .99) or Linear Regression Program (this program will automatically re-analyze standards)
B. Save analysis files to Data Disk
   1. Remove system disk from Drive 1
   2. Insert Data Disk into Drive 1

3. Press (F-2)
4. Choice 2 ENTER
5. Press (F-13) "EXIT"
6. Save choice 1
7. Press (F-4)
8. Choice 2 ENTER
9. Press (F-13) "EXIT"
10. Save choice 1
11. Re-analyze standards to give numerical values (concentrations)

C. Error in peaks (represented by the letter "E" in the calculation report) must be injected at different range

D. Samples are to be recorded in runlog book and also must have proper chain of custodies

E. Calibration check chart

F. Make hard copies of analysis files (print)
1. Press (F-2)
2. Choice 4 ENTER
3. Press (F-4)
4. Choice 4 ENTER

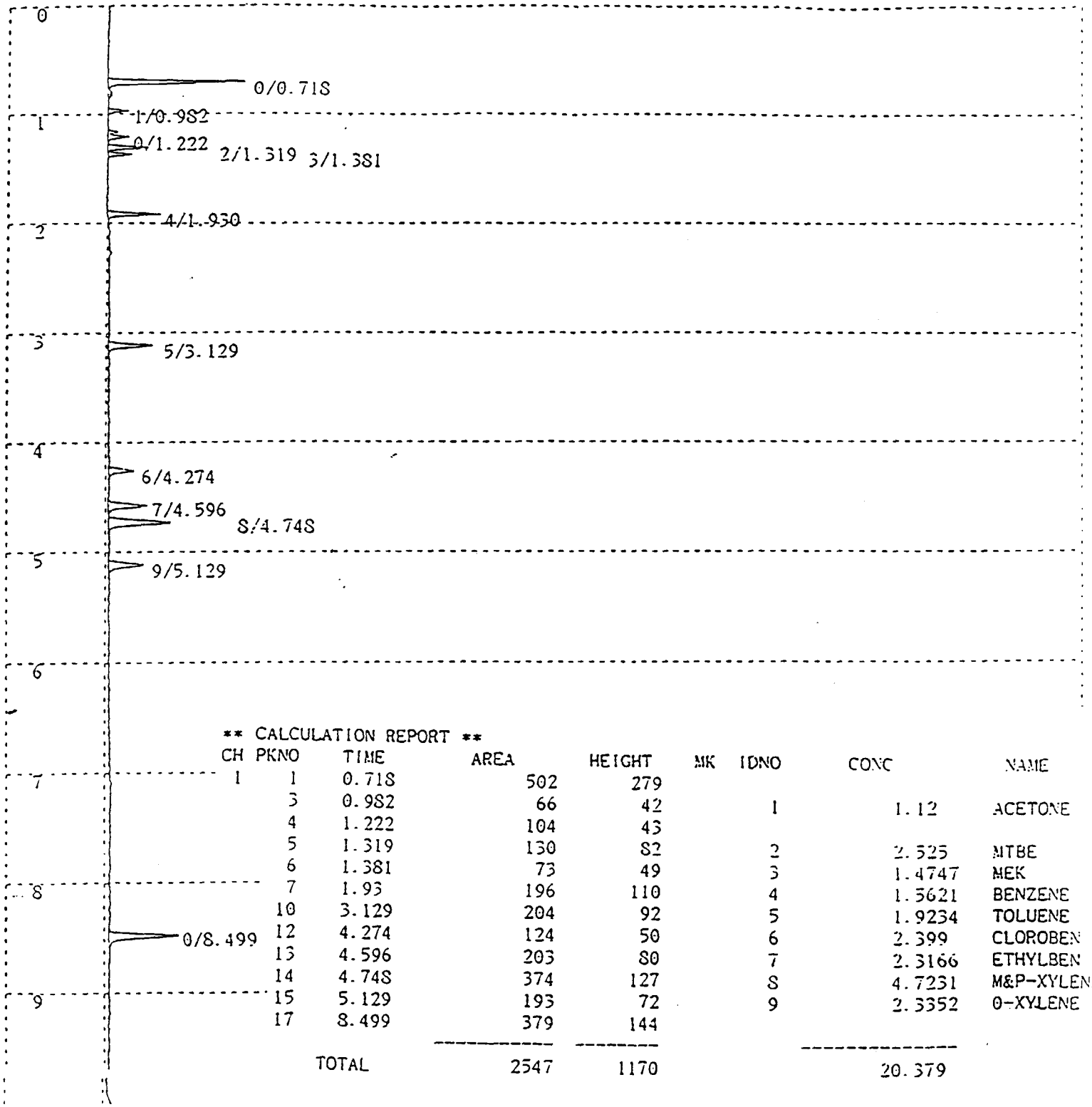
NOTE: For more detailed discussion of QA/QC procedures for data review, please see "SOP for Data Review".

C-R4A CHROMATOPAC CH=1 REPORT No.=27 CHROMATOGRAM=1:CMVOB.C01 91/02/26 00:35:46

Analysis File : 1:FILE-1.

(FID) CMVO(B) - # **STANDARD 1**

ATTN:



** CALCULATION REPORT **

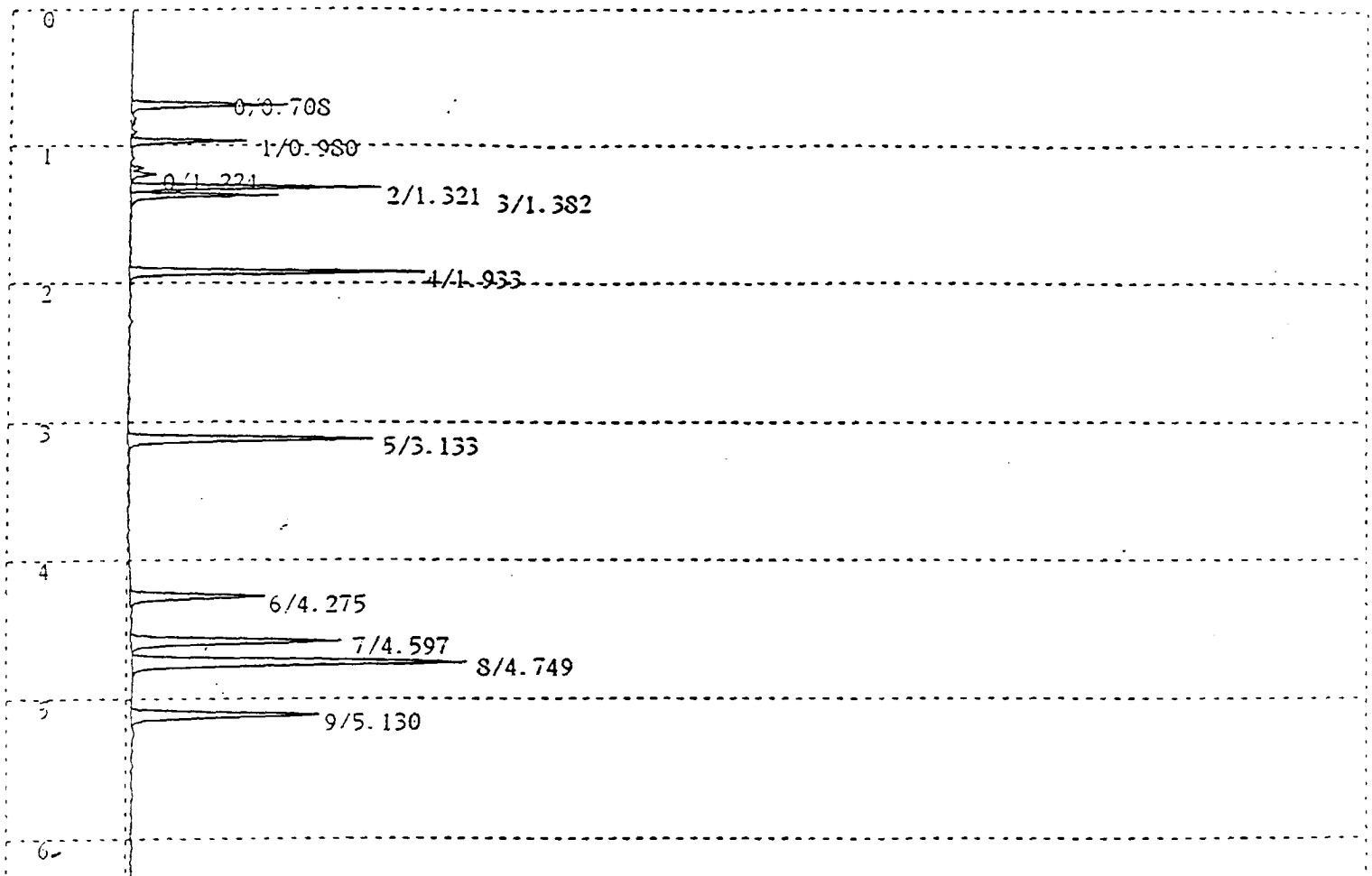
CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
1	1	0.718	502	279				
	3	0.982	66	42		1	1.12	ACETONE
	4	1.222	104	43				
	5	1.319	130	82		2	2.525	MTBE
	6	1.381	73	49		3	1.4747	MEK
	7	1.93	196	110		4	1.5621	BENZENE
	10	3.129	204	92		5	1.9234	TOLUENE
	12	4.274	124	50		6	2.399	CLOROBEN
	13	4.596	203	80		7	2.3166	ETHYLBEN
	14	4.748	374	127		8	4.7231	M&P-XYLEN
	15	5.129	193	72		9	2.3352	O-XYLENE
	17	8.499	379	144				
		TOTAL	2547	1170			20.379	

C-R4A CHROMATOPAC CH=1 REPORT No.=28 CHROMATOGRAM=1:CMVOB.C03 91/02/26 01:08:35

Analysis File : 1:FILE-1.

(FID) CMVO(B) - # **STANDARD 3**

ATTN:



** CALCULATION REPORT **

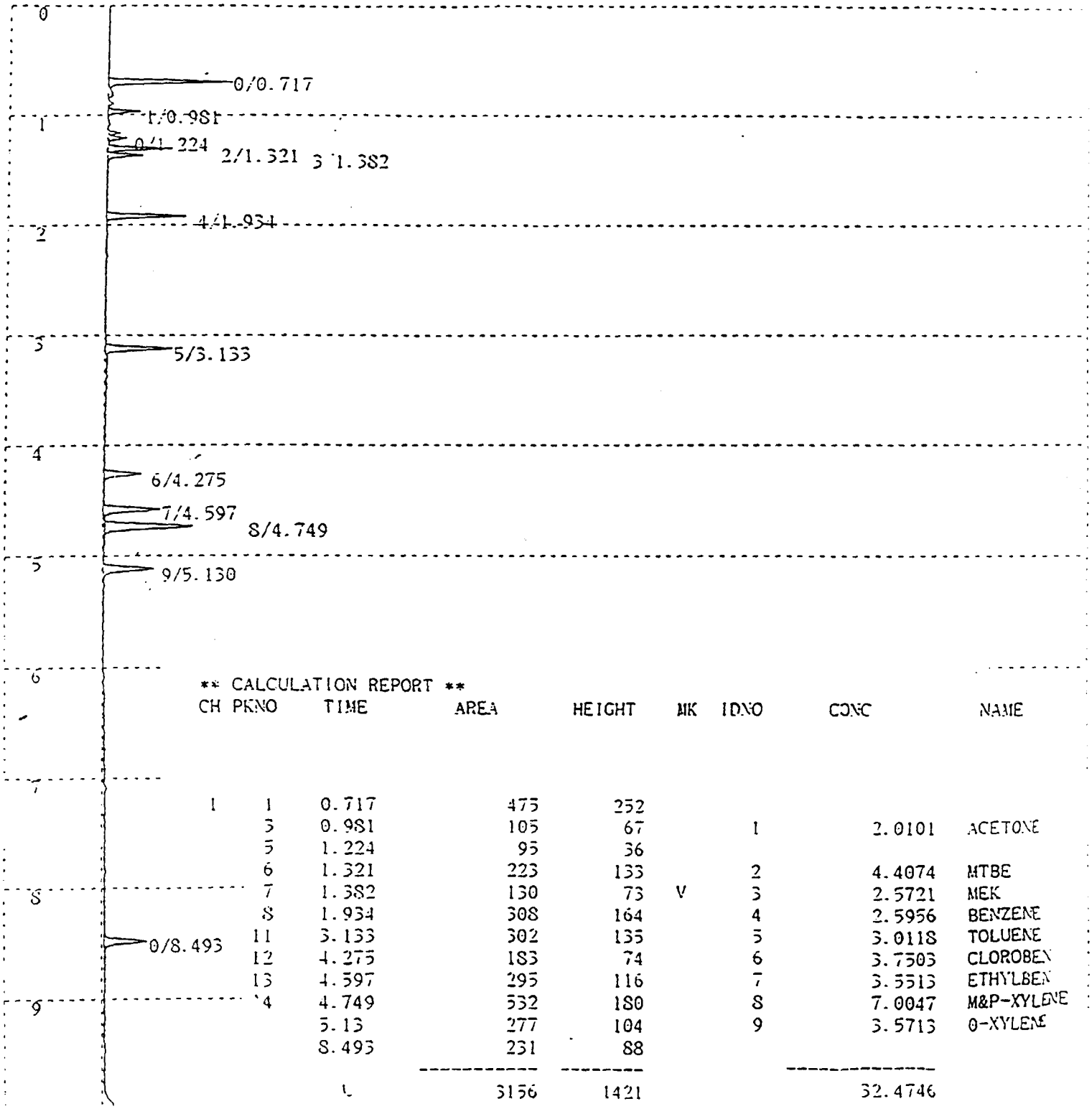
CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
1	1	0.708	469	249				
	4	0.98	275	186		1	5.9	ACETONE
	5	1.224	104	39				
	6	1.321	648	396		2	13.0077	MTBE
	7	1.382	391	236	V	3	7.6032	MEK
	9	1.933	876	470		4	7.8123	BENZENE
	11	3.133	874	388		5	9.3247	TOLUENE
	12	4.275	529	214		6	11.6307	CLOROBEN
	13	4.597	858	336		7	11.132	ETHYLBEN
	14	4.749	1587	534		8	22.2722	M&P-XYLENE
	15	5.13	792	302		9	11.1335	O-XYLENE
	20	8.496	438	173				
		TOTAL	7842	3524			99.8163	

C-R4A CHROMATOPAC CH=1 REPORT No.=26 CHROMATOGRAM=1:CMVOB.C02 91/02/26 00:52:17

Analysis File : 1:FILE-1.

(FID) CMVO(B) - # **STANDARD 2**

ATTN:



** CALCULATION REPORT **

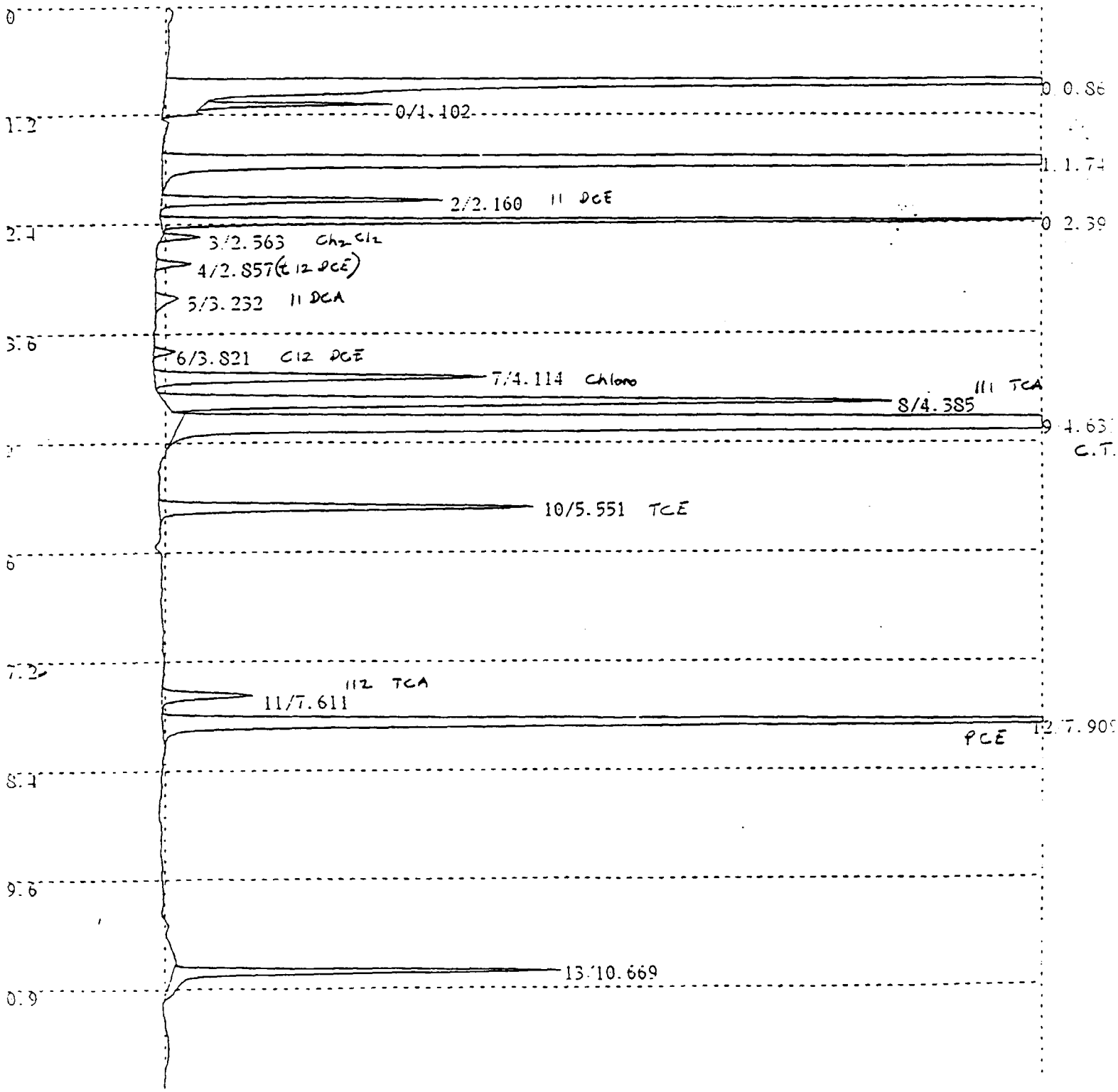
CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
1	1	0.717	475	252				
	3	0.981	105	67		1	2.0101	ACETONE
	5	1.224	95	36				
	6	1.321	223	133		2	4.4074	MTBE
	7	1.382	130	73	V	3	2.5721	MEK
	8	1.934	308	164		4	2.5956	BENZENE
	11	3.133	302	135		5	3.0118	TOLUENE
	12	4.275	183	74		6	3.7303	CLOROBEN
	13	4.597	295	116		7	3.5513	ETHYLBEN
	14	4.749	532	180		8	7.0047	M&P-XYLENE
		5.13	277	104		9	3.5713	O-XYLENE
		8.493	231	88				
			3156	1421			32.4746	

RHA CHROMATOPAC CH=2 REPORT No.=1S CHROMATOGRAM=2:MRBH2E.C02 91/02/23 02:29:37

Analysis File : 1:@FILE2.

(ECD) MRBH-2 # **STANDARD 2**

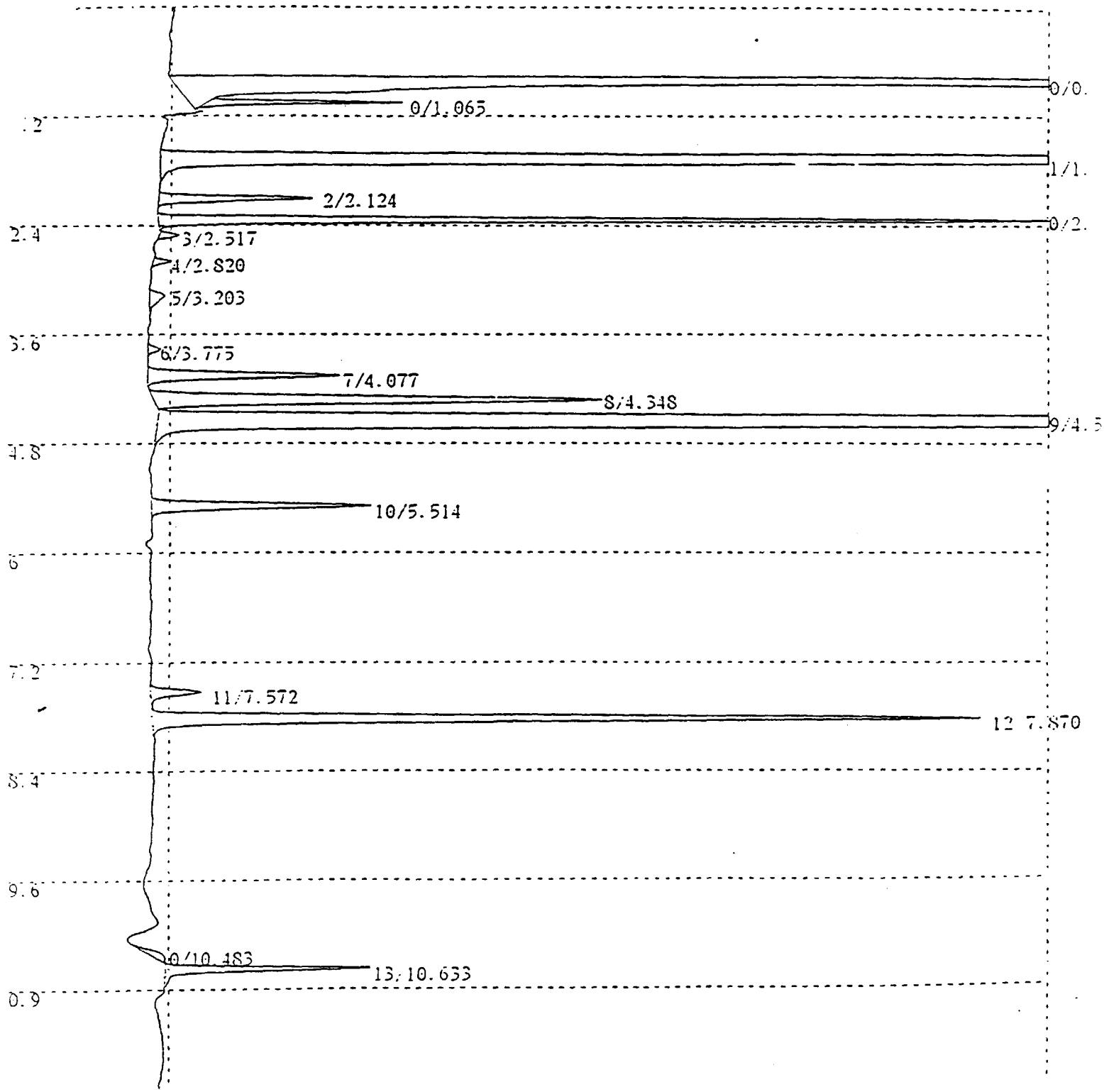
ATTN:



ATOPAC CH=2 REPORT No.=17 CHROMATOGRAM=2:MRBH2E.C01 91/02/23 02:10:38

File : 1:@FILE2.

MRBH-2 # **STANDARD I**



STANDARD_1_

** CALCULATION REPORT **

CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
2	1	0.827	3623950	1213049	S E			
	2	1.065	30607	12759	T			
	3	1.701	1693540	433669		1	-0.0486	TCFM
	4	2.124	37468	10111		2	0.1699	11DCE
	5	2.359	193246	63424				
	6	2.517	4180	1302		3	0.1375	CH2CL2
	7	2.82	3774	1128		4	0.1689	t12DCE
	8	3.203	6591	951		5	0.0593	11DCA
	9	3.775	3357	800		6	0.4062	C12DCE
	10	4.077	57725	12610		7	0.026	CHLOROFORM
	11	4.348	156750	29387		8	0.0255	111TCA
	12	4.591	1892617	360005		9	-0.0576	CARBON TETT
	13	5.514	63564	14525		10	0.0205	TCE
	14	7.572	15310	3385		11	0.0448	112TCA
	15	7.87	240255	54454		12	0.0305	PCE
	16	10.483	6917	771				
	17	10.633	46289	13631		13	0.0161	TECA
		TOTAL	8076138	2225959			0.999	

STANDARD 2

** CALCULATION REPORT **

CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
2	1	0.863	3395775	1161263	S E			
	2	1.102	28815	12153	T			
	3	1.742	2841889	684017		1	0.5588	TCFM
	4	2.16	68958	18295		2	1.0386	11DCE
	5	2.395	188763	63258				
	6	2.563	8471	2607		3	0.6514	CH2CL2
	7	2.857	8500	2339		4	1.2359	t12DCE
	8	3.232	9634	1508		5	1.3839	11DCA
	9	3.821	5931	1494		6	1.3747	C12DCE
	10	4.114	101020	21696		7	0.1259	CHLOROFORM
	11	4.385	256938	47921		8	0.1163	111TCA
	12	4.633	3383578	617555		9	0.7778	CARBON TETT
	13	5.551	109201	24618		10	0.111	TCE
	14	7.611	27432	6003		11	0.1977	112TCA
	15	7.909	436063	96497		12	0.1518	PCE
	16	10.669	94557	25624		13	0.1269	TECA
		TOTAL	10965521	2786846			7.8506	

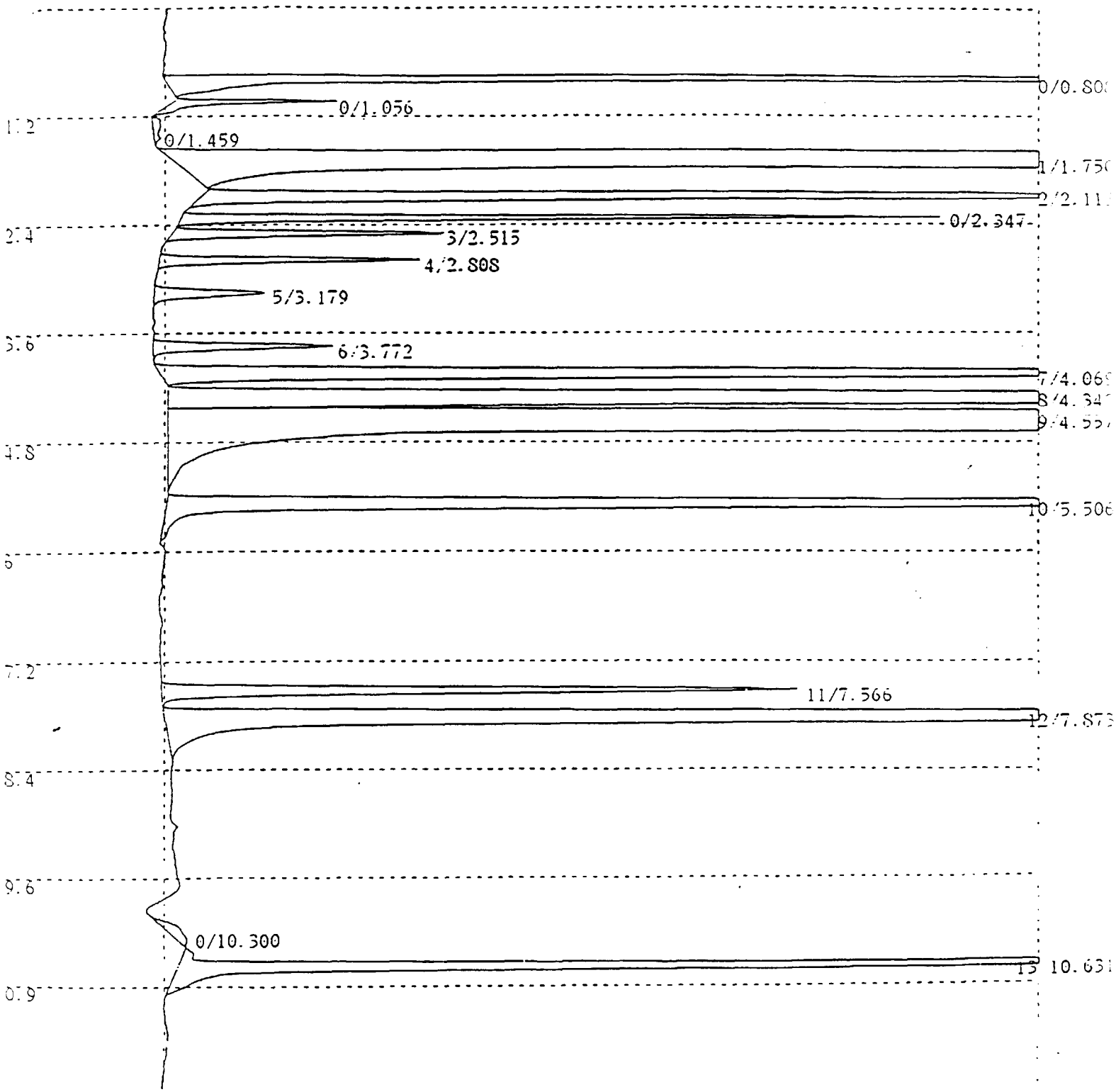
CHROMATOPAC CH=2 REPORT No.=19 CHROMATOGRAM=2:MRBH2E.C03 91/02/23 02:48:41

ysis File : 1:@FILE2.

,D) MRBH-2 #

STANDARD 3

/TN:



STANDARD 3

** CALCULATION REPORT **

CH	PKNO	TIME	AREA	HEIGHT	MK	IDNO	CONC	NAME
2	1	0.808	1387252	593091				
	2	1.056	31652	10619				
	3	1.459	6048	373				
	4	1.75	10765192	1244812	E	1	4.7498	TCFM
	5	2.113	460555	118725		2	11.8415	11DCE
	6	2.347	150391	50230				
	7	2.515	67596	17838		3	7.7311	CH2CL2
	8	2.808	63858	17124		4	13.7352	t12DCE
	9	3.179	38538	7255		5	13.9668	11DCA
	10	3.772	49291	11756		6	17.6891	C12DCE
	11	4.069	669819	140026		7	1.4382	CHLOROFORM
	12	4.342	1650048	291177		8	1.3782	111TCA
	13	4.557	14060308	1245278	VE	9	6.7598	CARBON TETT
	14	5.506	727963	155809		10	1.3386	TCE
	15	7.566	201819	42240		11	2.3976	112TCA
	16	7.873	2980144	607055		12	1.7277	PCE
	17	10.3	13565	721				
	18	10.631	630377	172991		13	1.3569	TECA
		TOTAL	33954400	4727118			86.1103	

Attachment 3

SITEWORKS, INC.
QUALITY ASSURANCE PROGRAM PLAN (QAPP)

A site-specific QAPP for onsite GC/MS services will be prepared by the subcontractor. The site-specific QAPP will be inserted here.

Attachment 4

SITEWORKS, INC.
TDGC/MS METHODS FOR FIELD ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOIL MATRICES

TDGC/MS METHODS FOR FIELD ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOIL MATRICES

1.0 SCOPE AND APPLICATION

1.1 Two methods are reported capable of providing quantitative and qualitative (screening level) measurements for the presence of polycyclic aromatic hydrocarbons in organic extracts prepared from nonaqueous solid wastes and soils *and* from soil/sediment media directly.

Polycyclic Aromatic Hydrocarbon	CAS Number[a]
Naphthalene	91-20-3
Acenaphthylene	208-96-8
Acenaphthene	83-32-9
Fluorene	86-73-7
Phenanthrene	85-01-8
Anthracene	120-12-7
Fluoranthene	206-44-0
Pyrene	129-00-0
Chrysene	218-01-9
Benzo[a]anthracene	56-55-3
Benzo[a]pyrene	50-32-8
Benzo[b]fluoranthene	205-99-2
Benzo[k]fluoranthene	207-08-9

[a]CAS Number = Chemical Abstracts Service registry number

1.2 These methods can be used to separate and identify the above PAH's through methylene chloride extraction followed by thermal desorption, or by direct thermal desorption from the soil matrix into a fused silica capillary column containing a slightly polar stationary phase.

1.3 The practical quantitation limit of this method for determining an individual PAH compound is approximately 30-ng/g (dry weight) for soil/sediment samples directly desorbed with no sample pre-treatment.

1.4 The screening level qualitative detection limit for this method is < 0.2 ppm for compounds that are solvent extracted from the soil/sediment matrix using methylene chloride.

2.0 SUMMARY OF METHOD

2.1 The sample (whether it be a liquid extract or soil/sediment) is placed on a Petri dish. The sample is then thermally desorbed onto the capillary column. The column is heated using a temperature program, and the effluent from the column is introduced into the mass spectrometer for analysis.

2.1.1 Screening Method - The soil/sediment sample (1-10g) is weighed and a known quantity of internal standard (pyrene-d_{10}) is added. The "spiked" soil is placed on a Pyrex petri dish. The heated head (260°C) of the instrument's sampling probe is lowered onto the soil and the compounds are thermally desorbed. Gas chromatographic separation is partially achieved in the short capillary column which is heated using a temperature program. The eluted compounds are introduced into the mass spectrometer for identification and quantitation.

2.1.2 Quantitative method - The soil/sediment sample (0.5-2g) is weighed and placed into a sampling vial. An aliquot of methylene chloride (2-10mL) is added and the vial is shaken for two minutes. An aliquot of the extract (5-10μL) and 5-10μL of the internal standard are placed onto a Pyrex petri dish. The

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compounds are then thermally desorbed as above and identified and quantified by the mass spectrometer system.

3.0 INTERFERENCES

3.1 Contamination by carry-over can occur whenever low-level samples are analyzed after high-level samples. This can be avoided by baking out the sampling probe and the capillary column at 260° and 240° respectively, for a few minutes after high-level samples are analyzed. The Pyrex dish should be cleaned with analyte-free solvent after each analysis.

3.2 The use of high purity (HPLC grade) reagents will help to minimize interference problems.

4.0 SAFETY

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely determined; however, many of the higher molecular weight PAH analytes have been determined to be carcinogenic to some degree. From this viewpoint, exposure to these chemicals by ingestion or dermal contact must be reduced to the lowest possible level by whatever means available.

5.0 APPARATUS AND MATERIALS

5.1 Thermal Desorption Gas Chromatograph System

5.1.1 Thermal Desorption Gas Chromatograph (TDGC), Bruker Instruments GC Probe.

5.1.2 Column: 3.5-m x 0.32-mm i.d. and 0.25-μ film thickness, silicone coated, fused silica capillary column, (5% diphenyl, 94% dimethyl, 1% vinylpolysiloxane; J & W Scientific DB-5 or equivalent).

5.1.3 Note: the capillary column is contained within the TDGC and is not a separate system.

5.1.4 The TDGC is a temperature programmable housing for the GC column.

5.2 Mass Spectrometer (MS) System

5.2.1 Mass spectrometer, Bruker Instruments, Inc. Electron impact ionization source mass spectrometer capable of scanning from 1 to 400 amu every second or less using 70 volts (nominal) electron energy in the electron impact ionization mode and a metal coated quartz shock-resistant hyperbolic quadrupole. No external cooling of the MS or any environmental control of the instrument room is required for the MS. The TDGC/MS system utilizes activated carbon filtered ambient air as the carrier gas.

5.2.2 GC/MS interface - Direct inlet system through a semi-permeable methyl silicone mesh membrane. This inlet membrane allows the organic compounds to permeate into the mass spectrometer while prohibiting air and its components from entering the EI chamber and, subsequently, MS system.

5.2.3 Data System - A computer may be interfaced to the TDGC/MS but is not necessary since there is a read-out screen incorporated in the TDGC/MS system which gives logarithmic response values updated every second as well as amount vs. time curves at the end of the analysis. If an external data system is interfaced, it must allow the continuous acquisition and storage on machine-readable media of all mass spectra obtained throughout the duration of the TDGC (chromatographic) program. The computer must have software that can search any MS data file for ions of a specific mass (or group of masses). The software must be capable of plotting ion abundances versus time or scan number.

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5.3 Tools and equipment

5.3.1 Metal spatula and/or scoopula

5.3.2 Pyrex dish, 3.5-in. in diameter

5.3.3 Portable battery charged balance, 60-g capacity, 0.02-g sensitivity (AND model EW-60B or equivalent).

5.3.4 Analytical balance, capable of accurately weighing 0.0001-g.

5.3.5 Sample vials and containers

5.3.6 gastight syringes; 10, 25, 50-µL

5.3.7 Cooler and ice

6.0 REAGENTS

6.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 Stock standard solutions (2000-ng/µL) - Standard solutions may be prepared from pure standard materials or purchased as certified solutions.

6.2.1 Prepare stock standard solutions by accurately weighing out 0.0200-g of pure material. Dissolve the material in a small amount of HPLC grade methylene chloride, or other suitable solvent, and dilute to 10-mL in a volumetric flask. Larger volumes may be used at the convenience of the analyst. When the compound purity is assayed to be 96% or greater, the weight may be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards may be used if they are certified by the manufacturer or by an independent source. Stock standard solution containing all of the PAH's of interest was purchased from Supelco, Inc. (Bellefonte, PA), but any equivalent standard can be used.

6.2.2 Transfer the stock standard solutions into bottles with teflon lined screw tops with septums. Refrigerate the solutions at 4°C. Stock standard solutions should be checked frequently for signs of degradation or evaporation, especially prior to use in preparation of calibration standards.

6.2.3 Stock standard solutions must be replaced after one year, or sooner if comparison with quality control check samples indicates a problem.

6.3 Internal standard solution - The internal standard recommended is pyrene-d_{10}. Other compounds may be used as internal standards as long as the requirements given in section 8.0 are met. Dissolve 10-mg pyrene-d_{10} with a small volume of HPLC grade methylene chloride. Transfer this solution to a 50-mL volumetric flask and dilute to volume with methylene chloride. The resulting solution will contain the standard at a concentration of 200-ng/µL. Smaller amounts of this internal standard are transferred to a smaller vial with a teflon lined screw top with septum and is replenished as needed. Store internal standard solution at about 4°C before, and between, use. The internal standard solution was purchased from Cambridge Isotope Laboratories (Woburn, MA), but any equivalent solution can be used.

6.4 Calibration standards - A minimum of five calibration standards should be prepared. One of the calibration standards should be at a concentration near, but above, the method detection limit; the remaining standards should

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correspond to the range of concentrations found in real samples, but should not exceed the working range of the TDGC/MS system. Each standard should contain each analyte of interest (e.g. all of the compounds listed in Section 1.1). The standard is injected onto the dish along with the internal standard for analysis. The purpose of the calibration standards is to produce a linear dynamic range plot for each PAH or pair of isomeric PAH's over a range of concentrations, and to check MS response factors.

7.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

7.1 For details concerning the proper techniques in collecting, preserving, and handling samples, refer to PRINCIPLES OF ENVIRONMENTAL SAMPLING, Lawrence H. Keith ed. (American Chemical Society: 1988).

7.2 Samples that are taken back to the lab for confirmation must be stored in sealed vials and placed in ice. The soil must be extracted within two weeks from collection, and the extracts must be analyzed within four weeks from extraction or as otherwise agreed upon depending upon the oversight regulatory agency requirements.

8.0 TUNING OF THE TDGC/MS

8.1 MS automatic calibration- For the automatic calibration of the instrument, eight masses of the calibration compound (FC-77, a mixture of fluorinated hydrocarbons) are selected: 69, 100, 119, 169, 219, 269, 331, and 397 as well as argon (m/z = 40) and moisture (m/z = 18) in the carrier gas (air). The procedure is automatically implemented upon manual selection of the automatic calibration feature of the instrument. For all 10 masses, starting with 18 amu, the MS system adjusts the mass, peak width and energy in that order until it achieves the optimized values. The resolution is set to unity with a *ca.* 10% valley definition; this is done by measuring the actual peak width and adjusting the peak width parameter accordingly. Typically, the auto-calibrate procedure is all that is required for field measurements. The MS system periodically checks the mass alignment at a rate of every 15 minutes the first two hours, every half hour the second two hours, and every hour for each hour thereafter. Mass spectral drift is automatically monitored through the on-board microprocessor diagnostics. The mass alignment values should be manually verified on a regular basis as a secondary means of quality assurance.

9.0 DAILY CALIBRATION AND QA/QC PROTOCOLS

9.1 Response Factor Calculations- Before mobilizing the TDGC/MS unit to the field, the analyst must prepare calibration standards to establish a five point analyte calibration curve at the beginning of each study. Using a standard mixture of all of the PAH's will reduce the time needed to prepare these standards. The lowest concentration calibration standards should be at a concentration near, but above, the instrument detection limit. The other concentrations should correspond to the expected range of concentrations found in the "real-world" samples or the establishment of the TDGC/MS dynamic range.

9.2 <u>PAH's in Soil:</u>

9.2.1 Prior to any calibration curve standard analyses, the TDGC/MS system is checked for background contamination by performing an instrument blank. The instrument blank is performed by running the TDGC temperature program without analyte desorption.

9.2.2 Following the instrument blank, a method blank is performed where the extraction solvent, apparatus, and petri dish are checked for background contamination. A blank (no soil) extraction procedure is performed and an aliquot of the resulting extract solvent is placed on the petri dish and allowed to volatilize. The residue is then thermally desorbed off of the Pyrex dish by heating the sample head of the GC probe at 260°C. The solvent residue is thus analyzed using the method GC temperature program with MS detection for the presence/absence of background contaminants due to methodology. If background contamination is found, a stepwise process of elimination is perfomed from the Petri dish back to the initial extraction solvent to isolate and eliminate the source of contamination. Prior to any analyses (calibration or site samples) the system must be found to be free of any outside sources of contamination. Carrier gas contamination is not a problem due to the ability of the instrument threshold settings to be manually

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established on a site to site basis dependent upon the ambient air levels of contamination by targeted volatile PAH's. If the internal standard (d_{10}-pyrene) is suspected to be contaminated, this procedure must be repeated using the d_{10}-pyrene in lieu of the extraction solvent.

9.2.3 Analyze the calibration sample as described in Section 10. Repeat each analysis one time for each concentration. Tabulate the area response of the characteristic ions against concentration for each compound and internal standard and calculate response factors (RF) for each compound using Eq. 1:

$$RF = (A_x)(C_{is})/(A_{is})(C_x) \quad \text{where,} \quad [1]$$

A_x = area of the standard target analyte ion current signal
C_{is} = concentration of the internal standard (d_{10}-pyrene)
A_{is} = area of the internal standard ion current signal (d_{10}-pyrene)
C_x = concentration of the standard target analyte

If the RF value is constant (i.e., < 30% relative standard deviation, RSD) over the dynamic range, the RF can be assumed to be invariant and the average from the RF value(s) can be used for quantitation. If the average RF values for any analytes fall outside of the 30% RSD window, the instrument must be checked for mass drift and the point or points skewing the curve must be performed again.

9.2.4 The working calibration curve or RF must be verified each working day by measurement of the analyte response factors. If the response for any compound varies from the initial calibration curve response factor by more than ± 30%, the test must be repeated using a fresh calibration standard at a second concentration. If any of the analyte RF's calculated from this second point fall outside of the 30% window, a third concentration is analyzed thus establishing a new 3-point calibration curve. If all of the analyte RF's from this new 3-point curve have respective %RSD's within 30% across the concentration gradient, the average RF for each analyte becomes the new calibration curve RF for the study. It should be noted that the concentrations analyzed for this 3-point curve need to be carefully selected to encompass the range of actual real world analyte concentrations encountered at the site.

9.2.5 For direct thermal desorption soil measurements, a second calibration curve must be generated to establish linearity and response factors to calculate relative concentrations. These experiments must emulate the above stated experiments with the exception that the PAH standard solutions and internal standard must be injected directly into a known quantity of field blank soil sample and thermally desorbed directly from the soil matrix. The response factor calculation, five point initial calibration curve, and daily RF update protocols will be performed. The response factors generated through this curve will obviate the need for direct soil thermal desorption extraction efficiency correction factors. Due to the direct nature of the GC column/soil interface high levels of background interferants should be expected and, therefore, this type of analysis must be performed in the SIM MS mode of the TDGC/MS. Long TDGC bakeout times should be expected between direct soil analyses to avoid carryover and allow the MS system to remain free of high molecular weight hydrocarbons.

9.2.6 Prior to sample analyses, an analyte recovery experiment must be performed. To perform this experiment, a representative soil sample field blank must be collected. This soil sample is spiked with a known concentration of all targeted analytes and allowed to bond to the soil matrix for a period of at least 30 minutes. The spiked soil sample is then extracted as discussed in section 10, and analyzed by TDGC/MS. This procedure should be performed in triplicate for each different soil type at the site to determine the precision of the recovery values. If the precision values fall within 30% RSD for triplicate spiking experiments, the individual analyte method recovery numbers are incorporated into the quantitation calculation. If the recovery values fall outside of the 30% RSD precision criteria, a more homogenous representative soil matrix is used for a second set of experiments and the MS system is checked for mass alignment.

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10.0 SAMPLE EXTRACTION AND THERMAL DESORPTION GAS CHROMATOGRAPHY

10.1 After tuning the TDGC/MS as discussed in Section 8, calibrate the system daily as described in Section 9.

10.2 Sample preparation

10.2.1 Thermal desorption of soil extracts: The analyst must weigh out ~0.5-g of the dried soil/sediment sample and place it in a 5-mL sample bottle with a teflon lined screw cap. To this bottle, add 2-mL of HPLC grade methylene chloride as the organic solvent. This solution is then shaken for 2 minutes, allowed to settle briefly (5-10 seconds or use a centrifuge), then is extracted using a Pasteur pipette. The extract is then filtered using a 5-mL disposable syringe and disposable syringe filter. A 5-μL aliquot of this extract is injected onto a Pyrex petri dish (using a 10-mL gastight syringe) along with (using a different 10-μL syringe) 5-μL of the 50-ng/μL pyrene-d_{10} internal standard previously prepared. The liquid sample and internal standard are then thermally desorbed into the capillary column of the TDGC. The weight of the soil before and after drying are noted for inclusion into the quantitation calculation as needed. Internal standard concentration will vary dependent upon individual instrument sensitivity and levels of monitored analytes expected to be found at the sampling location.

10.2.2 Thermal desorption of soil directly: The analyst must weigh out ~1.00-g of dried soil/sediment sample into a Pyrex petri dish. To this sample is injected 5-μL of 200-ng/μL pyrene-d_{10} internal standard. The soil is then mixed thoroughly using a scoopula. The probe is then placed on the sample and the PAH's are thermally desorbed by the thermal desorption head of the TDGC. Internal standard concentration will vary dependent upon individual instrument sensitivity and levels of monitored analytes expected to be found at the sampling location.

10.3 TDGC Conditions

10.3.1 In both cases (soil or extract), the sample analytes are thermally desorbed off of the Pyrex petri dish by heating the sample head of the GC probe isothermally at 260°C. The sample is introduced at the head of the capillary column by volatilization at 260°C, the carrier gas flow rate through the probe, and the temperature gradient between the thermal desorption head and the initial column temperature. The column temperature is held at 70°C for 40 seconds followed by linear temperature programmed heating to 233°C at 35°C/minute. Follow the temperature program with an isothermal heating period of 80 seconds at 233°C, and then cool the column to 70°C. The total analysis time is 400 seconds.

10.4 MS Conditions: MS data can be collected in two modes: the selected ion monitoring (SIM) mode or the total ion current chromatogram (TIC) mode. The SIM mode of the TDGC/MS allows the analysis of up to 12 analytes (one must be reserved for the internal standard) simultaneously. By employing analyte-specific MS algorithms (SiteWorks, Inc. owns the proprietary rights to these algorithms) the targeted VOC's can be detected using up to four representative ions/analyte. These algorithms incorporate such descriptors as reliability level, warning level, alarm level, and interference which are all described below. When operating in the SIM mode coupled with the rapid GC temperature programming (400 seconds/analysis) TDGC/MS detection limits are improved up to 5 times, however, interferences are sometimes difficult to filter. Cases where interferences pose problems are when pure product such as coal tar extracts are analyzed. SIM can be used in these cases if operated by an experienced user with a strong background in MS. In the TIC mode, the quadrupole is scanned was between 125 and 260 amu with the MS scan time approximately 2 sec and is altered dependent upon the target analytes at a specific site. Details concerning the SIM MS algorithms and detection schemes have been cited elsewhere[1-4].

10.4.1 The reliability level of the mass spectrometer refers to the difference of the normalized ion current signal abundances and the established ion monitoring designation between the selected ions current signals monitored for each analyte. This parameter has arbitrary units between 0 and 20. Practically, this means that when the signal intensities of the four ions are normalized to approximately the same levels then the instrument reports that the desired compound has been detected. This instrument identifies the presence of such compounds by indicating an alarm to the operator. Smaller values mean that the measured

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intensities for all ions must be within a small degree of error to their established criteria for positive detection. Typical values for reliability lie between R = 1 and 5 and must be determined from experience. For the reliability criteria to be met, $(d_1 + d_2 + d_3) < 0.3 \times 5$ where d_1, d_2, and d_3 are the differences when the lowest normalized ion current signal difference is subtracted from the three higher normalized ion currents signal differences for the four ions.

10.4.2 The instrument provides so-called warning levels with the presence of potential target compounds. Alarm and warning levels are set in logarithmic intensity units. In general, alarm levels should be at least 0.5 log units above their associated warning levels. These values must be established by experience. If the alarm level is not set higher than the warning level after entering a value for the latter, the alarm level will be automatically set at 0.1 log units higher than the warning level. These settings simply indicate to the operator that the compound has been detected at a predetermined signal intensity level and can be set at the detection limit of the instrument to ensure that low levels are not precluded from compound detection.

10.4.3 The interference parameter has units of log amount and typical values are between 0.5 and 2.0; the best values must be determined from experience. In general, the function of the interference parameter is to suppress alarms when large amounts of interfering substances are present. Larger values mean a higher concentration of an interfering compound is required to suppress an alarm. There is no interfering substance if the maximum ion current for substance A (if substance A has the highest single ion current) minus the average ion current for substance B (average of all four ion currents) in logarithmic values less than the interference number.

11.0 COMPOUND IDENTIFICATION

11.1 TIC Mode: Obtain mass and relative abundance criteria for the four characteristic ions established in the analyst-derived target PAH library based upon a TIC analysis of a standard sample. The ion abundances should be calculated relative to the 100% ion. For positive PAH analyte identification in the TIC mode, the following criteria must be met:

11.1.1 The characteristic ions of each compound of interest must maximize within one scan of each other.

11.1.2 The retention time of the suspected analyte must fall within ± 20 seconds of the retention time of the actual PAH analyte as determined by the calibration data. This window is wide to accomodate the short capillary column and rapid elution of the analytes.

11.1.3 The relative abundances of the four characteristic ions in the TIC's must fall within ± 30% of the relative abundances of these ions according to the mass spectra obtained during calibration for targeted analytes or from a reference mass spectrum for non-targeted analytes. Further detection assurance descriptors can be formulated to vary the level of error allowed for individual mass relative abundances for each compound as determined by the analyst similar to the SIM mode of analysis.

11.2 SIM Mode: Since rapid GC temperature programming devaluates the use of retention time data for compound identification purposes, analyte identification must be based primarily upon the MS data. Through the use of analyst derived MS algorithms, up to four characteristic ions for each target analyte will be monitored during each analysis. Post-analysis ion current amount versus time curves allow for the analyst to positively verify the instrument response by monitoring the normalization of the individual ion current signals over the length of the analysis and to assign a relative retention time window for compound elution with respect to the internal standard.

11.3 Structural isomers that have very similar mass spectra and less than 20 seconds difference in retention time, can be explicitly identified only if the resolution between authentic isomers in a standard mixture is acceptable. Acceptable resolution is achieved if the baseline to valley height between the isomers is less than 25% of the sum of the two peak heights. Otherwise, structural isomers are identified as isomeric pairs.

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Table 3. The linearity of the PAH dynamic range directly desorbed from a soil matrix.

COMPOUND(S)	CONCENTRATION (ng)	SIGNAL (n=5)	LINEARITY (r)
Naphthalene	4000	510084 ± 22.9%	0.999
	2000	255648 ± 22.9%	
	1600	210541 ± 31.2%	
	800	110357 ± 12.9%	
	120	28371 ± 13.2%	
	80	5312 ± 23.4%	
	40	1995* ± 22.4%	
Acenaphthylene	4000	255648 ± 22.9%	0.999
	2000	129245 ± 26.1%	
	1600	94858 ± 10.8%	
	800	51454 ± 26.1%	
	80	3575 ± 13.2%	
	40	794* ± 17.2%	
Acenaphthene	4000	94858 ± 10.8%*	0.999
	2000	23397 ± 12.7%	
	1600	20307 ± 22.9%	
	800	9936 ± 34.5%	
	80	740 ± 12.7%	
	40	251* ± 16.8%	
Fluorene	4000	52714 ± 11.0%	0.999
	2000	24197 ± 32.8%	
	1600	18585 ± 12.7%	
	800	8971 ± 13.2%	
	120	371 ± 12.8%	
	80	794* ± 13.4%	
	40	251* ± 15.4%	
Phenanthrene & Anthracene	8000	42578 ± 35.4%	0.999
	4000	21245 ± 12.2%	
	3200	16271 ± 26.1%	
	1600	8084 ± 22.9%	
	240	877± 24.3%	
	160	3981* ± 18.6%	
	80	316* ± 20.2%	
Fluoranthene & Pyrene	8000	17498 ± 24.3%	0.999
	4000	8629 ± 13.8%	
	3200	6854 ± 13.8%	
	1600	3221 ± 40.1%	
	240	371 ± 12.8%	
	160	1995* ± 15.3%	
Chrysene & Benzo[a]anthracene	8000	325 ± 32.0%	

*These values were not included in the dynamic range.

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12.0 CALCULATIONS

12.1 The quantitation of an identified compound should be based on the integrated abundance from the TIC of the normalized four characteristic ions given in Table 1 or by the logarithmic ion signal in the SIM mode.

12.2 Thermal desorption of soil directly.

12.2.1 Calculate the concentration of the PAH analytes directly desorbed from the soil using the response factor generated by direct soil-injected standards analysis and by using the internal standard calculation procedure described in section 9 and Eq. 2:

$$\text{Concentration (ng/g)} = (A_x)(C_{is})/(A_{is})(RF)(W_s)(D)(E) \quad \text{where,} \quad [2]$$

W_s = Weight of the sample (g)
D = (100-% moisture in the sample)/100 where appropriate

The remaining parameters are described in Section 9.

12.3 Thermal desorption of solvent extracted analytes.

12.3.1 Calculate the concentration of each identified analyte in the sample as follows:

$$\text{concentration (ng)} = (A_x)(C_{is})/(A_{is})(RF)(W_s)(D)(E) \quad \text{where,} \quad [3]$$

W_s = Weight of the sample (g)
D = (100-% moisture in the sample)/100 where appropriate
E = extraction efficiency derived from recovery experiments.

13.0 METHOD PERFORMANCE Data comparison studies between TDGC/MS and fixed laboratory methods of analysis have been published elsewhere.[1-4] The data shown here is representative of typical performance benchmarks achievable following this methodology.

13.1 APPENDIX A: Thermal desorption directly from a soil matrix with no sample pretreatment. The experiments in this appendix were performed using the procedures previously described.

13.1.1 Appendix A-1: The dynamic range of the instrument with regard to PAH detection in a soil matrix. The dynamic range of each PAH (or pair of PAH isomers) was determined by spiking 0.5-g soil matrix samples with varying amounts of PAH standard from low concentrations to high concentrations. The results are shown in Table 3 where r, the correlation coefficient, refers to the linearity of the line. These results show the TDGC/MS to be linear in the concentration range between 40 and 4000-ng for each PAH thermally desorbed directly from the spiked soil matrix. PAH concentrations that fall outside of the linear range and can be detected are also shown in the Table.

13.1.2 Appendix A-2: Mean relative response factors of the calibration standards -The response factors for the direct soil desorption are calculated as previously explained in Section 9 by spiking a 0.5-g soil matrix with a known amount of PAH standard mixture and analyzing along with 1000-ng of internal standard solution (pyrene-d_{10} directly injected onto the Pyrex petri dish) using the TDGC/MS. The results of this analysis are shown in Table 2. It is observed here that the response factors vary somewhat with concentration.

13.1.3 Appendix A-3: Minimal detectable amounts of PAH's directly desorbed from a soil matrix. The minimal detectable amount of PAH is the smallest amount of PAH injected into a soil matrix and analyzed by the TDGC/MS that gave a response above the background level of the instrument. This was determined by spiking a 0.5-g soil matrix with small concentrations of PAH and analyzing. The results are shown in

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Table 3. The amount detected corresponds to the smallest amount of PAH injected into the soil matrix which gave a response above the background level.

13.2 APPENDIX B: TDGC/MS analysis of PAH's extracted from a soil matrix using methylene chloride as the organic solvent. The experiments in this appendix were performed following the procedure described previously discussed.

13.2.1 Appendix B-1: The dynamic range of PAH's in an organic solvent. The TDGC/MS linear dynamic range was determined by using varying concentrations of PAH's in methylene chloride. The linearity of the individual PAH's and of the PAH's is shown in Table 5 where r is the degree of linearity. These results show the mass spectrometer to be linear in the concentration range between 0.2 and 100-ng for each PAH thermally desorbed as a liquid.

13.2.2 Appendix B-2: The mean relative response factors of the PAH's desorbed as a liquid in organic solvent. The response factors for the PAH's in methylene chloride were calculated using the response factor equation shown in 9. These response factors were calculated using pyrene-d_{10} as the internal standard (1000-ng). The results are shown in Table 4.

13.2.3 Appendix B-3: The minimal detectable amounts of the PAH's in organic solvent. Table 5 shows the minimal amount of the PAH's that can be thermally desorbed and detected over the background levels by the TDGC/MS.

13.3 APPENDIX C: The following appendices are the results from the soil/organic extraction experiments performed. In these experiments, the methylene chloride extract is thermally desorbed by the TDGC/MS.

13.3.1 Appendix C-1: PAH recovery rates vs. extraction time. Soil extraction experiments were performed to determine optimum extraction times and corresponding PAH recovery rates. For example, 0.5-g of backyard soil spiked with 2000-ng of each PAH was added to a sample vial. To this 2-mL of methylene chloride was added. The vial was shaken for a timed period. This extraction was performed at different time intervals from 15 seconds to 1 hour. A 10-μL organic fraction of the extract was removed from the vial and analyzed by TDGC/MS as stated in Section 10. Table 6a shows typical results for the PAH/soil extraction experiments as a function of time. Two minutes was found to be the optimum time required for organic extraction out of backyard soil. The average recovery of PAH's from the soil was about a 77.2 $\pm$ 12.4% (n=5) after a single two minute extraction. To obtain higher PAH recovery, multiple 2-mL extractions can be performed. It should be noted that PAH/soil efficiencies may vary from one soil/sediment sample to the next due to different matrix adsorption characteristics. Thus, optimum extraction times may also vary depending upon the composition of the soils and sediments studied. The individual PAH recovery percentages for a 2 minute extraction with methylene chloride is shown in Table 6b.

13.3.2 Appendix C-2: PAH recovery rates vs. solvent composition. Three different solvent compositions were tested for efficiency of extracting PAH's from soil. As shown in Table 7, methylene chloride gave the best results. 0.5-g of backyard soil spiked with 2000-ng of each PAH was extracted with 2-mL of each one of the three solvents for two minutes and the extracts were separated from the soil. A 10-μL aliquot from the extracts together with 5-μL of the internal standard (200-ng/μL) were put in a Pyrex petri dish. The compounds were then thermally desorbed and analyzed by TDGC/MS as described in Section 10. The calculated amounts of PAH's were compared to the actual known amounts contained in the extracted soils. A 77.2 $\pm$ 12.4% recovery was calculated for methylene chloride while a 1:1 mixture of methylene chloride:acetone resulted in a 31.0 $\pm$ 5.8% recovery and a 1:1 hexane:acetone mixture resulted in a 51.9 $\pm$ 10.3% recovery.

13.3.3 Appendix C-3: PAH recovery rates vs. amount of solvent. The optimum amount of solvent used for the extraction of PAH's from soil was evaluated. For this, a number of samples containing 0.5-g of backyard soil spiked with 2000-ng of each PAH was extracted for 2 minutes with different volumes of

methylene chloride as shown in Table 8. The extracts were separated from the soil and a 10-μL aliquot plus 5-μL of internal standard was placed on the Pyrex dish and thermally desorbed and analyzed by TDGC/MS as previously stated. The optimum amount of methylene chloride was found to be 2-mL, which gave a 77.2 ± 12.4% recovery rate, consistent with the findings from other experiments in the method evaluation. It is understood that this value might differ with different soil matrices and different concentrations of PAH's. By increasing the amount of methylene chloride for the extraction of PAH's from soil, it was found that recovery steadily decreased.

13.4 APPENDIX D: Method detection limit (MDL) studies were performed according to USEPA procedure 40 CFR part 136 Appendix B. These calculated method detection limits are compared to the CLP contractor required quantitation limits (CRQL) and the EPA Region IX preliminary remediation goals (PRG's) for risk based assessment as shown in Table 9. Method detection limits are shown for instrument operation in the selected ion monitoring (SIM) and total ion current (TIC) modes. Results of this study show that the TDGC/MS system and this method can provide analyte method detection limits below those required by both federal and state regulatory agencies for risk assessment purposes.

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Table 1. Selected ions and relative abundances for PAH's and internal standard.

PAH	m/z	Relative Intensity
Naphthalene	128	100
	129	11.2
	127	10.4
	102	7.2
Acenaphthylene	152	100
	151	21.6
	150	14.0
	153	14.0
Acenaphthene	154	100
	153	86.5
	152	48.1
	151	14.0
Fluorene	166	100
	165	86.5
	167	15.0
	163	12.0
Phenanthrene & Anthracene	178	100
	176	15.0
	179	15.0
	177	8.4
Fluoranthene & Pyrene	202	100
	203	20.1
	200	16.2
	201	11.2
Chrysene & Benzo[a]anthracene	228	100
	226	21.6
	229	20.1
	227	6.8
Pyrene-d_{10}	212	100
	211	55.9
	210	31.1

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Table 2. Response factors for direct thermal desorption of PAH's from a backyard soil matrix.

COMPOUND(S)	AMOUNT SPIKED (ng)	RESPONSE FACTOR (n=5)	%STD DEV (%RSD)
Naphthalene	80	3.33	17.8
	120	2.42	12.3
	800	2.68	11.8
	1600	2.28	12.3
	2000	2.20	16.2
	4000	2.36	10.2
The ave. response factor is 2.39 ± 0.18 excluding the value of 4.33 at 80ng.			
Acenaphthylene	80	2.29	16.1
	120	1.68	16.3
	800	0.911	12.3
	160	0.842	18.4
	2000	0.910	12.1
	4000	1.68	12.2
The ave. response factor is 1.21 ± 0.43 excluding the value for 80ng.			
Acenaphthene	80	0.481	8.7
	120	0.213	22.5
	800	0.404	22.8
	1600	0.112	12.7
	2000	0.216	13.8
	4000	0.531	12.1
The ave. response factor is 0.326 ± 0.169.			
Fluorene	120	0.180	13.7
	800	0.161	22.8
	1600	0.170	20.9
	2000	0.121	22.7
	4000	0.356	12.5
The ave. response factor is 0.158 ± 0.026 excluding the value for 4000ng.			
Phenanthrene & Anthracene	160	4.46	13.2
	240	0.309	12.9
	1600	0.167	12.3
	3200	0.240	22.8
	4000	0.270	20.9
	8000	0.278	12.5
The ave. response factor is 0.253 ± 0.054 excluding the value for 160ng.			
Fluoranthene & Pyrene	160	1.13	20.3
	240	0.060	17.0
	1600	0.030	23.4
	3200	0.057	13.3
	4000	0.067	11.9
	8000	0.078	26.0
The ave. response factor is 0.058 ± 0.018 excluding the value for 160ng.			
Chrysene & Benzo[a]anthracene	8000	0.0025	22.9

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Table 4. Response factors for PAH's thermally desorbed as an organic liquid.

COMPOUND(S)	AMOUNT INJECTED (ng)	RESPONSE FACTOR (n=5)	%STD DEV
Naphthalene	100	0.125	7
Acenaphthylene	100	0.439	15
Acenaphthene	100	0.144	12
Fluorene	100	0.357	13
Phenanthrene & Anthracene	200	0.790	8
Fluoranthene & Pyrene	200	1.198	9
Chrysene & Benzo[a]anthracene	200	1.01	22

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Table 5. The linearity of the dynamic range of the PAH's desorbed as an organic liquid.

COMPOUND(S)	CONCENTRATION (ng)	SIGNAL (n=5)	LINEARITY (r)
Naphthalene	100	115536 ± 12.3	0.999
	50	58770 ± 12.7%	
	20	17901 ± 16.2%	
	1.0	740 ± 12.7%	
	0.6	588 ± 12.8%	
	0.2	343 ± 13.8%	
	0.1	200* ± 14.1%	
Acenaphthylene	100	177168 ± 13.8%	0.999
	50	80490 ± 18.8%	
	20	23397 ± 12.7%	
	1.0	2675 ± 12.2%*	
	0.6	1013 ± 18.8%*	
	0.2	378 ± 10.8%*	
	0.1	251* ± 12.8%	
Acenaphthene	100	166351 ± 34.5%	0.999
	50	80279 ± 16.3%	
	20	20484 ± 32.0%	
	1.0	1173 ± 12.8%*	
	0.6	357 ± 13.2%*	
	0.2	273 ± 13.8%*	
	0.1	316* ± 23.2%	
Fluorene	100	327992 ± 28.6%	0.999
	50	161303 ± 22.9%	
	20	71072 ± 36.4%	
	10	44965 ± 16.2%	
	1.0	1527 ± 32.8%	
	0.6	931 ± 12.8%*	
	0.2	753 ± 10.8%*	
	0.1	337* ± 16.5%	
Phenanthrene & Anthracene	200	637677 ± 16.3%	0.999
	100	321841 ± 22.9%	
	40	129639 ± 25.0%	
	20	68542 ± 13.8%	
	2.0	14762 ± 12.7%	
	1.2	7210 ± 20.3%*	
	0.4	1503 ± 10.8%*	
	0.2	931 ± 12.7%*	
	0.1	370* ± 14.6%	
Fluoranthene & Pyrene	200	475417 ± 10.8%	0.999
	100	238273 ± 10.8%	
	40	94858 ± 10.8%	
	20	50500 ± 13.4%	
	2.0	7535 ± 10.8%	
	1.2	3396 ± 11.8%*	
	0.4	966 ± 8.7%*	
	0.2	398* ± 12.3%	
Chrysene & Benzo[a]anthracene	200	121272 ± 32.8%	0.999
	100	59852 ± 10.8%	
	40	21675 ± 13.8%	
	20	9314 ± 12.8%	
	2.0	803 ± 16.3%	
	1.2	411 ± 8.9%	
	0.4	251* ± 14.2%	

*These values were not included in the dynamic range.

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Table 6a. The total PAH recovery rates vs. the extraction time; n=5 at each time period.

TIME (s)	%RECOVERY	%STD. DEV.
15	21.2	14.3
30	67.8	10.8
60	76.4	13.2
120	77.2	12.4
180	75.0	9.8
240	74.6	12.2
300	76.0	13.4
1800	77.4	12.8
3600	75.2	12.8

Table 6b. Individual PAH recovery percentages for a 2 minute extraction with $MeCl_2$; n=5 for each compound studied.

COMPOUND(S)	ngINJECTED	ngRECOVERED	%RECOVERY	%STD. DEV.
Naphthalene	2000	1368	68.4	12.7
Acenaphthylene	2000	1361	68.1	12.1
Acenaphthene	2000	1440	72.0	1.5
Fluorene	2000	1275	63.7	13.7
Phenanthrene & Anthracene	4000	3412	85.3	1.5
Fluoranthene & Pyrene	4000	2818	70.4	3.4
Chrysene & Benzo[a]anthracene	4000	3367	84.2	5.4

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Table 7. The Total PAH recovery rate vs. the organic solvent composition; n=5 for each organic solvent.

ORGANIC SOLVENT	%RECOVERY	%STD. DEV.
Methylene Chloride	77.2	12.4
Hexane-Acetone 1:1	51.9	10.3
Methylene Chloride-Acetone 1:1	31.0	5.8

Table 8. Total PAH recovery rate vs. the amount of methylene chloride solvent for a 2 minute extraction.

AMOUNT OF SOLVENT	%RECOVERY	%STD. DEV.
2 mL	77.2	12.4
4 mL	52.4	13.5
6 mL	42.0	10.2
8 mL	36.8	12.2
10 mL	34.9	9.8

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Table 9. Comparison of TDGC/MS method detection limits (MDL[a]) with the EPA Region IX preliminary risk assessment remediation goals (PRG) and CLP Contract Required Quantitation Limits (CRQL's) for PAH's and PCB's. TDGC/MS detection limits were calculated according to EPA procedure 40 CFR part 136 Appendix B. Method detection limits are shown for instrument operation in the selected ion monitoring (SIM) and total ion current (TIC) modes.

PAH	PRG Residential (µg/kg)	CLP CRQL (µg/kg)	TDGC/MS TIC-MDL (µg/kg)	TDGC/MS SIM-MDL (µg/kg)
Naphthalene	80,000	330	67	59
Acenaphthylene	NL	330	78	39
Acenaphthene	36,000	330	91	42
Fluorene	28,000	330	86	60
Phenanthrene	NL	330	166[b]	99[b]
Anthrancene	1,900	330	166	99
Fluoranthene	1,600,000	330	159[b]	113[b]
Pyrene	1,200,000	330	159	113
Chrysene	120,000	330	139[b]	57[b]
Benzo(a)anthracene	1,200	330	139	57
Benzo(b)fluoranthene	1,200	330	45	57[b]
Benzo(k)fluoranthene	1,200	330	78[b]	57
Benzo(a)pyrene	120	330	78	57

[a] according to EPA CFR 40, Part 136 Appendix B
[b] co-eluted with its isomer, NL - not listed

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Attachment 5

SITEWORKS, INC.
TDGC/MS METHODS FOR FIELD ANALYSIS
OF POLYCHLORINATED BIPHENYLS IN SOIL MATRICES

TDGC/MS METHODS FOR FIELD ANALYSIS OF POLYCHLORINATED BIPHENYLS IN SOIL MATRICES.

1.0 SCOPE AND APPLICATION

1.1 Quantitative methods are provided for the identification and quantitation of polychlorinated biphenyls (PCB's) in soil or sediment. The methods differ in the precision of the data obtained and time required per experiment. The rapid isothermal PCB method requires approximately 3 min/experiment with measurement precision of ± 40% of dry sample, while the temperature programmed GC method requires approximately 5 min/experiment and measurement precision of ± 30%. A direct soil analysis screening method is also described. Total PCB and chlorination level (1-8) PCB may be determined by these methods. Since PCB's are identified and measured as chlorination level groups, the non-specific CAS number for each level of chlorination is used to identify method analytes.

Analyte	Formula	CAS no.*
Monochlorobiphenyls	$C_{12}H_9Cl$	27323-18-8
Dichlorobiphenyls	$C_{12}H_8Cl_2$	25512-42-9
Trichlorobiphenyls	$C_{12}H_7Cl_3$	25323-68-6
Tetrachlorobiphenyls	$C_{12}H_6Cl_4$	26914-33-0
Pentachlorobiphenyls	$C_{12}H_5Cl_5$	25429-29-2
Hexachlorobiphenyls	$C_{12}H_4Cl_6$	26601-64-9
Heptachlorobiphenyls	$C_{12}H_3Cl_7$	28655-71-2
Octachlorobiphenyls	$C_{12}H_2Cl_8$	31472-83-0

*CAS No. = Chemical Abstracts Service registry number

Nonachlorobiphenyls and decachlorobiphenyl are not detected by these methods because their molecular weights and primary ion molecular weights exceed the mass range of the mass spectrometer (1-400amu).

1.2 The two methods can be used with slight modifications to determine most semi-volatile compounds that can be thermally desorbed or solvent extracted from soil.

1.3 The practical quantitation limit (PQL) of the screening and the more quantitative methods for determining total PCB are approximately 0.1 mg/kg (dry weight) for soil/sediment samples.

2.0 SUMMARY OF METHODS

2.1 Screening method. Soil/sediment sample (1-10-g) is weighed and a known quantity of internal standard (pyrene-d_{10}) added. The "spiked" soil is placed in a Pyrex petri dish. The heated head (260°C) of the instrument's sampling probe is lowered onto the soil and the compounds are thermally desorbed. Gas chromatographic separation is partially achieved in the short capillary column which is heated using a temperature program. The eluted compounds are introduced into the mass spectrometer for identification and quantitation.

2.2 Quantitative method. Soil/sediment sample (0.5-2-g) is weighed and placed into a sampling vial. An aliquot of hexane (2-10-mL) is added and the vial shaken for two minutes. An aliquot of the extract (5-10-μL) and 5-10-μL of the internal standard are injected onto the Pyrex petri dish. The compounds are then thermally desorbed as above *and* identified and quantified by the mass spectrometer system.

3.0 INTERFERENCES

3.1 Cross-sample contamination can occur when low concentration samples are analyzed after highly concentrated samples. This can be avoided by thermally cleaning the sampling probe and the capillary column at 260°C and 240°C respectively, for a few minutes after a highly concentrated sample has been analyzed. The Pyrex

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petri dish must be cleaned with solvent after each analysis.

4.0 APPARATUS AND MATERIALS

4.1 Thermal desorption gas chromatogrph/mass spectrometer (TDGC/MS) system.

4.1.1 Mass spectrometer, Bruker Instruments Mobile Environmental Monitor (MEM), equipped with a shock-resistant hyberbolic quadrupole, capable of scanning from 1 to 400 amu every second or less, using 70 volts (nominal) electron energy in the electron impact ionization mode. The MS requires no external cooling or an environmentally controlled room for operation.

4.1.2 Sampling device - TDGC, Bruker Instruments or equivalent, capable of programmale isothermal desorption temperatures up to 260°C and fused silica GC column temperature programmable up to 240°C.

4.1.3 Column- 3.5-m x 0.32-mm i.d., 0.25-μ fused-silica capillary column (J&W Scientific DB-5).

4.1.4 GC/MS interface - Direct inlet system through a semi-permeable methyl silicone membrane capable of preferentially excluding components of air and moisture relative to organic compounds.

4.2 Data system - A computer may be interfaced to the TDGC/MS but is not necessary since there is a microprocessor incorporated in the system which gives logarithmic response values updated every second as well as amount vs. time ion signal chromatographic curves at the end of the analysis for each target analyte. If an external data system is interfaced, it must allow the continuous acquisition and storage on machine-readable media of all mass spectra obtained throughout the duration of the TDGC program. The computer must have software that can search any MS data file or ions of a specific mass (or group of masses). The system must be capable of plotting such ion abundances versus time or scan number. This type of plot is defined as a total ion current chromatogram (TICC). Software must also be available that allows for integration of the abundances of the ion intensities throughout the chromatographic run.

4.3 Tools and equipment

4.3.1 Pyrex dish

4.3.2 Metal spatula

4.3.3 Microsyringes, 10-µL, 25-µL, and 100-µL, gastight

4.3.4 5 or 10-mL sample vials

4.3.5 Analytical balance, capable of accurately weighing 0.0001-g.

4.3.6 Portable balance, 60-g capacity, 0.02-g sensitivity, AND model EW-60B or equivalent

5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2.1 Prepare stock standard solutions by accurately weighing about 0.0100-g of pure material. Dissolve the material in HPLC grade hexane or other suitable solvent and dilute in a 10-mL volumetric flask. Larger volumes can be used at the convenience of the analyst. When compound

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purity is assayed to be 96% or greater, the weight may be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards may be used at any concentration if they are certified by the manufacturer or by an independent source.

5.2.2 Transfer the stock standard solutions into bottles with Teflon lined screw caps. Store at 4°C and protect from light. Stock standard solutions should be checked frequently for signs of degradation or evaporation, especially prior to the preparation of calibration standards.

5.2.3 Stock standard solutions must be replaced after 1 year or sooner if comparison with quality control check samples indicates a problem.

5.3 Internal Standard solutions - The internal standards recommended are naphthalene-d_8, pyrene-d_{10}, and chrysene-d_{12}. Pyrene-d_{10} will be used for projects requiring one internal standard. Other compounds may be used as internal standards provided the chromatographic elution time and MS signal response have been deemed adequate to represent the group of target analytes without interferences. Add 100-mg of each compound in a 50-mL volumetric flask and dissolve with hexane or other suitable solvent. Agitate if needed to dissolve totally any solid residues. The resulting solution will contain each standard at a concentration of 2000-ng/μL. Dilute this stock standard with hexane to reach a concentration of 100-ng/μL or as needed. Store at 4°C or less when not being used.

5.4 Calibration standards - A minimum of five calibration standard concentrations should be used. One of the calibration standards should be at a concentration near, but above, the method detection limit; the remaining standards should correspond to the range of concentrations found in real samples, but should not exceed the working range of the TDGC/MS system. Since it is unrealistic to include all 209 PCB analytes in the PCB calibration standard solution, one congener representing each chlorination level will be used for calibrating the instrument. The nine congeners and their relative concentrations are shown in the following table. The solution was purchased from Ultra Scientific, Hope, RI, but any equivalent solution can be used.

IUPAC #	Compound	ng/μL
1	2-Chlorobiphenyl	50
5	2,3-Dichlorobiphenyl	50
29	2,4,5-Trichlorobiphenyl	50
50	2,2',4,6-Tetrachlorobiphenyl	100
87	2,2',3,4,5'-Pentachlorobiphenyl	100
154	2,2',4,4',5,6'-Hexachlorobiphenyl	100
188	2,2',3,4',5,6,6'-Heptachlorobiphenyl	150
200	2,2',3,3',4,5',6,6'-Octachlorobiphenyl	150
209	Decachlorobiphenyl	250

The total PCB concentration of the solution is 1-mg/mL. The EI 100% ion and many of the fragment ions of decachlorobiphenyl exceeds the mass range of the quadrupole and is therefore not included for detection. Stock solutions should be stored at -10°C to -20°C and should be freshly prepared once a year, or sooner if check standards indicate a problem. The daily calibration standard should be prepared weekly, and stored at 4°C. The purpose of the calibration standard is to produce a linear dynamic range plot over a wide range of concentrations and to check MS response factors.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 For a detailed study of these subjects see: Lawrence H. Keith, "Principles of Environmental Sampling", American Chemical Society, 1988.

6.2 Samples that are transported to the lab for confirmation must be stored in sealed vials and placed in ice. The soil must be extracted and analyzed within holding time deadlines.

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7.0 TUNING OF THE TDGC/MS

7.1 MS automatic calibration- For the automatic calibration of the instrument, eight masses of the calibration compound (FC-77, a mixture of fluorinated hydrocarbons) are selected: 69, 100, 119, 169, 219, 269, 331, and 397 as well as argon (m/z = 40) and moisture (m/z = 18) in the carrier gas (air). The procedure is automatically implemented upon manual selection of the automatic calibration feature of the instrument. For all 10 masses, starting with 18 amu, the MS system adjusts the mass, peak width and energy in that order until it achieves the optimized values. The resolution is set to unity with a *ca.* 10% valley definition; this is done by measuring the actual peak width and adjusting the peak width parameter accordingly. Typically, the auto-calibrate procedure is all that is required for field measurements. The MS system periodically checks the mass alignment at a rate of every 15 minutes the first two hours, every half hour the second two hours, and every hour for each hour thereafter. Mass spectral drift is automatically monitored through the on-board microprocessor diagnostics. The mass alignment values should be manually verified on a regular basis as a secondary means of quality assurance.

8.0 DAILY CALIBRATION AND QA/QC PROTOCOLS

8.1 Response Factor Calculations- Before mobilizing the TDGC/MS unit to the field, the analyst must prepare calibration standards to establish a five point analyte calibration curve at the beginning of each study. Using a standard mixture of either an Arochlor or chlorination level mixture of PCB's will reduce the time needed to prepare these standards. The lowest concentration calibration standards should be at a concentration near, but above, the instrument detection limit. The other concentrations should correspond to the expected range of concentrations found in the "real-world" samples or the establishment of the TDGC/MS dynamic range.

8.2 <u>PCB's in Soil:</u>

8.2.1 Prior to any calibration curve standard analyses, the TDGC/MS system is checked for background contamination by performing an instrument blank. The instrument blank is performed by running the TDGC temperature program without analyte desorption.

8.2.2 Following the instrument blank, a method blank is performed where the extraction solvent, apparatus, and petri dish are checked for background contamination. A blank (no soil) extraction procedure is performed and an aliquot of the resulting extract solvent is placed on the petri dish and allowed to volatilize. The residue is then thermally desorbed off of the Pyrex dish by heating the sample head of the GC probe at 260°C. The solvent residue is thus analyzed using the method GC temperature program with MS detection for the presence/absence of background contaminants due to methodology. If background contamination is found, a stepwise process of elimination is perfomed from the Petri dish back to the initial extraction solvent to isolate and eliminate the source of contamination. Prior to any analyses (calibration or site samples) the system must be found to be free of any outside sources of contamination. Carrier gas contamination is not a problem due to the ability of the instrument threshold settings to be manually established on a site to site basis dependent upon the ambient air levels of contamination by targeted volatile PCB's. If the internal standard (d_{10}-pyrene) is suspected to be contaminated, this procedure must be repeated using the pyrene-d_{10} in lieu of the extraction solvent.

8.2.3 Analyze the calibration sample as described in Section 9.0. Repeat each analysis one time for each concentration. Tabulate the area response of the characteristic ions against concentration for each compound and internal standard and calculate response factors (RF) for each compound using Eq. 1:

$$RF = (A_x)(C_{is})/(A_{is})(C_x) \quad \text{where,} \quad [1]$$

A_x = area of the standard target analyte ion current signal
C_{is} = concentration of the internal standard (d_{10}-pyrene)
A_{is} = area of the internal standard ion current signal (d_{10}-pyrene)
C_x = concentration of the standard target analyte

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If the RF value is constant (i.e., < 30% relative standard deviation, RSD) over the dynamic range, the RF can be assumed to be invariant and the average from the RF value(s) can be used for quantitation. If the average RF values for any analytes fall outside of the 30% RSD window, the instrument must be checked for mass drift and the point or points skewing the curve must be performed again.

8.2.4 The working calibration curve or RF must be verified each working day by measurement of the analyte response factors. If the response for any compound varies from the initial calibration curve response factor by more than ± 30%, the test must be repeated using a fresh calibration standard at a second concentration. If any of the analyte RF's calculated from this second point fall outside of the 30% window, a third concentration is analyzed thus establishing a new 3-point calibration curve. If all of the analyte RF's from this new 3-point curve have respective %RSD's within 30% across the concentration gradient, the average RF for each analyte becomes the new calibration curve RF for the study. It should be noted that the concentrations analyzed for this 3-point curve need to be carefully selected to encompass the range of actual real world analyte concentrations encountered at the site.

8.2.5 For direct thermal desorption soil measurements, a second calibration curve must be generated to establish linearity and response factors to calculate relative concentrations. These experiments must emulate the above stated experiments with the exception that the PCB standard solutions and internal standard must be injected directly into a known quantity of field blank soil sample and thermally desorbed directly from the soil matrix. The response factor calculation, five point initial calibration curve, and daily RF update protocols will be performed. The response factors generated through this curve will obviate the need for direct soil thermal desorption extraction efficiency correction factors. Due to the direct nature of the GC column/soil interface high levels of background interferants should be expected and, therefore, this type of analysis must be performed in the SIM MS mode of the TDGC/MS. Long TDGC bakeout times should be expected between direct soil analyses to avoid carryover and allow the MS system to remain free of high molecular weight hydrocarbons.

8.2.6 Prior to sample analyses, an analyte recovery experiment must be performed. To perform this experiment, a representative soil sample field blank must be collected. This soil sample is spiked with a known concentration of all targeted analytes and allowed to bond to the soil matrix for a period of at least 30 minutes. The spiked soil sample is extracted as discussed in section 9, and analyzed by TDGC/MS. This procedure should be performed in triplicate for each different soil type at the site to determine the precision of the recovery values. If the precision values fall within 30% RSD for triplicate spiking experiments, the individual analyte method recovery numbers are incorporated into the quantitation calculation. If the recovery values fall outside of the 30% RSD precision criteria, a more homogenous soil matrix is used for a second set of experiments and the MS system is checked for mass alignment.

9.0 SAMPLE EXTRACTION AND TDGC/MS ANALYSIS

9.1 After proper tuning of the MS, calibrate the system daily as described in Section 8.

9.2 Sample preparation

9.2.1 Thermal desorption of soil extracts: The analyst must weigh out ~0.5-g of the dried soil/sediment sample and place it in a 5-mL sample vial with a teflon lined screw cap. To this vial, add 2-mL of HPLC grade hexane as the organic solvent. This solution is then hand shaken for 2 minutes, allowed to settle briefly (5-10 seconds or use a centrifuge), then is extracted using a Pasteur pipette. The extract is then filtered using a 5-mL disposable syringe and disposable 0.45-μ syringe filter. A 5-μL aliquot of this extract is injected onto a Pyrex petri dish (using a 10-mL gastight syringe) along with (using a different 10-μL syringe) 5-μL of the 50-ng/μL d_{10}-pyrene internal standard previously prepared. The liquid sample and internal standard are then thermally desorbed into the capillary column of the TDGC. The weight of the soil before and after drying are noted for inclusion into the quantitation calculation as needed. Internal standard concentration will vary dependent upon individual instrument sensitivity and levels of monitored analytes expected to be found at the sampling location. Internal standard concentration will vary dependent

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