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FIELD SAMPLING PLAN
PHASE II REMEDIAL INVESTIGATION

INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

Prepared for:

NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
LESTER, PENNSYLVANIA

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1.0 INTRODUCTION

This Field Sampling Plan (FSP) has been developed to implement the Work Plan for the Phase II Remedial Investigation (Phase II RI) at the Naval Submarine Base-New London (NSB-NLON) in Groton, Connecticut. This work is being conducted as part of the Navy's Installation Restoration (IR) Program.

The NSB-NLON site vicinity and site location are provided in Figures 1-1 and 1-2, respectively.

The Work Plan summarizes the overall objectives of the Phase II RI. The objective and rationale for data requirements of the field investigation are also specified. The purpose of this FSP is to provide additional detail and specifications for the conduct of the field investigation. It is not intended to repeat the overall objectives of the program included in the Work Plan.

Sites included in the Phase II RI program and discussed in this FSP are in three different phases of the Installation Restoration Program. These phases and associated sites are discussed below. The site locations are indicated on Figure 1-3.

Supplemental Step I Investigations

Two sites are included in this category. These are sites where Step I investigations have been completed. The Step I investigations identified low levels of chemicals which were determined to pose no risk to human health and the environment. However, in responses to comments by the Connecticut Department of Environmental Protection (CTDEP) and the United States Environmental Protection Agency (U.S. EPA), supplemental field investigations are being conducted to confirm that chemicals are not present at levels of concern. The sites included for Supplemental Step I Investigations are as follows:

- CBU Drum Storage Area
- Over Bank Disposal Area Northeast (OBDANE)

Step II Investigations

The Step II Investigations involve sites which have undergone an initial (i.e., Step I) field sampling/analysis program in which contamination was determined to be present. Step II investigations involve comprehensive site studies designed to determine the nature and extent of contamination, associated health and environmental risks, and to conduct feasibility studies to evaluate remedial (cleanup) options. Step II investigations will be conducted at the following sites:

- Rubble Fill at Bunker A-86
- Torpedo Shops
- Goss Cove Landfill
- Spent Acid Storage and Disposal Area

INSTALLATION RESTORATION STUDY

NAVAL SUBMARINE BASE - NEW LONDON

GROTON, CT

SOURCE: Marshall Penn-York Co. Inc.

Miles

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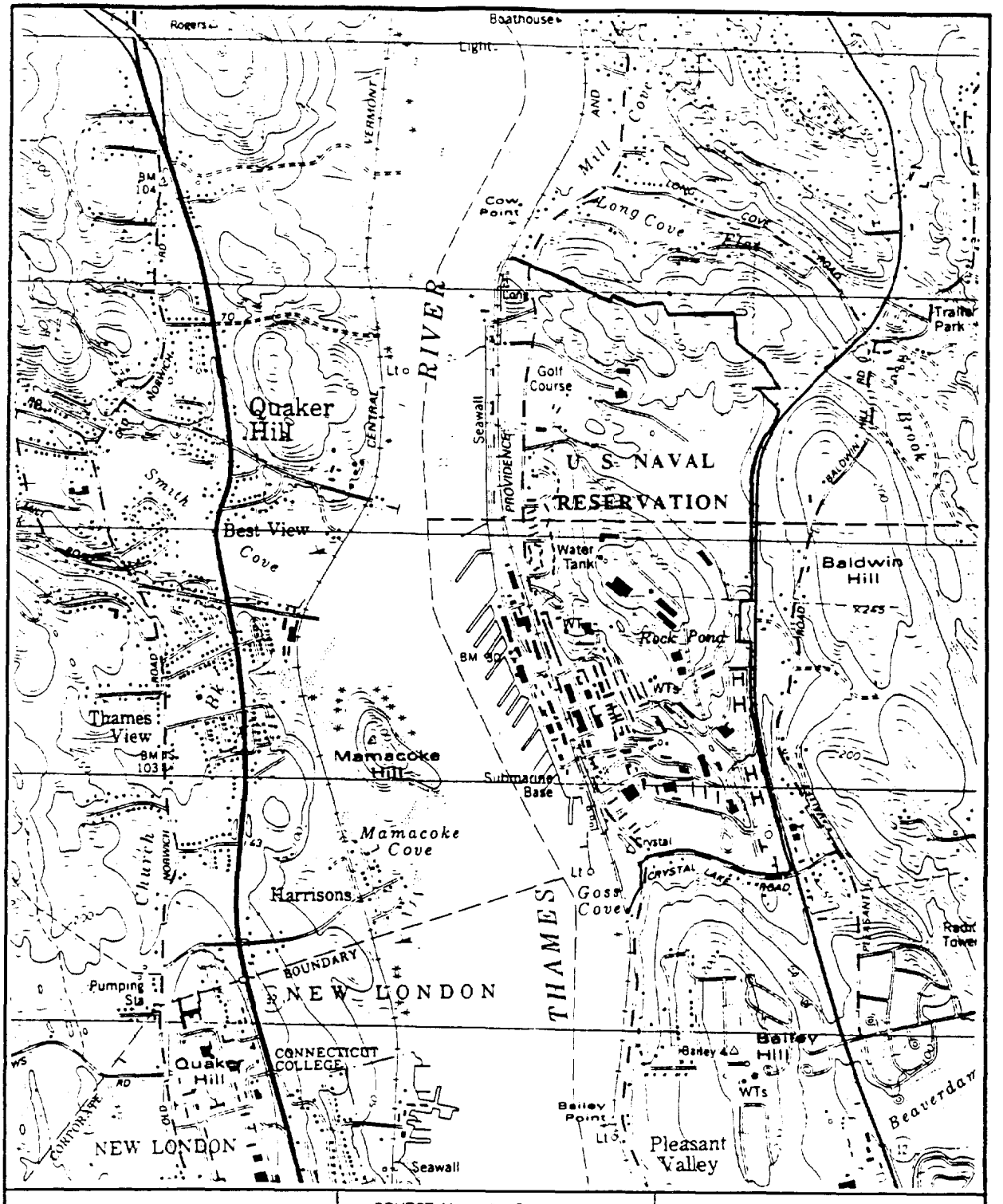
APPROXIMATE SCALE

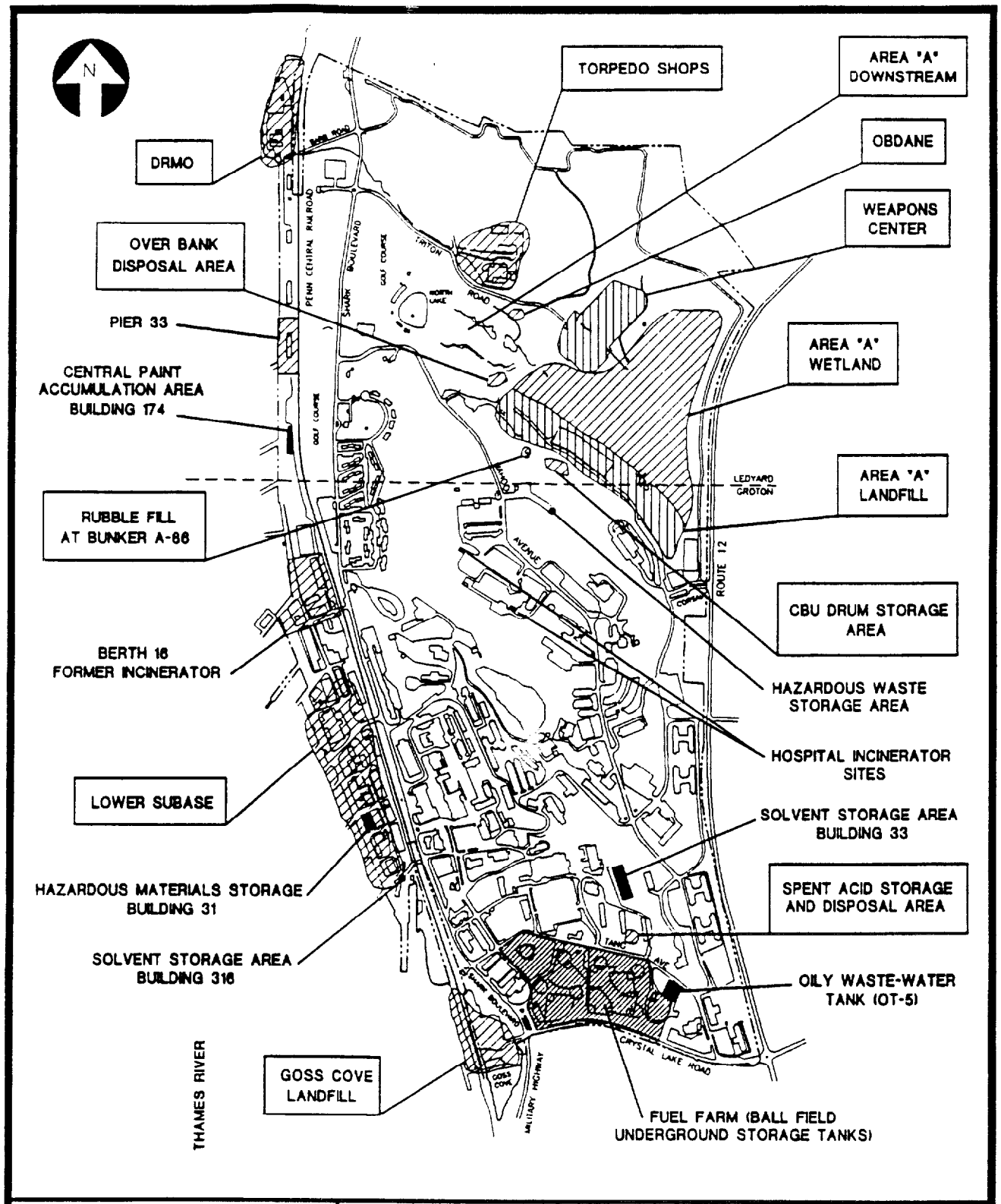
FIGURE 1-1

SITE VICINITY

ATLANTIC ENVIRONMENTAL SERVICES, INC.



INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT	SOURCE: Uncasville, Ct. U.S.G.S. Topographic Map 1984 N 0 1000 2000' SCALE	FIGURE 1-2 SITE LOCATION ATLANTIC ENVIRONMENTAL SERVICES, INC.



INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT

LEGEND

GOSS COVE LANDFILL — Phase II RI Workplan Investigation Site

SOURCE: Naval Submarine Base, Existing Conditions
Loureiro Engineering Associates, April 1985

0 600 1200
GRAPHIC SCALE IN FEET

FIGURE 1-3
INSTALLATION RESTORATION STUDY SITES

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Supplemental Step II Investigations

Supplemental Step II Investigations involve sites that have undergone extensive Step II investigations. However, supplemental information is required to further define the extent of contamination and health and ecological risks to support the development and evaluation of remedial alternatives. Supplemental investigations will be conducted at the following sites:

- Area A
  - Landfill
  - Wetland
  - Downstream/OBDA
  - Weapons Center
- Defense Reutilization and Marketing Office (DRMO)
- Lower Subase

Two additional Step I sites, Pier 33 and Berth 16/Former Incinerator, have also been added to the IR program and are included in a Field Sampling Plan dated July 1992. Furthermore, a separate Work Plan has been prepared to establish background levels for inorganics in soils and to further assess the source of boron in residential wells and in NSB-NLON ground water. The implementation of the boron study is contingent upon findings reported after the first year of quarterly residential well sampling. If boron is present in elevated levels, the Work Plan will be implemented. Otherwise, the background inorganics in soil will be the only focus of the Work Plan.

Subsequent sections of this FSP are summarized as follows:

Section 2.0 - Site Background: This section provides a brief summary of each site. Complete background discussions of each site, including geology and nature and extent of contamination, are provided in the Work Plan.

Section 3.0 - Field Mobilization: This section provides a discussion of pre-investigation activities, including establishment of field office and laboratory, waste storage areas, mobilization activities, and general emergency and safety briefing procedures.

Section 4.0 - Field Investigation: There are two subsections included: General Procedures and Field Sampling Program. The General Procedures section provides a detailed description of all field investigation items such as soil gas survey, well construction, surveying and mapping, etc. These discussions supplement the Standard Operating Procedures (SOPs) to be used for this project. The Field Sampling Program subsection details the sample locations, sample selection rationale procedures, quantities, type, analysis requirements, and other investigative details. The specific protocols discussed in the General Procedures section are not repeated; the site-specific detail and variations are specified as applicable.

Section 5.0 - Sample Preservation and Shipping: Protocols and procedures for sample preservation and shipping are provided in this section.

Section 6.0 - Record Keeping and Documentation: This section discusses the record keeping and documentation requirements for the field investigation portion of the project.

Section 7.0 - Schedule: This section describes the schedule for implementation of this field sampling plan.

2.0 SITE BACKGROUND

A brief summary of the physical and historic waste disposal/storage aspects of each site follow. Site plans for each site are included in Section 4.0, Field Investigation.

2.1 Supplemental Step I Investigations

2.1.1 CBU Drum Storage Area

The Construction Battalion Unit (CBU) Drum Storage Area is located in the northern section of NSB-NLON adjacent to the deployed personnel parking lot and on the southern limit of the Area A Landfill. The site is situated on a flat open area north of a wooded hillside that slopes down toward the site at a 25 to 30 percent grade. The size of the site is approximately 15 feet in width by 30 feet in length. The site is unpaved. Surface drainage from the site flows northeast across the unpaved deployed parking lot and into the Area A Wetland.

In 1982, the IAS identified twenty-six 55-gallon drums of waste oil, lube oil, and paint materials at the site. Some of the drums were leaking at that time. The IAS concluded that the site had not been used for several years.

Atlantic inspected the site on October 20, 1988 and observed two 55-gallon drums labeled as engine oil. No surface soil staining or stressed vegetation was evident. According to Navy personnel, the drums noted in the IAS report were removed and properly disposed of by the Navy; the two drums observed in 1988 subsequently have been removed. Atlantic reinspected the site on February 23, 1993; there were no drums observed onsite, nor was there any evidence of recent storage or leakage of drums.

2.1.2 OBDANE

The OBDANE site is located in a heavily wooded area on the edge of a ravine northwest of the Area A Landfill and south of the Torpedo Shops. A dirt road provides limited access to the wooded site. A nearly vertical 20-foot high bedrock face is located at the eastern edge of the site. The rest of the site slopes to the southwest. Surface runoff flows to the southwest and pools at the base of the slope in a small wetland area.

The IAS report stated that the vegetation at the site indicated that no dumping had occurred within ten years of their investigation (1982). Atlantic personnel inspected the site on September 30, 1988 and February 23, 1993 and verified the presence of several empty drums as stated in the IAS report.

2.2 Step II Investigations

2.2.1 Rubble Fill at Bunker A-86

Bunker A-86 is located on a dirt road off Wahoo Avenue in the north central section of NSB-NLON. The Area A Landfill is adjacent to the north, and the NSB-NLON hazardous

waste storage facility is adjacent to the south. The rubble fill area is located to the north of the dirt access road and to the west of the bunker.

Discarded construction material is present at this site including concrete, asphalt, an electric motor, wood and gravel. Chemical containers found at this site included an empty 5-gallon container of monothanolanine (labelled as corrosive product), an empty 5-gallon container of thorite (labelled as non-shrinking compound for patching concrete), and a 55-gallon drum of lube oil that was approximately 10 percent full.

2.2.2 Torpedo Shops

The Torpedo Shops are located in the northern portion of NSB-NLON on the north side of Triton Avenue. The two buildings onsite (Nos. 325 and 450) are torpedo overhaul/assembly facilities. These facilities were connected to an onsite septic system leach field until 1983, when they were connected to municipal sewers. A variety of fuels, solvents and petroleum products are used in these buildings. Direct disposal of these wastes to the septic system was reportedly not a routine practice, although sporadic, inadvertent chemical discharges to the subsurface septic system could have occurred. In the past, many of these wastes, along with spent Otto fuel, were discharged to floor drains connected to an underground storage tank. This tank has been properly abandoned; however, studies conducted at the time of closure indicate that the tank and associated plumbing had leaked. In addition, chemicals and chemical waste associated with overhaul activities, such as paints and solvents, have been stored onsite.

During recent construction activities near the entrance to this complex, an underground tank was discovered and removed. Soils in the tank excavation were determined to be contaminated with petroleum hydrocarbons.

2.2.3 Goss Cove Landfill

The Goss Cove Landfill site is located in the southwest portion of NSB-NLON, adjacent to the Thames River. The Nautilus Museum and a paved parking lot are constructed directly over the former landfill. The Nautilus Museum is a submarine museum operated by the Navy and open to the public.

The landfill reportedly operated from 1946 to 1957 and filled in the northern portion of Goss Cove. The southern portion of Goss Cove remains as a surface water body. Incinerator ash, inert rubble, and possibly other unknown materials were disposed at the site.

2.2.4 Spent Acid Storage and Disposal Area

This site is located in the southeastern section of NSB-NLON, in the southern portion of the area between Buildings 409 and 410. A 4' x 4' x 12' rubber-coated underground tank was used for temporary storage of waste battery acid during World War II. The tank top is still visible, but the tank has been filled with earth and capped with concrete.

2.3 Supplemental Step II Investigations

This section summarizes existing background information and data for the three Step II sites, which required supplemental information to complete the Step II (RI/FS) process. These sites are Area A, DRMO, and the Lower Subase.

2.3.1 Area A

Area A is comprised of individual sites including the Landfill, Wetland, Downstream/ OBDA, and Weapons Center.

The Area A Landfill is located in the northeastern and north-central section of NSB-NLON. It is approximately seven acres in size. Access is via a dirt road off Wahoo Avenue. The Area A Landfill is a relatively flat area bordered by a steep, wooded hillside that rises to the south, a steep wooded ravine to the west, and the Area A Wetland to the north. Aerial photographs show that the landfill appears to have extended east along the wetland to as far as the present position of the tennis courts. Runoff from the landfill drains as overland flow north into the Area A Wetland, which subsequently discharges to the Area A Downstream watercourses and into the Thames River.

The landfill opened sometime before 1957. The base incinerator ceased operating in 1963, and from 1963 to 1973 all wastes were disposed in the landfill unburned. During this time, all non-salvageable materials generated by the submarines and base operations were disposed in the Area A Landfill.

Landfilling operations ceased in 1973. After closure, a concrete pad was constructed in the southwest portion of the landfill for aboveground storage of industrial wastes. At the time of the IAS survey, 42 steel drums, 87 transformers (mineral and PCB), and 60 to 80 electrical switches were stored on the pad. Two transformers and several electrical switches were leaking. Past leakage of oil was also evident. Most drums were stacked on wooden pallets and those with PCB labels were covered and bound with plastic sheeting. All of these materials have since been properly disposed offsite.

Sand bags and contractors' supplies and equipment have, in recent years, been stored over the former landfill. Several transformers, excavated underground storage tanks, crane weights, and other equipment are stored on the concrete pad in the southwest portion of the landfill. The specific items stored in this area vary. The remainder of the landfill is not paved.

The construction of a paved parking lot on the southeast end of the Area A Landfill was planned, but has been delayed indefinitely.

The Area A Wetland abuts the north side of the landfill and is approximately 30 acres in size. The maximum wetland sediment thickness is approximately 35 feet, based on boring information. Until 1957, this portion of the site was undeveloped, wooded land. In 1957, dredge spoils from the Thames River were pumped to this area and contained within an earthen dike that extends from the Area A Landfill to the south side of the Weapons Storage Area.

Atlantic learned during the course of this study that pesticide ''bricks'' were previously placed on the wetland ice during winter and allowed to melt and discharge into the wetland for mosquito control.

The **Area A Downstream** watercourses drain the Area A Landfill and Wetland and ultimately flow into the Thames River. The Area A Downstream watercourses include North Lake and several small streams that discharge from Area A and the Torpedo Shop and ultimately discharge to the Thames River.

Ground water also discharges from the Area A Wetland to a small wetland at the base of the dike and the Over Bank Disposal Area. A stream flows from this wetland west toward North Lake, a recreational swimming area for Navy officers. The stream enters a culvert which bypasses the pond and discharges to a stream below the outfall of the pond. This stream flows west under Shark Boulevard and through the golf course to the Thames River. There is a manhole adjacent to North Lake, which was previously connected to a pipe designed to discharge overflow water from North Lake. This pipe has been plugged to prevent any possible water discharge from the stream to North Lake.

Further development is not planned for this area.

The **Over Bank Disposal Area (OBDA)** is located on the slope of the dike below and adjacent to the Area A Landfill. A small wetland exists at the base of the dike.

This area became a disposal site after the earthen dike was constructed in 1957. It was the finding of the previous studies (1982) that the material had been there for many years and included 30 partially covered 200-gallon metal fuel tanks and scrap lumber.

Atlantic personnel inspected the site in September 1988 and observed approximately 30 empty, unlabeled 200-gallon tanks, old creosoted telephone poles, several empty unlabeled 55-gallon drums, and rolls of wire. Bright orange, organic sediments were observed in the water discharging from the base of the dike embankment, apparently leachate from the landfill.

The **Weapons Center** site consists of Building 524 and the weapons storage bunkers. The storage bunkers area is divided into two portions (north and south), each constructed at different times and of different design. The site is located to the north and adjacent to the Area A Wetlands at the end of Triton Avenue.

The Weapons Center (Building 524) is located near the top of a bedrock ridge. The building was constructed in 1990-1991. Portions of the site were blasted to remove bedrock to allow construction of the building. The bunkers are located downhill of Building 524 adjacent to and at a slightly higher elevation than the wetlands. Surface runoff from the bunker storage areas flows to the wetlands via overland flow in small grassed swales and drainage culverts.

2.3.2 Defense Reutilization and Marketing Office (DRMO)

The Defense Reutilization and Marketing Office (DRMO) site is adjacent to the Thames

River in the northwest section of NSB-NLON. The DRMO is the storage and collection facility for items to be sold at auction sales held periodically through the year. Scrap metal is also temporarily stored prior to being transported off this site.

The DRMO site was used as a major base landfill and burning ground from 1950 to 1969. The materials burned and landfilled included construction materials, combustible scrap, and other non-salvageable waste items. These materials were reportedly burned on the shoreline and then disposed over the riverbank and partially covered. Also, a former battery acid handling facility was located adjacent to Building 491. An in-ground rubber-lined tank and associated pumping facilities were present, similar to the Spent Acid Storage and Disposal Area site.

DRMO operations at this site, after the closing of the landfill, included storage of various items, including submarine batteries, white goods, and empty drums.

Other routine grading and minor excavation can occur in the northern portion of the site. Future plans for this site include the construction of a Conforming Storage Facility for the temporary storage of hazardous waste generated at NSB-NLON.

2.3.3 Lower Subase

The Lower Subase is located along the western edge of NSB-NLON, adjacent to the Thames River. It is bound by the Thames River to the west and by the Penn Central Railroad to the east. The Lower Subase is the original subase, and its history dates back to 1867. Most of the construction took place in the early 1900s with major expansion between 1935 and 1945. Extensive portions of this area have been filled. The Lower Subase has always been used for operations and maintenance functions. Those functions typically generate industrial and hazardous wastes such as petroleum oils and cleaning solvents. Also at the Lower Subase are two sets of concrete underground storage tanks (USTs) located at the northern end of the study area. Four USTs are located just north of the powerhouse, and seven USTs are located just south of Building 107. In addition, there is an extensive underground fuel oil and diesel oil distribution system at the Lower Subase.

Previous investigations (NESO 1979, Wehran 1987) identified subsurface oil contamination associated with: both sets of underground storage tanks; a waste oil pit in Building 79 in which diesel train engines were serviced; and the underground fuel oil distribution system.

The Navy has implemented a substantial program to replace these underground tanks and the fuel oil distribution system. Of the ten concrete underground storage tanks, six now serve as spill containment for new steel tanks, three have been properly abandoned, and one is out-of-service. The Navy, while retrofitting or abandoning these tanks, did not detect any major structural defects or cracks. The underground No. 6 fuel oil lines will be abandoned in the future based upon present Navy plans. All of the subsurface No. 2 fuel oil lines were replaced or installed in 1980.

3.0 FIELD MOBILIZATION

The field mobilization will consist of the following steps which are subsequently discussed in the following sections. Section 7.0 presents the complete operation schedule.

- Field Office
- Decontamination Area and Equipment Storage Area
- Field Laboratory
- Waste Storage Area
- Sampling Locations
- Heavy Equipment Mobilization
- Emergency Procedures
- Onsite Safety Briefing

3.1 Field Office

An onsite trailer will serve as Atlantic's field office/operations center. The trailer will be located at the northern end of the Lower Subase, just north of Building 181 near the marina. Electricity and telephone (mobile unit) are available at the field office location. A portable toilet will be placed next to the trailer. Also, sanitary facilities are available in buildings adjacent to the sites to be investigated.

The field office will be designated as a "clean area" and only authorized personnel will be allowed access. The site trailer will serve as the main field operation and communications center throughout the field activities. Copies of all site reports, investigation plans, maps, sample log books, and chain-of-custody records will be maintained in this trailer. As specified in the project Health and Safety Plan (HASP), critical emergency situation information (e.g., emergency numbers, hospital location map) will be prominently displayed in the field office for quick reference.

3.2 Equipment Storage and Decontamination Area

A portion of the field office trailer will be used for the storage of field equipment, field instruments, and protective clothing and equipment. The trailer will have separate areas to segregate the protective clothing and equipment from the field equipment and instruments.

The equipment decontamination area will be located in Area A and will be clearly marked. This is the same location used for the Installation Restoration Study work conducted to date. Hand tools and drilling equipment (augers, drill rods, and core barrels) will be steam cleaned over a bermed plastic liner. Field sampling equipment will also be cleaned and decontaminated in this area. A personnel decontamination area will also be located next to the decontamination area. This decontamination area will be used for heavy equipment and drilling auger/casing decontamination. Individual decontamination areas will be located within the exclusion zone for each site as indicated in the HASP. Facilities for boot and glove washing, disposable coverall removal, and hand-washing will be available at each site. Decontamination procedures are described in the site Health and Safety Plan (HASP). Wastewater generated from

both personnel and equipment decontamination activities will be collected and stored in 55-gallon drums or portable tanks meeting applicable Department of Transportation (DOT) specifications. Disposable gloves, boots and coveralls will also be drummed. After a container or tank is filled it will be transferred to the Navy's onsite hazardous waste storage facility. Atlantic will provide for waste classification and disposal of the drums. However, the Navy is the generator of the waste and will be responsible for signing waste profile sheets and shipping documents, and approving the ultimate disposition of the wastes.

Areas of equipment storage and equipment decontamination within Area A are depicted in Figure 3-1.

3.3 Field Laboratory

A field laboratory will be located in a section of the field office trailer. The laboratory will contain a drying oven, soil shaker and sieves, hydrometer, electronic scale, pH meter, Eh meter, conductivity meter, filtering apparatus, analytical glassware, organic vapor analyzers (PID/FID), pre-cleaned and pre-preserved sample containers, deionized water, decontamination solutions, sample shipping containers, mailing labels, and field notebooks. A portable gas chromatograph (GC) and an X-ray fluorescence analyzer will be used for field screening select soil samples as specified in this plan. They will be used either at the site or in the field laboratory.

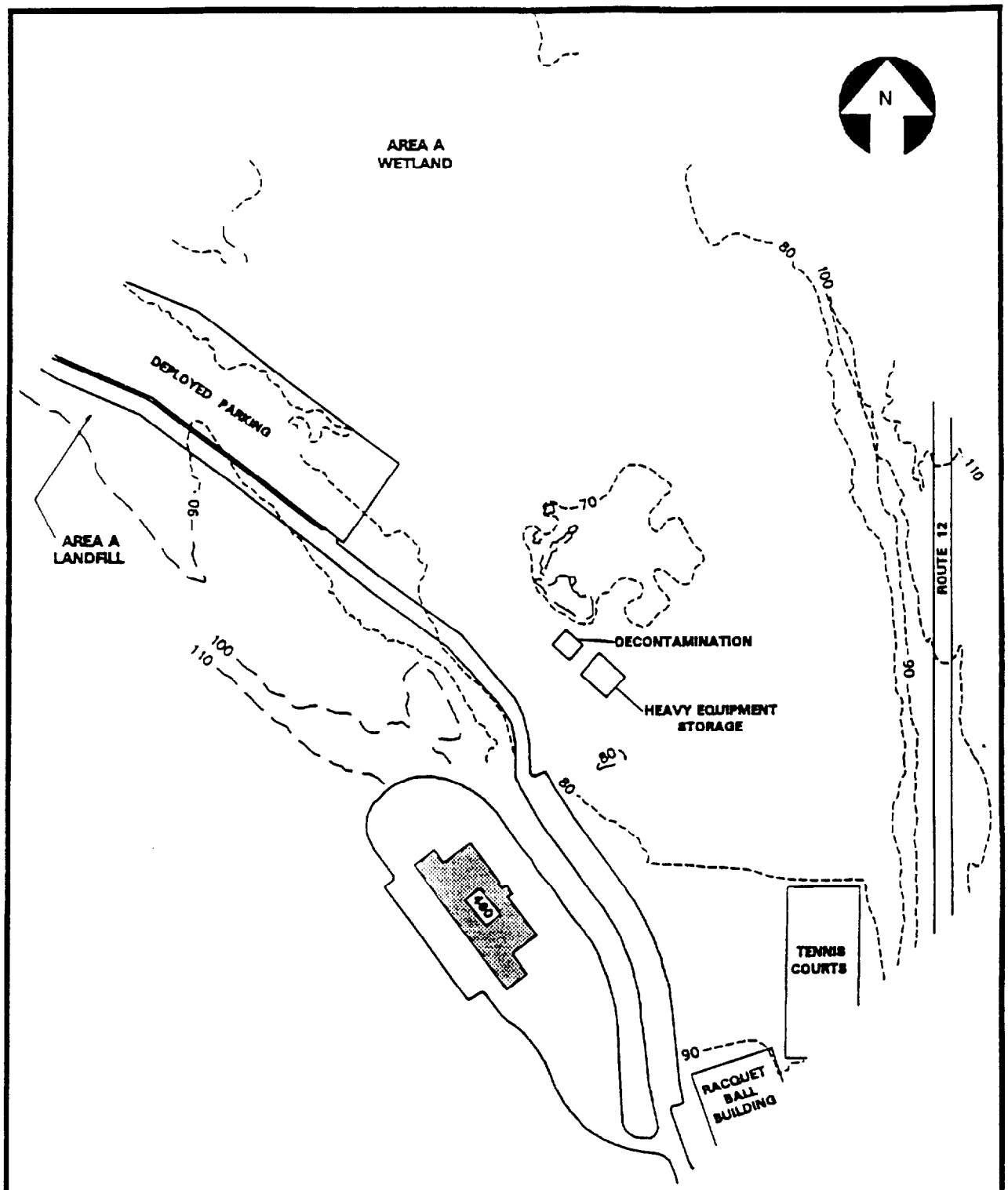
3.4 Waste Storage Area

Various wastes will be generated during field operations. These wastes may include: decontamination solutions, disposable equipment, well development water, and drill cuttings. These wastes will be collected daily and stored near the point of generation in 55-gallon drums or portable tanks meeting applicable DOT specifications. The drums will be labeled according to site name, date, volume, and type of material. Full drums will be transferred and stored in the Navy's RCRA permitted hazardous waste storage area. Final drum disposition will be handled as described in Section 3.2.

3.5 Sampling Locations

All proposed test boring and monitoring well locations will be marked by using fluorescent paint, and indicated by a circle. The sample location number will be painted adjacent to the marker. Sampling locations, including biological and air monitoring locations and soil gas sampling locations, are specified in the field sampling program (Section 4.2).

Information concerning the locations of underground utilities has been developed from available Navy mapping as part of this plan. Navy personnel will be contacted 10 days in advance of subsurface investigation for clearance of drilling locations.



INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT	LEGEND -- 95 --- Existing Grade	- Building Approximate Scale 0 80 160'	FIGURE 3-1 LOCATION OF ATLANTIC'S EQUIPMENT DECONTAMINATION AREA ATLANTIC ENVIRONMENTAL SERVICES, INC.

3.6 Heavy Equipment Mobilization

Drilling rigs will be mobilized to the site and will be parked in a designated section of the private contractors area at the Area A Landfill.

3.7 Emergency Procedures

Specific emergency procedures and routes to both the emergency room at the Naval Submarine Base and Lawrence and Memorial Hospital are identified in the HASP. The HASP will be reviewed by all site workers. Directions to the hospitals will be posted in the field office trailer.

3.8 Onsite Safety Briefing

Prior to field sampling activities, a safety briefing will be conducted by the Atlantic Site Safety Officer. The briefing will include a review of potential safety hazards inherent to each specific site and an explanation of the HASP. Documentation of safety training and medical histories of all site workers will be verified at this time. No one will be allowed to work on any of the sites until this documentation has been obtained.

4.0 FIELD INVESTIGATION

The field investigation portion of the subject investigations at NSB-NLON includes the following activities:

- field screening
- soil gas surveying
- test borings and subsurface soil sampling
- monitoring well construction, development and sampling
- hydraulic conductivity testing
- surface soil sampling
- surface water and sediment sampling
- dioxins and dibenzofurans sampling
- land surveying and mapping
- geologic surveying
- ecological studies
- air monitoring
- waste classification and disposal
- soils testing for engineering parameters

4.1 General Procedures

Atlantic procedures to be used in the field along with additional procedures to be used during this investigation are listed in Table 4-1. Complete procedures are provided in Appendix A. Associated procedural modifications for this site investigation are presented in Appendix A. The project specific modifications to the procedures take into consideration previous U.S. EPA and CTDEP comments regarding their review of the 1989 Plan of Action and other comments by the Technical Review Committee (TRC).

4.1.1 Field Screening

4.1.1.1 Sample Headspace Screening for VOCs

Atlantic will use a 11.8 eV photoionization detector (PID) or a flame ionization detector (FID) for total organic vapor analysis to perform headspace screening on all soil samples in the field, prior to laboratory analysis. Resulting data will not be used qualitatively. The operation and calibration of the organic vapor analyzers will be in accordance with manufacturers recommendations. The organic vapor analyzers will be calibrated at the beginning and end of each day of use, or more often as believed necessary. All calibrations will be recorded in a project instrument calibration log book.

TABLE 4-1 TECHNICAL PROCEDURES	
Procedure Number	**Atlantic Procedure**
1020	Field Procedures for Collection of Surface Soil Samples
1021	Field Procedures for Collection of Subsurface Soils
1022	Field Procedures for Collection of Surface Water and Sediment Samples for Hazardous Waste Determination
1023	Field Procedures for Collection of Ground Water Samples for Hazardous Waste Determination
1024	Field Procedures for Collection of TCDD Samples
1030	Field Procedures for Logging Subsurface Conditions During Test Borings and Well Logging
1041	Sample Chain-of-Custody Procedure
1042	Shipping Procedures for Environmental Field Samples
1051	Operation and Calibration of the HNu Systems Photoionizer Model PI-101
1052	Operation of the Photovac 10S50 Portable Gas Chromatograph
1053	Soil Gas Screening for Volatile Organics
1060	Cleaning Procedure for Sampling Devices Used in Environmental Site Investigations
1070	Well Development Procedures for Small Diameter Monitoring Wells
1071	Field Procedures for Determination of *In Situ* Hydraulic Conductivity with Single Well Hydraulic Tests
1256A	Gas Chromatography Analysis Using External Standard Calibration
1256B	Microscale Extraction
1256C	PCB and Pesticide Analysis by Gas Chromatography
1256D	The Determination of Volatile Organic Compounds in Ambient Air Using Tenax® Adsorption
GTP002	Operation of the Scitec Map Analyzer Model 310 for Lead in Soil Analyses
Standard Number	**ASTM Standards**
D422[1]	Standard Practice for Particle-size Analysis of Soils
D854[1]	Standard Test Method for Specific Gravity of Soils
D2216[1]	Standard Method for Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures
D2217[1]	Standard Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
D2974[2]	Standard Test Methods for Moisture, Ash, and Organic Matter of Peat Materials
Method Number	**U.S. EPA Method (SW 846)**
9040	pH Electrometric Measurement (SW 846)
9045[1]	Soil pH (SW 846)

TABLE 4-1 (continued) TECHNICAL PROCEDURES	
9050	Specific Conductance (SW 846)
9081[2]	Cation Exchange Capacity of Soils (SW-846)
Method Number	**U.S. EPA Method (Methods for the Determination of Toxic Organic Compounds in Ambient Air)**
TO1[2]	Determination of Volatile Organic Compounds in Ambient Air Using Tenax® Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS)
Method Number	**APHA Standard Methods for Examination of Water and Wastewater**
2580	Oxidation - Reduction Potential (Eh)
2340[2]	Hardness - Total as $CaCO_3$

[1] At the discretion of the project manager, these methods may be performed in a field laboratory or an offsite laboratory.

[2] These methods will be performed in an offsite laboratory.

4.1.1.2 PCB and DDT Screening

A gas chromatograph (GC) with an electron capture detector and isothermal or programmable oven will be used for PCB and DDT screening analysis. The practical detection limits range from 1 to 10 ppm for DDT and PCB using GC methods. U.S. EPA Method FM-18, *PCB Analysis Using a Gas Chromatograph in an On-Site Laboratory - Hexane/Methanol/Water Extraction*, will be followed.

Standards and blanks will be run every tenth sample. Calibration is determined by peaks and retention times of PCB and/or DDT standards. Calibration and use of the GC will be performed in accordance with the manufacturer's instrument manual. The GC instrument will be calibrated at the beginning and end of each day of use, or more frequently as deemed necessary. All calibrations will be recorded in a project instrument calibration log book.

4.1.1.3 Screening of pH, Eh, Temperature, Specific Conductance, Salinity, Hardness and Turbidity

Select soil samples as specified will also be screened for pH in the field using Method 9045 in SW-846 (EPA Test Methods for the Evaluation of Solid and Hazardous Waste). Ground water prior to sampling will also be screened in the field for pH, Eh, temperature, specific conductance and turbidity; and surface water will be screened for temperature, pH, Eh, hardness, and in samples from the Thames River salinity. The test methods are shown in Table 4-1. Methods 9040 and 9050 in SW-846 will be used for field measurements to determine pH, Eh and specific conductance in ground and surface water. Hardness will be determined by Method 2340C in APHA, *Standard Methods for the Examination of Water and Wastewater*.

Instruments used for measurement of pH, Eh, temperature, specific conductance and turbidity will be calibrated in accordance with the manufacturers' instructions at the beginning and end of each day of use. Additional field calibrations will be performed as deemed necessary. All calibrations will be recorded in a project instrument calibration log book.

4.1.1.4 Lead Screening

Lead screening will be performed at select sites as specified in Section 4.2. This screening will be conducted using a lead specific Scitec Portable X-ray Fluorescence (XRF) Analyzer. The practical detection limits range from 100 to 500 ppm for lead using XRF. U.S. EPA Method FM-3 *X-Ray Fluorescence (XRF) for Heavy Metals (Onsite)* will be used for the XRF survey with modification for use with the Scitec equipment.

The protocol for calibration and use of the Scitec XRF analyzer for the subject investigations is provided below:

- Bulk samples of the soil from the lead-contaminated plot will be collected and analyzed by means of atomic absorption spectrophotometry. Analysis will include concentrations of lead, iron, and calcium carbonate.

- Remaining material from the bulk samples will be returned by the laboratory to the XRF testing company. These samples and the XRF will be forwarded to the Scitec Corporation of Richland, Washington, for calibration of the instrument to the specific soil type (Note: The instrument will be recalibrated by the above procedures as necessary to compensate for changes in sample matrices).

- Initial assessment of the contaminated plot will be conducted as specified in the field sampling plan.

- At each of the sample locations, the technician will perform a nominal 240-second "confirmation" test, adjusted for source decay, as specified by the manufacturer of the device.

4.1.2 Soil Gas Surveying

Soil gas surveys will be performed to identify areas containing elevated levels of VOCs and potential "hot spots." This data will be used to facilitate effective placement of test borings and monitoring wells. The soil gas surveys will be performed using a Photovac Model 10S50 portable field gas chromatograph with CPSIL 19 capillary column and a photoionization detector. Soil gas samples will be obtained by using a plunger bar and air sampling pump. Photovac analytical procedures are specified in Atlantic Procedure No. 1052. Sampling procedures are specified in *Soil Gas Screening for Volatile Organics* (Atlantic Procedure No. 1053). Note that air standards (versus aqueous headspace standards) will be used to calibrate the Photovac for soil gas surveys during these investigations. The instrument will be calibrated at the beginning and the end of each day of use, and at a minimum average of one time per ten samples analyzed.

4.1.3 Test Borings and Subsurface Soil Sampling

Soil borings will be advanced with 4¼-inch (inside diameter) hollow stem augers. Samples will be collected continuously with a 3-inch diameter, 2-foot long split-spoon sampler or, alternatively, with a 5-foot Central Mining Equipment (CME) or Waterloo Sampler. Subsurface soil samples will be collected in accordance with Atlantic Procedure No. 1021. Bedrock corings will be advanced using a diamond carbide coring bit.

Atlantic personnel will log physical characteristics such as color, density, lithology and moisture as well as any visual evidence of contamination (i.e., staining or sheen) according to Atlantic Procedure No. 1030. All soil samples will be screened with a PID or FID organic vapor analyzer.

4.1.4 Monitoring Well Construction, Development and Sampling

4.1.4.1 Monitoring Well Construction

Overburden monitoring well borings will be drilled using hollow stem augers with a minimum inside diameter of 4¼ inches. Subsurface soils may be sampled in accordance with

procedures described in Section 4.1.3. Overburden monitoring wells will be constructed using 2-inch inside diameter, flush-threaded Schedule 40 PVC screen and blank casing. The screened interval will not exceed 10 feet in length. The screen slot size will be small enough to retain 90 percent of the filter pack (d_{10} grain size). In most installations, a 0.010-inch slot will be appropriate. In shallow overburden monitoring wells, the top of the screen will be placed approximately 1 foot above the high ground water elevation to allow for ground water fluctuations. This height may be adjusted to allow for the proper seal around the well at the ground surface. In deep overburden monitoring wells, the screen will not extend across the water table. High ground water elevation will be determined based on Phase I field investigation data and observations made during drilling. In selecting a screened interval, the character of the soil will be considered to ensure that screens are not installed across confining layers and, if possible, screens will be confined to discrete stratigraphic or hydrologic units. Also, screen placement will be based on the physical characteristics and mobilities of the contaminants of concern present at each site.

The annular space between the well screen and the borehole wall will be backfilled with washed silica sand to at least 1 foot above the top of the screen, and a bentonite pellet seal (minimum 2 feet thick) will be placed above the sand. The annulus will be sealed with cement/bentonite (6 to 1 ratio, respectively) grout above the bentonite seal.

Unscreened bedrock monitoring wells within Area A will be installed to a minimum depth of 20 feet below the bedrock surface. Wells will be constructed using 6-inch diameter steel casing. The wells will be cased through the overburden and sealed at the bedrock interface to avoid possible contamination of the bedrock aquifer by the material above. Using either air rotary or mud rotary methods, an 8- or 10-inch bit will be used to drill through the overburden and the first 5 feet of bedrock. The mud rotary technique will only be used as a last resort after all other methods have failed if borehole caving in the overburden prevents the placement of the bedrock casing. The mud should not come in contact with the open hole within the bedrock in order to prevent impacting ground water quality. Well casings will be grouted in place with a bentonite-cement slurry seal and allowed to set for 24 hours. A 6-inch roller bit or air hammer bit will be used to drill through the casing seal to the bedrock aquifer. Bedrock drilling will continue until a sufficient water bearing fracture is encountered. A flow rate of approximately 1-gallon per minute or greater will be considered adequate flow. This flow rate is estimated, based on the experience of the driller, by observing the flow of drilling fluids. Overburden and bedrock monitoring well construction diagrams are presented in Appendix B.

4.1.4.2 Monitoring Well Development

Monitoring wells will be developed no earlier than one day after installation. Development will include the use of a surge block and simultaneous pumping to remove fines from the sand backfill. Development will proceed until three successive measurements of specific conductance, temperature, and pH have stabilized (i.e., vary less than 10 percent) and turbidity is less than 5 NTUs, or until seven well volumes have been removed or four hours have elapsed, whichever is greater (Atlantic Procedure No. 1070). Atlantic's logging procedures (Atlantic Procedure No. 1030) will be followed.

4.1.4.3 Monitoring Well Sampling

Monitoring wells will be sampled according to Atlantic Procedure No. 1023. All shallow overburden wells will be purged and sampled with a peristaltic pump outfitted with Teflon® tubing. Teflon® bailers will be used for sampling VOCs. In bedrock wells containing a large volume of water, a centrifugal pump may be used for purging and a peristaltic pump for sampling. In bedrock wells where water level is below 25 feet, a positive displacement pump will be used for purging. Samples will be collected with Teflon® bailers or positive displacement pumps for non-volatiles. All purging or sampling equipment will either be dedicated, single-use disposable, or pre-cleaned as specified in Atlantic Procedure No. 1060. All ground water samples will be collected at least two weeks after well development has been completed.

Prior to the extraction of any ground water, the depth to water will be measured to the nearest 0.01 feet using an electronic water level indicator. If an oil layer is present, its thickness will be measured with a sonic interface probe. The depth of the well will also be sounded. The well volume will then be calculated. The water well measurement device will be properly decontaminated between wells. A minimum of three well volumes will be purged while measuring pH, temperature and conductivity at regular intervals. The ground water sample will be collected when these three parameters stabilize to within 5 percent fluctuation. In wells where a peristaltic pump is used for purging, the pump and tubing will be used to collect non-volatile samples. Following the collection of the last non-volatile sample, the peristaltic pump tubing will be removed from the well and the VOC sample will be collected with a Teflon® bailer. When a bailer is used to collect all samples, VOCs will be collected first to avoid the loss of volatiles that could be caused by agitation of ground water with a bailer. All samples for dissolved metals analysis will be field filtered with a 0.45 micron filter.

4.1.5 Evaluation of Aquifer Hydraulic Properties

Single well permeability tests, step-drawdown, and long-term aquifer pump tests will be performed to estimate aquifer properties across the site.

Single well permeability tests will be performed according to Atlantic Procedure No. 1071. Wells for permeability testing will be selected based on their placement within aquifer units relative to the areal distribution of aquifer material across the site. The type of permeability test performed will be based on criteria presented in Atlantic Procedure No. 1071 including position of well screen, expected permeability of sediments, need to contain discharge water, and site logistics. Slug displacement tests will be the preferred test method where relatively low permeabilities are expected. Single well pump tests will be recommended for units in which relatively high permeabilities are expected as long as discharge water can be properly contained.

Prior to each single well test, the static water level will be measured with an electronic water level indicator. A pressure transducer, displacement device or pump will be placed in the well and allowed to equilibrate. When the water level returns to the static position, either the displacement device will be removed or the pump will be started and the water levels will be

continuously monitored by the pressure transducer and recorded by a data logger. Hydraulic conductivity estimates from slug test data performed in wells situated in unconfined aquifers will be calculated using the Bouwer and Rice Method (1978 with 1989 update). Confined aquifer slug displacement test data will be used to calculate transmissivity by the Cooper, Bredehoeft, and Papadopoulous Method (1967). Transmissivity values will be calculated from single well pump test drawdown and recovery data using the Cooper Straight-line Method (Fetter 1980).

An aquifer pumping test will be conducted in the overburden materials in the northwest section of the Area A Landfill in order to determine hydraulic properties to evaluate the feasibility of pump-and-treat ground water remediation. The aquifer test design will include one pumping well and four drawdown observation wells located at different distances from the pumping well. Proposed well locations are illustrated on Figure 4-7. The observation wells will be installed approximately 30, 60, 100 and 200 feet from the pump well. The advantage of having numerous observation wells is that drawdown measurements can be used to study both time-drawdown and distance-drawdown relationships. The observation wells will be placed to form two radial lines from the pumping well. This will enable the analysis of variations in aquifer properties in more than one direction away from the pumping well. The pumping well will be constructed of 6-inch PVC screen and solid casing. The pump well will be installed to a depth of approximately 40 feet (i.e., to the top of the bedrock surface), and will be screened through the entire saturated thickness of the unconfined overburden aquifer. The drawdown observation wells will be constructed of 2-inch inside diameter, flush-threaded (Schedule 40) PVC screen (0.020-inch slot size) and solid casing. Each observation well will be screened through the full length of the overburden aquifer, so they can be used to measure the average hydraulic head in the overburden aquifer. The annular space between the well screen and the borehole will be backfilled with uniform coarse sand to facilitate the interflow of water. The remaining annular space will be filled to grade with cement-bentonite grout. Each observation well will be fitted with a 6-inch diameter flush-mounted cover, secured with cement.

A step-drawdown test will be conducted to determine the optimum pumping rate for the long-term aquifer test. The step-drawdown test will consist of pumping the well at successively higher rates for equal periods of time and measuring the resulting drawdowns in the observation wells. These drawdown and discharge measurements will be used to choose, empirically, an optimum yield and to determine the efficiency of the well. The entire test will be conducted for 24 hours.

After the optimum pumping rate has been selected and the water levels have returned to static levels, the long-term constant rate aquifer test will begin. Water levels will be continuously measured and recorded logarithmically during the pumping period using pressure transducers and a data logger. Pump discharge rate will be measured at least once every hour, and any necessary adjustments will be made to keep the rate constant. In addition to the four proposed observation wells, four existing monitoring wells located within Area A Landfill will be used as observation wells. Monitoring wells 2LMW7S, 2LMW9S and 2LMW13S will provide water level measurements at distances greater than 200 feet from the pump well. Measurements of water levels in monitoring well 2LMW7D, 2LMW9D and 2LMW13D (screened in the bedrock aquifer) will be collected to determine if there is any hydraulic interconnection between the overburden aquifer and the bedrock aquifer. The response of this

bedrock well to pumping may be delayed, depending on the degree of hydraulic connection. Monitoring well 2WMW3S and 3D (located approximately 1,500 feet from pump wells) will be monitored to asseas the natural behavior of the hydraulic head in the overburden aquifer. If water levels in this well change during the aquifer test (e.g., changes caused by natural discharge or recharge), these data will be needed to correct the drawdown induced by the pump test. The pumping period of the test will be 72 hours. This time may be reduced if a pseudo-steady-state is reached and/or boundary conditions are defined. This will be determined in the field by the site hydrogeologist, based on plots of preliminary drawdown data. Recovering water levels also will be monitored and recorded logarithmically once the pump is turned off. The aquifer test data will be used to calculate aquifer transmissivity and storativity using appropriate analytical techniques which will be dictated by the shape of the time-drawdown and distance-drawdown plots.

Ground water removed from the aquifer during the pump test will not be discharged into the subsurface. Purge water will either be discharged directly to the POTW by the existing onsite sanitary sewer system, or stored in aboveground liquid contaminant tanks, and transported and disposed in an offsite facility (e.g., POTW or TSDF). Implementation of the direct sewer discharged option would require an Emergency Discharge of Ground Water Authorization from the CTDEP, issued under Section 22a-449 of the Connecticut General Statutes and will require pretreatment. Purge water discharged to the sewer system or transported to the POTW will also require approval by the Town of Groton Wastewater Treatment Plant authorities.

4.1.6 Surface Soil Sampling

The surface soil sampling program is designed to screen for contamination within the upper 6 to 12 inches of soil. Protocols for sampling surface soils will be followed as specified in Atlantic Procedure No. 1020. Only discrete samples will be collected. Atlantic personnel will collect samples with a 4-inch, stainless steel hand-auger and stainless steel spoons. Samples will be logged by Atlantic personnel.

4.1.7 Surface Water and Sediment Sampling

Surface water and sediment samples will be collected in accordance with Atlantic Procedure No. 1022. At locations with intermittent flow, such as storm sewer outfalls, surface water samples will be collected from a discharge resulting from a storm event that is greater than 0.1 inches in magnitude and that occurs at least 72 hours after any previous storm event of 0.1 inches or greater. Where feasible, grab samples will be collected during the first 30 minutes of a storm event.

4.1.8 Dioxin (TCDD) and Dibenzofuran Sampling

TCDD/dibenzofuran sampling will be conducted in accordance with Atlantic Procedure No. 1024. This procedure includes rigorous criteria for sample homogenization and decontamination of used sampling equipment after sampling.

4.1.9 Land Surveying and Mapping

Methodologies and references to be used for surveying and for mapping are described below.

4.1.9.1 Surveying

Elevations and coordinates will be established for all monitoring wells and test borings. Coordinates/locations will be surveyed for the surface soil and sediment samples. Grid points will be surveyed and painted or staked in the field for the soil gas surveys.

All elevations will be based on differential leveling runs between known vertical control points and objects requiring elevations. All vertical control will be double run to confirm final elevations. Elevations will be accurate to Class V-2. The datum to be used is as shown on a map entitled, Base Traverse and Monuments, NAVFAC Drawing No. 2,037,619; Code Ident. No. 80091; Size: F; Contr. No. N62472-78-C-3422(ES) Sheet 1 of 2 prepared for the Department of the Navy by Kieltyka, Woodis & Pike Land Surveyors. The elevations are in the Subase datum, which is 1.41 $\pm$ feet below the USGS NGVD datum.

All coordinates will be based on field methods that conform to the standards of a Class A-2 survey. The Connecticut State Plane Coordinate System will be used.

4.1.9.2 Mapping

Map information for NSB-NLON (e.g., topography, buildings) was developed based on maps of NSB-NLON, prepared by Loureiro Engineering Associates, December 1980. These maps are 1 inch = 40 feet and have a 2-foot contour interval.

Maps of site plans and field sampling plans will be developed as required from the above-referenced maps using AutoCAD™, a computer aided design software package.

4.1.10 Geologic Surveying

An Atlantic geologist will map major fracture and lineament traces from overlapping aerial photographs of NSB-NLON, and obtain supplemental field measurements of geologic structures (e.g., joints, fractures) at major rock outcrops located primarily within the northern section of NSB-NLON. Any outcrops located along any adjacent roadways will also be mapped. The primary objective of geologic mapping is to identify major geologic structures which may be areas of high hydraulic conductivity (i.e., possible preferential pathways for ground water movement). Fracture and lineament traces often represent the surface expression of nearly vertical zones of fracture concentrations which are often areas with hydraulic conductivity greater than that of adjacent rock. Final well placement will take this data into consideration.

4.1.11 Ecological Studies

Methods for conducting biological studies are described in the Ecological Risk

Assessment Work Plan (Section 5.0).

4.1.12 Air Monitoring

All indoor and exterior background air monitoring samples will be collected in accordance with Section 10 (''sampling'') of the U.S. EPA T01 methodology. The T01 method is published in the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Supplement* (EPA/600/4-89/018 June 1988). The sampling method employs the use of glass tubes containing Tenax® adsorption media through which ambient air is drawn by a sampling pump. Method T01 and Atlantic's sampling SOP (1256D) for T01 analysis are provided in Appendix A.

4.1.13 Waste Classification and Disposal

All well purge and development waters and drill cuttings will be contained in 55-gallon drums or other appropriate containers or portable tanks meeting applicable DOT specifications. The drums will be labeled to identify the type of material contained (i.e., soil, water or sludge), the date collected, the site location, and boring number (or some other sampling location designation if appropriate). Drums, while being filled, will be stored at or near the site being investigated. After the drums are full, they will be transferred to the NSB-NLON RCRA-permitted hazardous waste storage facility until Atlantic's waste disposal contractor can dispose of drums found to contain contaminated media. Soils and wastewater will be properly characterized prior to disposal primarily based upon analyses of samples collected from the boring or well from which the contained soils/water originated. If necessary, supplemental analyses such as TCLP, VOC and SVOC (semi-volatile organic compounds) analyses will be performed. If the characterization indicates that any soils are not contaminated, these soils will be used as fill. Wastewater meeting the NSB-NLON NPDES discharge permit criteria may be disposed of at the onsite treatment facility. Contaminated soil/water will be disposed by a properly permitted disposal facility. Wastewaters generated from the pump test will be disposed under a temporary emergency discharge permit to be obtained from the CTDEP.

All waste collected will be disposed at facilities that are approved by the Navy and that are properly permitted for the specific waste type being disposed. Atlantic will arrange for waste classification and disposal. The Navy will sign as the generator of the material if offsite disposal is required.

4.1.14 Sampling and Testing of Soils for Engineering Parameters

Soils will be collected and analyzed for engineering parameters in accordance with the following standards:

- grain-size distribution (ASTM D422)
- specific gravity (ASTM D854)
- water content (ASTM D2216)
- organic content (ASTM D2974)
- total organic carbon content (Walkley-Black Determination in Piper 1942)

- cation exchange capacity (SW 846 9081)

4.1.15 Sampling and Testing of Ground Water for Engineering Parameters

Ground water will be collected and analyzed for engineering parameters in accordance with the following EPA standards in Methods for Chemical Analysis or Water and Wastes:

- Biochemical Oxygen Demand (25-day) (EPA 405.1)
- Chemical Oxygen Demand (EPA 410.2)
- Total Organic Carbon (EPA 415.1)
- Oil and Grease (EPA 413.1)
- Total Suspended Solids (EPA 160.2)
- Ammonia (as nitrogen) (EPA 350.2)
- Phosphorous (total) (EPA 365.1)
- Hardness (EPA 130.1 or 130.2)

4.1.16 Basewide Bedrock and Ground Water Contour Maps

A basewide bedrock map will be prepared as part of the Phase II RI Report. This report will be based on an evaluation of available boring logs and mapping of bedrock outcrops.

A basewide ground water contour map will also be prepared for the Phase II RI Report. This map will be based on water elevations measured during ground water sampling events (twice) and on the monthly monitoring for one year at 32 select locations. These 32 locations include 10 single monitoring wells, 19 nested monitoring wells, and three residential wells. The three residential wells are on property recently acquired by the Navy and are vacant. These locations are shown in Plate 2 and listed in Table 4-2 along with comments regarding selection of wells.

TABLE 4-2
LIST OF WELLS FOR MONTHLY WATER LEVEL MEASUREMENTS

Well I.D.	Comment
15MW3S, OBG-7, MW-6, ERM-4, 8MW8S/8D, 8MW6S/6D	South end of base transect
13MW1, 13MW19, 13MW8	Lower base transect
6MW5S/5D, 6MW3S/3D	DRMO transect
OSW28, OSW12, OSW29, 2LMW19S/19D, 2WMW21S/21D, 2WMW2D, 2WMW1D, 2WMW3D/3S, 2LM20S/20D, 2WMW5S/5D, 2LMW18S/18D	Near east gate and along Route 12
2LMW7D/7S, 3MW12S/12D, 7MW3S/3D, 2DMW16S/16D, 2DMW24S/24D, 2DMW25S/25D, 2DMW27S/27D, 19MW4, 2WMW22D, 2DMW23D	Area A transect and at North Lake

4.2 Field Sampling Plan

The following sections contain a description of the Field Sampling Plan for each of the investigation sites. The overall objectives of these sampling plans is provided in Section 7.0 of the Work Plan. This section details samples to be collected at each site, analyses to be performed, and the rationale for selection of samples from individual borings, placement of supplemental borings, placement of well screens and other sampling details specific to a site that are not elsewhere described. Section 4.1 above describes in detail methods and techniques to be used to obtain samples and for implementation of the Field Sampling Plan. (The QA/QC Plan contains reporting limits and testing methodologies).

4.2.1 Supplemental Step I Investigations

4.2.1.1 CBU Drum Storage Area

The constituents to be analyzed for at this site and the rationale for their selection are provided in Table 4-3A. The rationale for this program is provided in Table 4-3B and the Field Sampling Plan is shown in Figure 4-1.

A total of three test borings (including the monitoring wells) will be drilled at this site to characterize the stratigraphy and fill material at the site. Monitoring well 1MW1 will be advanced to a depth 4 feet below any evidence of contamination based on field screening with an organic vapor analyzer. The well screen will be set 10 feet into the uppermost aquifer. The remaining two borings 1TB1 and 1TB2 will be advanced to a depth of 15 feet or 4 feet below any evidence of contamination based on field screening with an organic vapor analyzer, whichever is greater. Continuous core samples will be collected from each boring for geologic logging and subsurface soil sample collection. Proposed boring locations are shown in Figure 4-1; however, final boring locations may differ due to field conditions and/or potential interference with utilities.

Subsurface soil samples will be collected from each boring for chemical analysis to determine if contamination exist and the nature of the contamination if present. Samples will be collected from within the CBU Drum Storage Area only. Samples will be collected from a depth of 0-2 feet from each of the three borings. Samples to be collected at a non-specified depth will be selected based upon field screening with an organic vapor analyzer (OVA), visual observations, water table elevation, or the presence of any fine-grained soil layer. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observation will be selected for analysis. If no such contamination is evident, a sample will be collected from either the elevation of ground water or from any fine-grained soil layers present above the water table.

One ground water monitoring well will be installed at the site. The well will be installed within the former drum storage area to characterize the quality of ground water at the site. No specific upgradient well will be installed at this site; however, proposed monitoring well 4MW1S will be used to determine upgradient ground water quality. Final well depth is expected to be no deeper than 20 feet based on adjacent monitoring well 2LMW8S. The proposed well is

TABLE 4-3A
CBU - DRUM STORAGE AREA
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	VOCs were detected in previously collected surface soil samples.
SVOC[2]	•	SVOCs were detected in previously collected surface soil samples.
Inorganic[3]	•	Elevated lead concentrations were detected in previously collected surface soils.
Pesticides	•	The pesticide DDD was detected in a previously collected surface soil sample.
PCB[4]	•	Not detected in Step I Study, regardless PCB will be tested for as possibly waste materials stored in this area contained PCB.
TCLP[5]	•	Determine leaching potential of metals in soils.
Radiological[6]		Further ground water analyses are being performed at Area A.
Dioxin[7]		Historically, neither petroleum products nor chlorinated compounds have been burned at this site and dibenzofuran was not detected during the Step I investigation.
Engineering Characteristics[8]		Feasibility study data requirements not necessary at this time.

Notes:

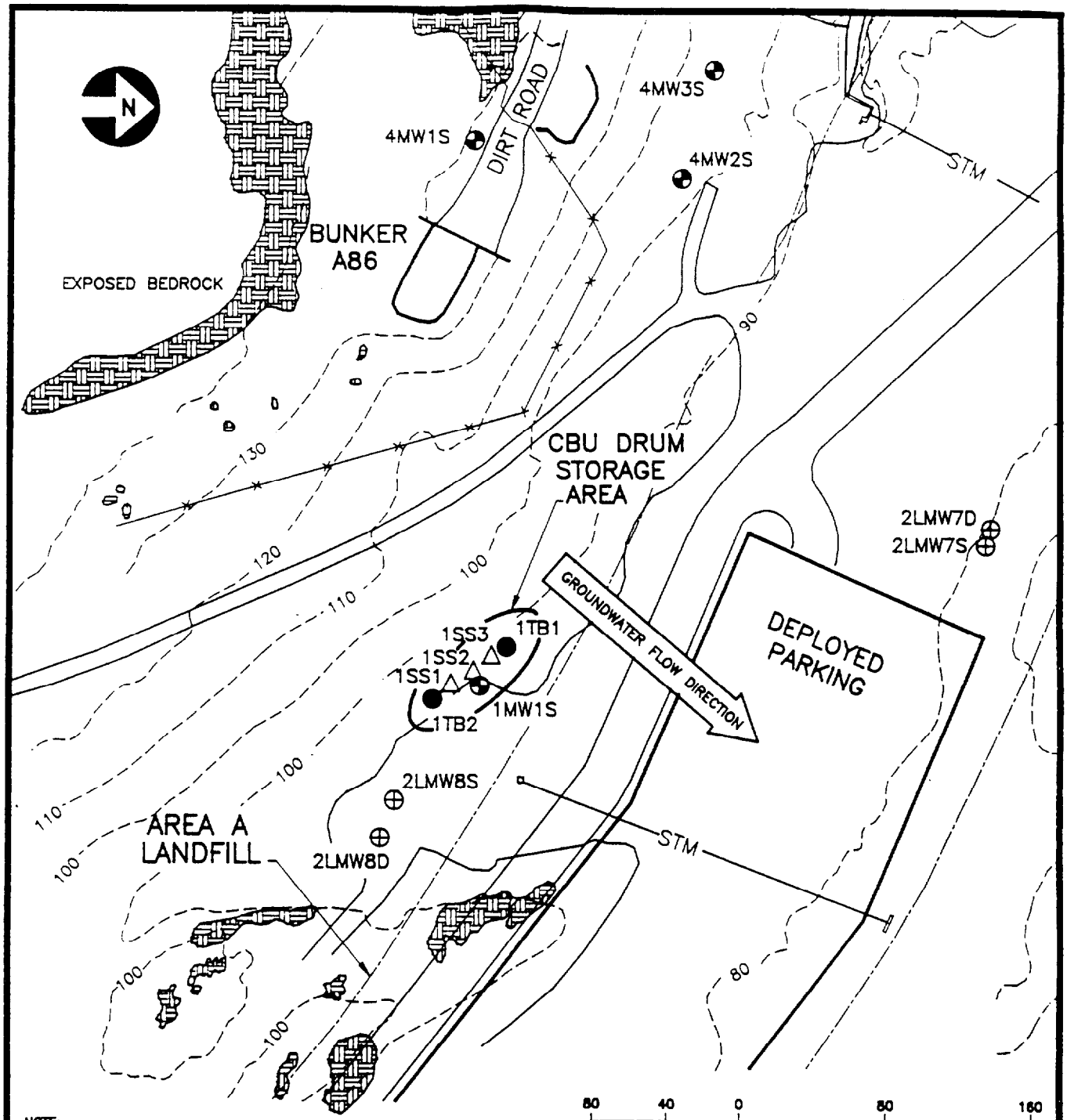
1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures (Analysis to be performed for metals only).
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).

TABLE 4-3B
CBU DRUM STORAGE AREA FIELD SAMPLING PLAN

Sample Location	Well Depth/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis							
				Soil	Water	VOC	SVOC	Inorganics	Pesticides	PCB	TPH	TCLP[2]	Engineering
			Monitoring Well										
1MW1S	Overburden/20±	Monitor quality of ground water and test for subsurface soil contamination within the CBU Drum Storage Area.	1MW1S (0-2')	●		●	●	●	●	●	●	●	
			1MW1S (depth)	●		●	●	●	●	●	●	●	
			1GW1S		●	●	●	●	●	●	●		
			Test Borings										
1TB1	NA/15'	Further evaluate potential subsurface soil contamination.	1TB1 (0-2')	●		●	●	●	●	●	●		
			1TB1 (depth)	●		●	●	●	●	●	●		
1TB2	NA/15'	Further evaluate potential subsurface soil contamination.	1TB2 (0-2')	●		●	●	●	●	●	●		
			1TB2 (depth)	●		●	●	●	●	●	●		
			Total Soils	**6**		**6**	**6**	**6**	**6**	**6**	**6**	**2**	**0**
			Total Water[1]		**2**	**2**	**2**	**2**	**2**	**2**	**2**	**0**	**0**

PROPOSED
3 Test borings (including well boring)
1 Well

Notes:
[1] Total includes 2 sampling rounds.
[2] TCLP metals only.



NOTE:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB–NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980. ELEVATIONS ARE BASED ON NSB–NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.

INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE – NEW LONDON
GROTON, CT

LEGEND

EXIST.	PROP.	
6MW1	7MW5	MONITORING WELL
6TB1	7TB6	TEST BORING
2DSD1	2DSD5	SEDIMENT SAMPLE
6SS1	7SS5	SURFACE SOIL SAMPLE
2DSW1	5DSW5	SURFACE WATER SAMPLE

10 EXIST CONTOUR
123 BUILDING No.
WATERCOURSE
STM STORM SEWER
CATCH BASIN

FIGURE 4–1
FIELD SAMPLING PLAN
CBU DRUM STORAGE AREA

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intended to intercept the shallow overburden aquifer; however, bedrock outcroppings adjacent to the area indicate the possibility that the well may need to be installed into bedrock to intercept the water table. If a bedrock well is required, it will be installed to intercept the first significant water bearing unit and extend a minimum of 20 feet below the bedrock surface. If an overburden well is installed, a 10-foot screen interval will be placed so that the top of the screen is located a minimum of 1 foot above the water table.

Two rounds of ground water sampling will be performed. The first sampling round will be collected a minimum of two weeks after well development and the second round approximately three months following completion of the first round.

4.2.1.2 OBDANE

The constituents to be analyzed for at this site, and the rationale for their selection, are provided in Table 4-4. The rationale for this program is provided in Table 4-5, and the Field Sampling Plan is shown in Figure 4-2.

A total of three test borings (including monitoring well) will be drilled at this site to characterize the stratigraphy and fill material at the site. Monitoring well 14MW-1 will be advanced to a depth 4 feet below any evidence of contamination based on field screening with an organic vapor analyzer. The well screen will be set 10 feet into the uppermost aquifer. The remaining two borings, 14TB1 and 14TB2 will be advanced to a depth of 15 feet or 4 feet below any evidence of contamination based on field screening with an organic vapor analyzer, whichever is greater. Continuous split-spoon samples will be collected from each boring for geologic logging and subsurface soil sample collection. Proposed boring locations are shown in Figure 4-2; however, final boring locations may differ due to field conditions and/or potential interference with utilities.

Subsurface soil samples will be collected from each boring for chemical analysis to determine if contamination exists and the nature of contamination if present. Samples will be collected from within the OBDANE area only. Samples will be collected from depths of 0-2 feet. Samples to be collected at a non-specified depth will be selected based upon field screening with an organic vapor analyzer, visual observations, water table elevation, or the presence of any fine-grained soil layer. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observation will be selected for analysis. If no such contamination is evident, a sample will be collected from either the elevation of ground water or from any fine-grained soil layers present above the water table.

One ground water monitoring well will be installed at the site. The well will be installed within the OBDANE area to characterize the quality of ground water at the site. No specific upgradient well will be installed at this site; however, existing monitoring well 2WMW6S will be used to determine upgradient ground water quality. Due to the absence of site-specific geologic information for this site, final well depth will be determined on the basis of field observations. The proposed well is intended to intercept the shallow overburden aquifer; however, bedrock outcroppings adjacent to the area indicate the possibility that the well may need to be installed into bedrock to intercept the water table. If a bedrock well is required, it

TABLE 4-4
OBDANE AREA
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	Tetrachloroethene was detected in a previously collected surface soil sample.
SVOC[2]	•	Included for completeness.
Inorganic[3]	•	Included for completeness.
Pesticides		Not detected in Step I Investigation.
PCB[4]		Not detected in Step I Investigation.
TCLP[5]	•	Determine leaching potential of metals in soils.
Radiological[6]		Further ground water analysis are being performed at Area A.
Dioxin[7]		Historically, neither petroleum products nor chlorinated compounds have been burned at this site and dibenzofuran was not detected during the Step I investigation.
Engineering Characteristics[8]		Feasibility study data requirements not necessary at this time.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures (analysis to be performed for metals only).
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).

TABLE 4-5
OBDANE FIELD SAMPLING PLAN

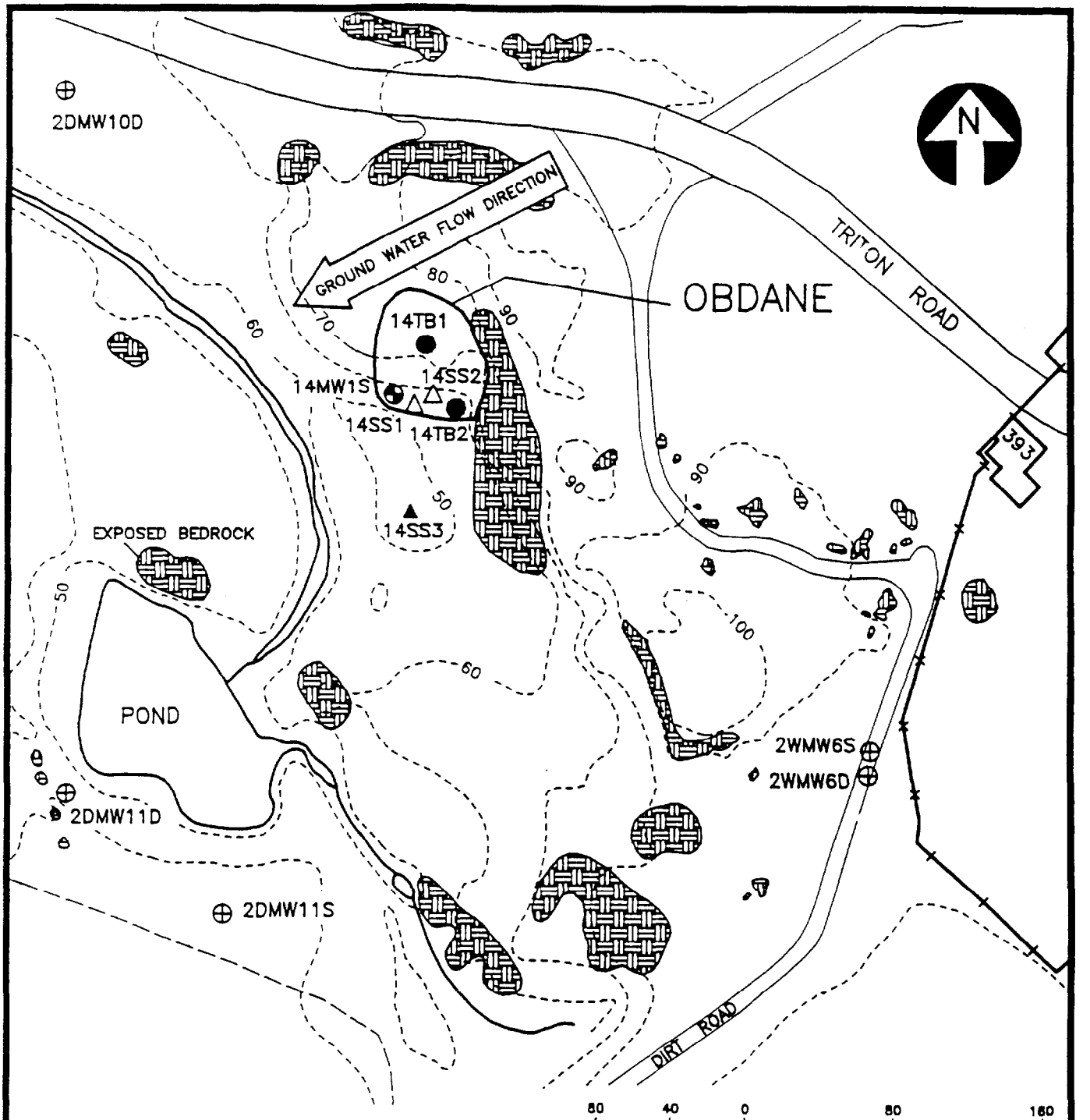
Sample Location	Well Depth/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis						
				Soil	Water	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP[2]	Engi-neering
Monitoring Well												
14MW1S	Overburden/20±	Monitor quality of ground water and test for subsurface soil contamination within the OBDANE area.	14MW1S (0-2')	●		●	●	●			●	
			14MW1S (depth)	●		●	●	●			●	
			14GW1S		●	●	●	●				
Test Borings												
14TB1	NA/15'	Further evaluate potential subsurface soil contamination.	14TB1 (0-2')	●		●	●	●				
			14TB1 (depth)	●		●	●	●				
14TB2	NA/15'	Further evaluate potential subsurface soil contamination.	14TB2 (0-2')	●		●	●	●				
			14TB2 (depth)	●		●	●	●				
Sediment Samples												
14SS3	0-6"	To determine if contaminants have accumulated in low spot downgradient of OBDANE.	14SS3 (0-6")	●		●	●	●	●			
			Total Soils	7		7	7	7	1	0	2	0
			Total Water[1]		2	2	2	2	0	0	0	0

PROPOSED

3 Test borings (including well boring)
1 Well

Notes:

[1] Total includes 2 sampling rounds.
[2] TCLP metals only.



NOTE:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980. ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.

INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE – NEW LONDON
GROTON, CT

LEGEND

EXIST.	PROP.	
6MW1	6TMW5	MONITORING WELL
6TB1	6TB6	TEST BORING
2DSD1	2DSD6	SEDIMENT SAMPLE
6SS1	7SS5	SURFACE SOIL SAMPLE
2DSW1	5DSW5	SURFACE WATER SAMPLE

---10---	EXIST CONTOUR
123	BUILDING No.
	WATERCOURSE
—STM—	STORM SEWER
□	CATCH BASIN

FIGURE 4-2
FIELD SAMPLING PLAN
OBDANE

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will be installed to intercept the first significant water bearing unit and extend a minimum of 20 feet below the bedrock surface, whatever is greater. If an overburden well is installed, a 10-foot screen interval will be placed so that the top of the screen is located a minimum of 1 foot above the water table.

Two rounds of ground water sampling will be performed. The first sampling round will be collected a minimum of two weeks after well development and the second round approximately three months following completion of the first round.

4.2.2 Step II Investigations

4.2.2.1 Rubble Fill at Bunker A-86

The constituents to be analyzed for at this site, and the rationale for their selection, are provided in Table 4-6. The rationale for this program is provided in Table 4-7 and the Field Sampling Plan is shown in Figure 4-3.

A total of eight test borings (including monitoring wells) will be drilled at this site to characterize the stratigraphy of the overburden and better define the overburden/bedrock interface. Each boring will be advanced to the depth of refusal (e.g., bedrock contact). Continuous core samples will be collected from each boring in order to characterize the contents of the rubble fill for geologic logging and subsurface soil sample collection. Proposed boring locations are shown in Figure 4-3; however, final boring locations may differ due to field conditions and/or potential interference with utilities.

Subsurface soil samples will be collected from each boring for chemical analysis to determine the nature, extent, and degree of soil contamination within, and immediately downgradient of, the rubble fill zone. Samples to be collected at a non-specified depth will be selected based upon field screening with an organic vapor analyzer, visual observations, or at the ground surface. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observation will be selected for analysis. If field screening does not identify contamination in the boring, a shallow subsurface sample (0-1 foot depth) will be collected. Samples from borings 4TB2 and 4MW1S will be collected from the shallow subsurface to ensure adequate characterization of near-surface contamination immediately downgradient and upgradient of the rubble fill zone. Soil samples for engineering characteristics evaluation will be collected from the two monitoring well borings within the screened interval.

Surface soil samples will be collected at five locations in the vicinity of the rubble fill zone. Three samples will be collected downgradient of the rubble to determine whether surface contamination extends further north than identified during the Step I investigation. One surface soil sample will be collected east of the rubble and one within the rubble fill pile to further evaluate potential surficial contamination. Surface soils at each sample location will be collected from a depth of 0-6 inches.

Sediment samples will be collected from two locations within a nearby seasonal stream to assess whether site contaminants may be transported offsite by this mechanism. The seasonal

TABLE 4-6
RUBBLE FILL AT BUNKER A-86
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	Chlorinated solvents were detected in two previous surface soil samples. Study area not adequately characterized for this parameter.
SVOC[2]	•	Detected in composite surface soil sample. Study area not adequately characterized for this parameter.
Inorganics[3]	•	High arsenic concentration detected in composite surface soil sample. Study area not adequately characterized for this parameter.
Pesticides	•	Pesticides (BHC and methoxychlor) detected in composite surface soil sample. Study area not adequately characterized for this parameter.
PCB[4]	•	Study area not adequately characterized for this parameter.
TCLP[5]	•	Determine hazardous characteristics for selected samples.
Radiological Analyses[6]		Further ground water analyses are being performed at Area A.
Dioxin[7]		Historically, neither petroleum products nor chlorinated compounds have been burned at this site and dibenzofuran was not detected during Step I investigations.
Engineering Characteristics[8]	•	Feasibility study data requirements for select samples.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).

TABLE 4-7
RUBBLE FILL AT BUNKER A-86 FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth	Rationale	Sample Designations	Sample Type		Analysis						
				Soil	Water	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Engi-neering
Monitoring Wells												
4MW1S[1]	Overburden/20±' (Bedrock well installed if no overburden aquifer)	Monitor quality of shallow ground water and test for subsurface soil contamination upgradient of Rubble Fill area.	4MW1S (0-1')	•		•	•	•	•	•		
			4GW1S		•	•	•	•	•	•		
4MW2S[1]	Overburden/20±' (Bedrock well installed if no overburden aquifer)	Monitor quality of shallow ground water and test for subsurface soil contamination downgradient of Rubble Fill area.	4MW2S (depth)	•		•	•	•	•	•		•
			4GW2S		•	•	•	•	•	•		
4MW3S[1]	Overburden/20±' (Bedrock well installed if no overburden aquifer)	Monitor quality of shallow ground water and test for subsurface soil contamination downgradient, northwest of Rubble Fill area.	4MW3S (depth)	•		•	•	•	•	•		•
			4GW3S		•	•	•	•	•	•		•
4MW4S[1]	Overburden/20±'	Monitor quality of shallow ground water and test for subsurface soil contamination downgradient, northwest of Rubble Fill area.	4MW4S (depth)	•		•	•	•	•	•		
			4GW4S		•	•	•	•	•	•		
4MW4D[1]	Bedrock	Monitor quality of deep ground water and test for subsurface soil contamination downgradient, northwest of Rubble Fill area.	4GW4D		•	•	•	•	•	•		
Test Borings												
4TB1	NA/Bedrock (20±')	Determine stratigraphy/nature of fill material in center of Rubble Fill area. Determine nature and extent of subsurface soil contamination in potential source area.	4TB1 (depth)	•		•	•	•	•	•	•	
4TB2	NA/Bedrock (20±')	Further define extent of subsurface soil contamination northeast of Rubble Fill area.	4TB2 (depth)	•		•	•	•	•	•	•	
4TB3	NA/Bedrock (20±')	Further define extent of subsurface soil contamination northeast of Rubble Fill area.	4TB3 (0-1')	•		•	•	•	•	•		
		Subtotal Soil		7		7	7	7	7	7	2	2
		Subtotal Water/1 Sampling Round			5	5	5	5	5	5	0	1
Surface Soil Sampling												
4SS4	Surficial	Determine nature and extent of surface soil contamination downgradient of Rubble Fill area.	4SS4 (0-6")	•		•	•	•	•	•		
4SS5	Surficial	Further define extent of surface soil contamination downgradient of Rubble Fill area.	4SS5 (0-6")	•		•	•	•	•	•		
4SS6	Surficial	Assess surface soil quality in Rubble Fill area.	4SS6 (0-6")	•		•	•	•	•	•		

TABLE 4-7 (continued)
RUBBLE FILL AT BUNKER A-86 FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth	Rationale	Sample Designations	Sample Type		Analysis							
				Soil	Water	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Engi-neering
4SS7	Surficial	Determine nature and extent of surface soil contamination east of Rubble Fill area west of Bunker.	4SS7 (0-6")	•		•	•	•	•	•		
4SS8	Surficial (0-1')	Determine nature and extent of surface soil contamination northwest of Rubble Fill area.	4SS8 (0-6")	•		•	•	•	•	•		
4SS9	Surficial	Assess surface soil quality in Rubble Fill area.	4SS9 (0-6')	•		•	•	•	•	•		
4SS10	Surficial	Assess surface soil quality in Rubble Fill area.	4SS10 (0-6")	•		•	•	•	•	•		
		Subtotal Surface Soils		7		7	7	7	7	7	0	0
Surface Water/Sediment Sampling												
4SW1/SD1	-	Generate chemical data for surface water and sediments from surface drainage upgradient of Rubble Fill area to determine contaminant loading.	4SW1		•	•	•	•	•	•		
			4SD1	•		•	•	•	•	•		•
4SW2	-	Upgradient of wetland at stormwater outlet that passes by Rubble Fill at Bunker A-86.	4SW2		•	•	•	•	•	•		
4SD2[2]	-	Generate chemical data for sediment in surface drainage downgradient of Rubble Fill area to determine whether site contaminants are being transported offsite by this mechanism.	4SD2	•		•	•	•	•	•		•
		Subtotal Sediments		2		2	2	2	2	2	0	2
		Subtotal Surface Water			2	2	2	2	2	2	0	0
		Total Soils		**16**		**16**	**16**	**16**	**16**	**16**	**2**	**4**
		Total Water[2]			**12**	**12**	**12**	**12**	**12**	**12**	**0**	**1**

PROPOSED

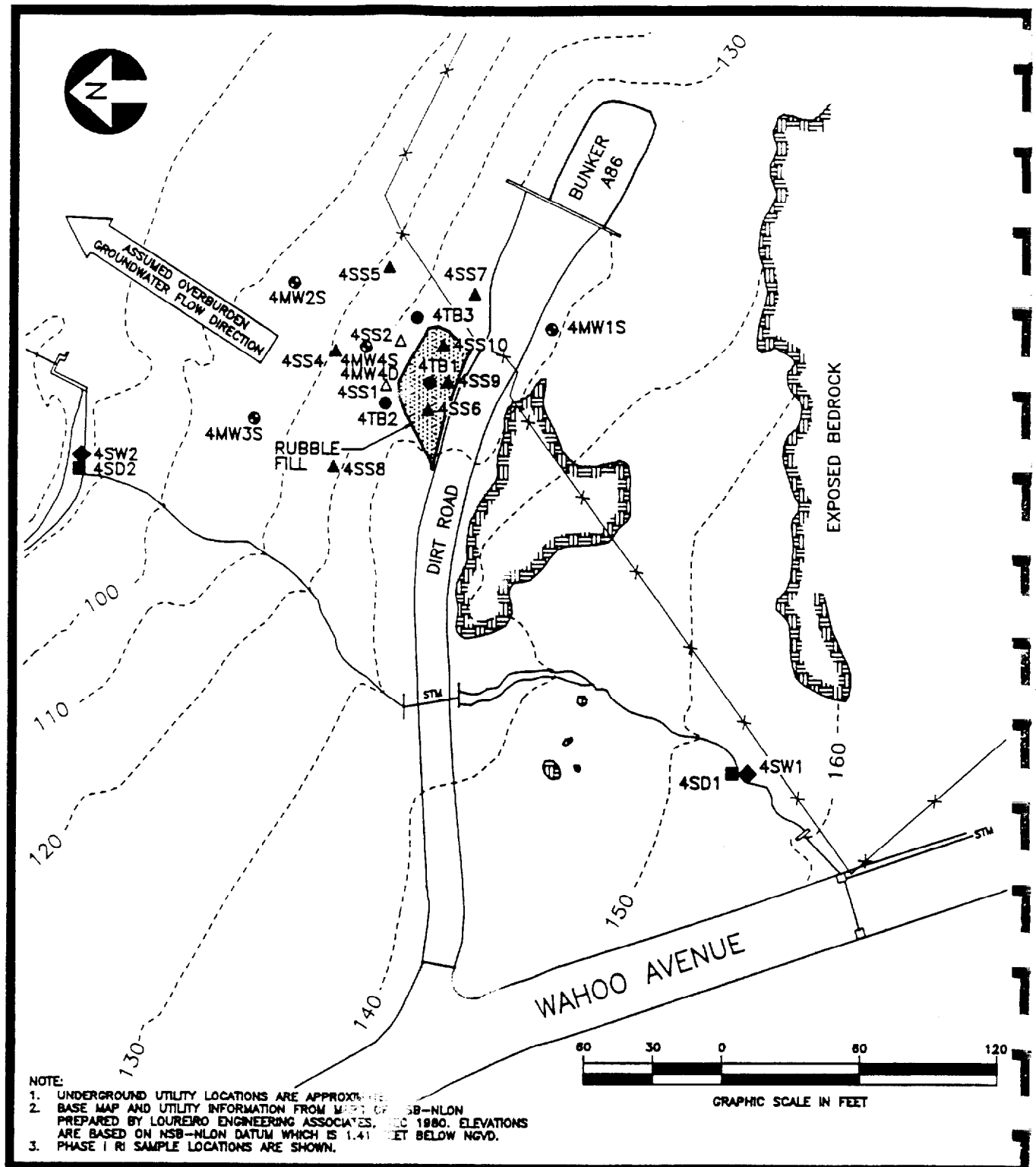
6 Test borings (including well borings)

3 Wells

Notes:

[1] If a bedrock well is required, it will be installed into the first significant water bearing unit and to a minimum depth of 20 feet or whichever is greater.

[2] Total includes two sampling rounds.



NOTE:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, INC 1980. ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.

INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE – NEW LONDON
GROTON, CT

LEGEND

EXIST.	PROP.	
4MW1	7MW5	MONITORING WELL
4TB1	7TB5	TEST BORING
4SD1	7SD5	SEDIMENT SAMPLE
4SS1	7SS5	SURFACE SOIL SAMPLE
4SW1	7SW5	SURFACE WATER SAMPLE

10	EXIST CONTOUR
123	BUILDING No.
	WATERCOURSE
STM	STORM SEWER
	CATCH BASIN

FIGURE 4-3
FIELD SAMPLING PLAN
RUBBLE FILL AT BUNKER A86

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stream is located west of the rubble fill zone, and flows northeast to Area A. Sediment samples will be collected in one location upgradient and the other downgradient from the fill area. Surface water will also be sampled at the upgradient sediment sample location to characterize surface water quality entering the site. Additional downstream surface water sampling is discussed in the Area A Field Sampling Plan.

A total of five ground water monitoring wells will be installed at the site. One upgradient well will be installed southeast of the rubble fill to characterize the quality of ground water entering the site. Three additional shallow wells and one deep well will be installed downgradient to monitor water quality beyond the fill area. A 5 foot long core sample will be collected from bedrock at location 4MW4D. Due to the absence of site-specific geologic information for this site, final well depth will be determined on the basis of field observations. Proposed wells are intended to intercept the shallow overburden aquifer; however, proximity of several significant bedrock outcroppings on, or adjacent to, this site indicate the possibility that wells may require installation into bedrock to intercept the water table. If a bedrock well is required in an area of proposed shallow wells, it will be installed to intercept the first significant water bearing unit and extend a minimum of 20 feet below the bedrock surface, whatever is greater. Overburden wells will be installed with 10-foot screens, placed so that the top of the screen is located a minimum of 1 foot above the water table.

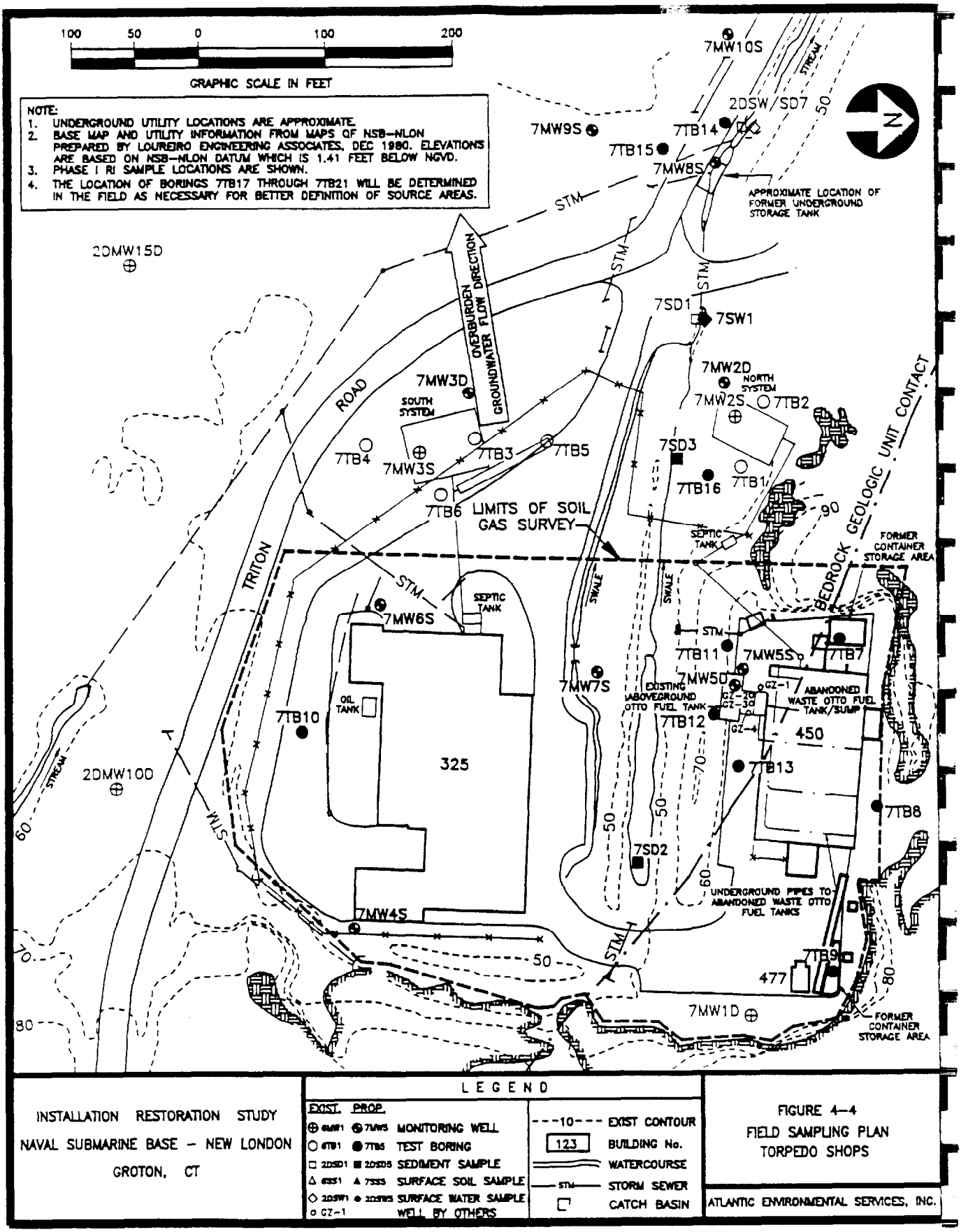
Two rounds of ground water sampling will be performed. The first sampling round will be collected a minimum of two weeks after well development and the second round approximately three months following completion of the first round. In addition, a single well hydraulic conductivity test will be run in well 4MW2S.

4.2.2.2 Torpedo Shops

Prior to any subsurface investigation, a soil gas survey will be conducted in areas surrounding the Torpedo Shop buildings, and in areas of past/present exterior chemical storage to aid in the selection of final boring and monitoring well locations. A geologic survey of the site and surrounding areas will also be conducted to define site geology and aid in the selection of final ground water monitoring well and boring locations. The soil gas survey area is shown in Figure 4-4. Samples will be collected at grid points 25 feet on center in areas of suspected contamination (e.g., areas where possible staining has been identified in aerial photographs), and 50 feet on center in the remaining areas within the sampling area, exclusive of areas beneath buildings. If contamination is detected, the sampling grid will be extended as necessary to define the extent of any such area of contamination. Boring and/or well locations will be relocated to any location where the soil gas survey identifies any area of moderate to high contamination and where potential preferential flow zones are identified in the bedrock.

The constituents to be analyzed at this site and rationale for their selection are provided in Table 4-8, and the Field Sampling Plan is summarized in Table 4-9. Sample locations are shown in Figure 4-4.

A total of 20 primary test borings (including monitoring wells) will be drilled at this site to assess the nature, extent, and degree of contamination. Each boring will be advanced to the depth of refusal (e.g., bedrock contact). The actual location may vary based on results of the



INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE – NEW LONDON
GROTON, CT

LEGEND

EXIST.	PROP.	
6MW1	7MW5	MONITORING WELL
6TB1	7TB5	TEST BORING
2DSD1	2DSD5	SEDIMENT SAMPLE
6SS1	7SS5	SURFACE SOIL SAMPLE
2DSW1	2DSW5	SURFACE WATER SAMPLE
GZ-1		WELL BY OTHERS

10 EXIST CONTOUR
123 BUILDING No.
WATERCOURSE
STM STORM SEWER
CATCH BASIN

FIGURE 4-4
FIELD SAMPLING PLAN
TORPEDO SHOPS

ATLANTIC ENVIRONMENTAL SERVICES, INC.

TABLE 4-8
TORPEDO SHOPS
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	Detected in ground water and soils during Step I. Constituents of onsite chemicals/materials and potentially present in petroleum products.
SVOC[2]	•	Detected in soils during Step I and potentially present in petroleum products.
Inorganics[3]	•	Detected in soils during Step I and potentially present in petroleum products.
Pesticides	•	Detected in soils during Step I but not ground water. Not included in proposed ground water analysis.
PCB[4]	•	Detected in soils during Step I but not ground water. Not included in proposed ground water analysis.
TCLP[5]	•	Determine hazardous waste characteristics for selected samples.
Radiological Analyses[6]		Radiological contamination not suspected.
Dioxins[7]		Historically, neither petroleum products nor chlorinated solvent have been burned at this site and dibenzofuran was not detected during the Step I investigation.
Engineering Characteristics[8]	•	Feasibility study data requirements for select samples.
TPH[9]	•	Useful in assessing petroleum contamination.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).
9. TPH means total petroleum hydrocarbons.

TABLE 4-9
TORPEDO SHOPS FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type (No. of Samples)		Analysis								
				Soil	Water	VOC	SVOC	Inorganics	Pesticides	PCB	TCLP	TPH	Engineering
			Monitoring Wells										
7MW1D	Bedrock/25'	Existing	7GW1D		•	•	•	•					
7MW2S	Overburden/15±'	Existing	7GW2S		•	•	•	•					
7MW2D	Bedrock/20' (minimum penetration of bedrock)	Monitor quality of deep (bedrock) aquifer downgradient of north system leach field.	7GW2D		•	•	•	•					•
7MW3S	Overburden/15±'	Existing	7GW3S		•	•	•	•					
7MW3D	Bedrock/20' (minimum penetration of bedrock)	Monitor quality of deep (bedrock) aquifer downgradient of south system leaching field.	7GW3D		•	•	•	•					•
7MW4S	Overburden/25±'	Monitor quality of shallow ground water in area of paint shop and test for soil contamination upgradient of Building 325.	7GW4S		•	•	•	•					
			7MW4S (depth)	•		•	•	•	•	•			•
7MW5S	Overburden/25±'	Provide chemical data for shallow ground water and soils downgradient and near the former underground Otto fuel tank.	7GW5S		•	•	•	•					•
			7MW5S (depth)	•		•	•	•	•	•			•
7MW5D	Bedrock/20' (minimum penetration of bedrock)	Monitor quality of deep ground water in area of former Otto fuel tank.	7GW5D		•	•	•	•					•
7MW6S	Overburden/25±'	Provide chemical data for shallow ground water in and soils near and downgradient of Building 325.	7GW6S		•	•	•	•					
			7MW6S (depth)	•		•	•	•	•	•			
7MW7S	Overburden/25±'	Provide chemical data for shallow ground water in between both buildings and provide essential hydrogeologic data in center of site.	7GW7S		•	•	•	•					
			7MW7S (depth)	•		•	•	•	•	•			•
7MW8S	Overburden/25±'	In former tank grave.	7GW8S		•	•	•	•				•[1]	
			7MW8S (water table)	•		•	•	•	•	•	•	•[1]	•
7MW9S	Overburden/25±'	Downgradient of former tank.	7GW9S		•	•	•	•				•	
			7MW9S (water table)	•		•	•	•				•	
7MW10S	Overburden/25±'	Downgradient of former tank.	7GW10S		•	•	•	•				•	
			7MW10S (water table)	•		•	•	•				•	
			Test Borings										
7TB7	NA/Bedrock (25±')	Determine stratigraphy and nature of fill. Provide chemical characteristics of soils upgradient of north system. At location of bedrock formation contact.	7TB7 (depth)	•		•	•	•	•	•			
7TB8	NA/Bedrock (25±')	Determine stratigraphy and nature of fill in "back door" area of site.	7TB8 (depth)	•		•	•	•	•	•			

TABLE 4-9 (continued)
TORPEDO SHOPS FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type (No. of Samples)		Analysis								
				Soil	Water	VOC	SVOC	Inorganics	Pesticides	PCB	TCLP	TPH	Engineering
7TB9	NA/Bedrock (25±')	Determine stratigraphy and nature of fill in former drum storage area. Provide chemical data to determine if possible chemical release occurred in area.	7TB9 (depth)	•		•	•	•	•	•			
7TB10	NA/Bedrock (25±')	Determine stratigraphy and nature of fill south of Building 325. Chemically characterize soils.	7TB10 (depth)	•		•	•	•	•	•			
7TB11-7TB13	NA/Bedrock (25±')	Determine stratigraphy and nature of fill in area of abandoned underground Otto fuel tank. Evaluate extent of soil contamination.	7TB11 (depth)-7TB13 (depth)	• (3)		• (3)	• (3)	• (3)	• (3)	• (3)		• (3)	•
7TB14	NA/Bedrock (25±')	Downgradient of former tank.	7TB14 (water table)	•		•	•	•				•	
7TB15	NA/Bedrock (25±')	Downgradient of former tank.	7TB15 (water table)	•		•	•	•				•	
7TB16	NA/Bedrock (25±')	At sample point SG21 with high soil gas measurement.	7TB16 (depth)	•		•	•	•	•	•			
7TB17-7TB21	NA/Bedrock (25±')	Optional borings to be installed to determine the extent of soil contamination, if detected, based upon the field screening results.	7TB17 (depth) - 7TB21 (depth)	• (5)		• (5)	• (5)	• (5)				• (5)	• (5)
		Subtotal Soil		22		22	22	22	13	13	1	14	10
		Subtotal Water[2]			13	13	13	13	0	0	0	5	4
Sediment and Surface Water Sampling													
7SD2 7SD3 7SW1	NA	Provide chemical data for sediments both in up- and downgradient locations. Surface water sample is upgradient of Area A Downstream and downgradient of this site.	7SD2 and 7SD3	• (2)		• (2)	• (2)	• (2)	• (2)	• (2)			• (2)
			7SW1		•	•	•	•	•	•			
		Subtotal Soils		2		2	2	2	2	2	0	0	2
		Subtotal Surface Water			1	1	1	1	1	1	0	0	0
		Total Soils		**24**		**24**	**24**	**24**	**15**	**15**	**1**	**14**	**12**
		Total Water[3]			**27**	**27**	**27**	**27**	**1**	**1**	**0**	**10**	**8**

PROPOSED

20 Primary test borings (including well borings)
5 Supplemental test borings
10 Wells
- 3 Bedrock
- 7 Overburden

Notes:

1 Sample also to be analyzed for oil type by fluorescence analysis.
2 One round of sampling.
3 Total includes two monitoring well sampling rounds.

soil gas and geologic surveys and potential utility conflicts. In addition to the 20 primary test borings, up to 5 supplemental test borings may be conducted as necessary to define the full extent of VOC or petroleum contamination. These supplemental borings will be made if contamination is evident at the limit of existing borings based on field screening organic vapor analysis and visual observation.

Soil samples will be collected at the intervals depicted in Table 4-9 (Torpedo Shops Field Sampling Plan). Samples for engineering analysis will be selected based on representations of aquifer materials and/or contaminated soils that may require remediation. Samples to be collected at a non-specified depth (i.e., 7TB1 (depth)) will be selected based upon field screening with an organic vapor analyzer, visual observations, water table elevation, or the presence of any fine- grained soil layer. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observation will be selected for analysis. If no such contamination is evident, a sample will be collected from either the elevation of ground water or from any fine-grained soil layers present above the water table.

Two sediment samples will be collected from the drainage ditch as shown on Figure 4-4 to determine if there is any contamination present.

A total of ten monitoring wells will be installed. Seven of the borings described above will be completed as overburden monitoring wells and three as bedrock wells. Bedrock core samples will be collected from borings 7TB7 and 7MW3D. The purpose of the wells is to determine the nature, extent, and degree of contamination in both shallow (overburden) ground water and deeper (bedrock) ground water. Well screens in overburden wells will be no greater than 10 feet in length and will be placed so that the top of the screen is a minimum of 1 foot above the elevation of ground water. The bottom of the well screen will be on the bedrock surface unless a screen length greater than 10 feet is required. Bedrock wells will be drilled to the depth of the first water bearing zone and extend a minimum of 20 feet below the bedrock surface, whatever is greater.

Ground water samples will be collected twice: the first round will be collected a minimum of two weeks after well development and the second round, three months after the first round. Single well hydraulic conductivity tests will be run in wells 7MW5S and 7MW5D.

One surface water sample will be collected at the downstream end of the drainage swale. Additional downstream surface water sampling will be collected as part of the Area A field investigation (refer to Area A Field Sampling Plan).

4.2.2.3 Goss Cove

A geologic survey of the Goss Cove site will include mapping of the bedrock fractures and field identification of bedrock outcrops.

The rationale for selecting parameters to be sampled at the site is provided in Table 4-10.

TABLE 4-10
GOSS COVE LANDFILL
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	Detected in subsurface soil and water samples collected during Step I.
SVOC[2]	•	Detected in subsurface soil samples collected during Step I.
Inorganics[3]	•	Detected in subsurface soil samples collected during Step I.
Pesticides	•	Detected in subsurface soil samples collected during Step I, but not ground water. Not included in proposed ground water analysis.
PCB[4]	•	Detected in subsurface soil and water samples collected during Step I, but not ground water. Not included in proposed ground water analysis.
TCLP[5]	•	Determine hazardous waste characteristics for selected samples.
Radiological Analyses[6]	•	Detected in ground water collected during Step I above screening values.
Dioxins[7]	•	Determine the possible presence of dioxins in areas previously identified as having dibenzofuran contamination.
Engineering Characteristics[8]	•	Feasibility study data requirements for select samples.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).

The Field Sampling Plan is summarized in Table 4-11. A total of 14 primary test borings (including monitoring wells) will be drilled at this site. Each boring will be advanced to the base of fill or 4 feet below any evidence of contamination based on XRF and OVA field screening analyses, whichever is greater; or the bedrock overburden contact as specified in Table 4-11. Five foot long core samples will be collected at locations 8TB9 and 8MW8D. Boring locations are shown in Figure 4-5 (Field Sampling Plan, Goss Cove Landfill). Actual locations may vary based on utility or similar conflicts encountered in the field. In addition to the 14 primary test borings, as many as 5 supplemental resolution borings may be installed as necessary to define the extent of contamination across the site. Supplemental resolution borings will only be installed if there are areas where additional information is necessary to define the extent of contaminants. This decision will be based on field screening organic vapor analysis, visual observations, and XRF field screening for lead.

Soil samples will be collected at the intervals indicated in Table 4-11. Sample intervals collected and analyzed from the 0- to 1-foot interval are to address the risk assessment data requirements. Samples to be collected at an unspecified depth will be grab samples selected and determined in the field based on field screening with an organic vapor analyzer and XRF, visual observations, water table elevations, or the presence of any fine-grained soil layers. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observations will be selected for analysis. If no such contamination is evident, a sample will be collected from either the elevation of ground water or from any fine-grained soil layers encountered above the water table. Discrete samples for engineering analysis will be selected based on representative aquifer materials and/or contaminated soils that may require remediation.

A total of five sediment samples will be collected from Goss Cove to evaluate potential impacts to sediments from the site and for risk assessment purposes. Analysis will be performed as depicted in Table 4-11.

A total of seven monitoring wells will be installed during the Step II investigation, which includes four shallow overburden wells, two deep overburden monitoring wells, and one bedrock well. The additional monitoring wells will further assess onsite ground water quality and the water quality of ground water discharging into the Thames River (ecological risk data). An upgradient bedrock well will be installed to determine background levels of the various analytes.

Well screens in the shallow overburden wells will be no greater than 10 feet in length and will be placed so that the base of the well will be above the organic silt layer, and the top of the screen is a minimum of 1 foot above the elevation of the high tide ground water level. The deep overburden monitoring wells will be screened on top of bedrock or the first confining layer below the organic silt layer, whichever is encountered first. Screen lengths for the deep overburden wells will not exceed 10 feet in length. The bedrock well will be drilled to the depth of the first water-bearing zone and extend a minimum of 20 feet below the bedrock surface, whatever is greater.

Ground water samples will be collected twice: the first round will be collected a minimum of two weeks after well development, and a second round three months later. Sampling events will be conducted during low tide when ground water is flowing toward the

TABLE 4-11
GOSS COVE LANDFILL FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil	Water	Air	VOC	SVOC	Inorganics	Pesticides	PCB	TCLP	RAD[4]	Dioxin	Engineering
			Monitoring Wells												
8MW1	Existing	Existing	8GW1		●		●	●	●				●		
8MW2S	Existing	Existing	8GW2S		●		●	●	●						
8MW2D	Overburden/100±'	Located adjacent to area of high soil gas concentrations. Evaluates water quality at interval above bedrock surface; health and ecological risk data.	8MW2D (0-1)	●			●	●	●	●	●	●			●
			8MW2D (depth)	●			●	●	●	●	●				●
			8GW2D		●		●	●	●						
8MW3	Existing	Existing	8GW3		●		●	●	●						
8MW4	Existing	Existing	8GW4		●		●	●	●				●		
8MW5S	Overburden/15±'	Previous investigation indicates highest inorganic concentrations in soil at the site are at 8TB1; 8MW5 will provide additional soil data. Also provides additional hydrogeologic and ground water quality information; health and ecological risk data.	8GW5S		●		●	●	●						
			8MW5S (depth)	●			●	●	●	●	●	●			●
8MW6S	Overburden/15±'	Provide chemical data for soils and ground water directly adjacent to the Nautilus Museum Building; health risk and ecological risk data.	8MW6S (0-1)	●			●	●	●	●	●				
8MW6D	Overburden/100±'		8GW6S		●		●	●	●						
			8MW6S (depth)	●			●	●	●	●	●	●			●
			8MW6D (depth)	●			●	●	●	●	●				●
			8GW6D		●		●	●	●						
8MW7S	Overburden/15±'	Provide chemical data for soils and ground water in an area adjacent to moderate soil gas concentrations. Also provide additional hydrogeologic and water quality information near Goss Cove; health and ecological risk data.	8MW7S (0-1)	●			●	●	●	●	●				
			8GW7S		●		●	●	●						
			8MW7S (depth)	●			●	●	●	●	●	●			●
8MW8S	Overburden/top of bedrock (30±')	Upgradient background well to provide background water quality values for the site.	8GW8S		●		●	●	●						●
			8MW8S (depth)	●			●	●	●	●	●				●
8MW8D[1]	Bedrock/50±'	Upgradient background well to provide background water quality values for the site.	8MW8D (depth)	●			●	●	●	●	●				●
			8GW8D		●		●	●	●						

TABLE 4-11 (continued)
GOSS COVE FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil	Water	Air	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	RAD[4]	Dioxin	Engi-neering
Test Borings															
8TB4	NA/Base of fill (20±')	Provide chemical characteristics of soils located in an area of moderate soil gas concentrations. Also provide stratigraphy and depth to bedrock information.	8TB4 (0-1)	•			•	•	•	•	•				
			8TB4 (depth)	•			•	•	•	•	•	•			
8TB5	NA/Base of fill (20±')	Near area of elevated PAH and area of moderate soil gas concentrations.	8TB5 (depth)	•			•	•	•	•	•	•		•	
8TB6	NA/Base of fill (20±')	Near area of elevated PAHs found in 8TB2 and 8TB3 soils.	8TB6 (0-1)	•			•	•	•	•	•				
			8TB6 (depth)	•			•	•	•	•	•	•		•	
8TB7	NA/Base of fill (20±')	Provide data regarding the extent of landfill material; chemical characteristics.	8TB7 (depth)	•			•	•	•	•	•				
8TB8	NA/Base of fill (20±')	Provide chemical data in area of high soil gas concentrations.	8TB8 (0-1)	•			•	•	•	•	•				
			8TB8 (depth)	•			•	•	•	•	•	•			
8TB9	NA/Base of fill (20±')	Provide data regarding the extent of landfill material; chemical characteristics.	8TB9 (depth)	•			•	•	•	•	•	•			
8TB10	NA/Base of fill (20±')	Provide data regarding the extent of landfill material; chemical characteristics.	8TB10 (depth)	•			•	•	•	•	•				
8TB11-15	NA/Base of fill (20±')	Optional borings to be installed to determine extent of soil contamination, if required, based upon the field screening results.	8TB11-15 (depth)	• (5)			• (5)	• (5)	• (5)	• (5)	• (5)				
			Subtotal Soil	25	0		25	25	25	25	25	9	0	2	8
			Subtotal Ground Water[2]	0	11		11	11	11	0	0	0	2	0	1
Surface Water/Sediment Sampling															
8SW2	Surface water	Provide chemical data for surface water and sediments in Goss Cove; near shore of landfill.	8SW2		•		•	•	•	•	•				•
8SD2	Sediment		8SD2	•			•	•	•	•	•				•
8SW3	Surface water	Provide additional data for the surface water and sediments in Goss Cove; near shore of landfill.	8SW3		•		•	•	•	•	•				•
8SD3	Sediment		8SD3	•			•	•	•	•	•	•			•

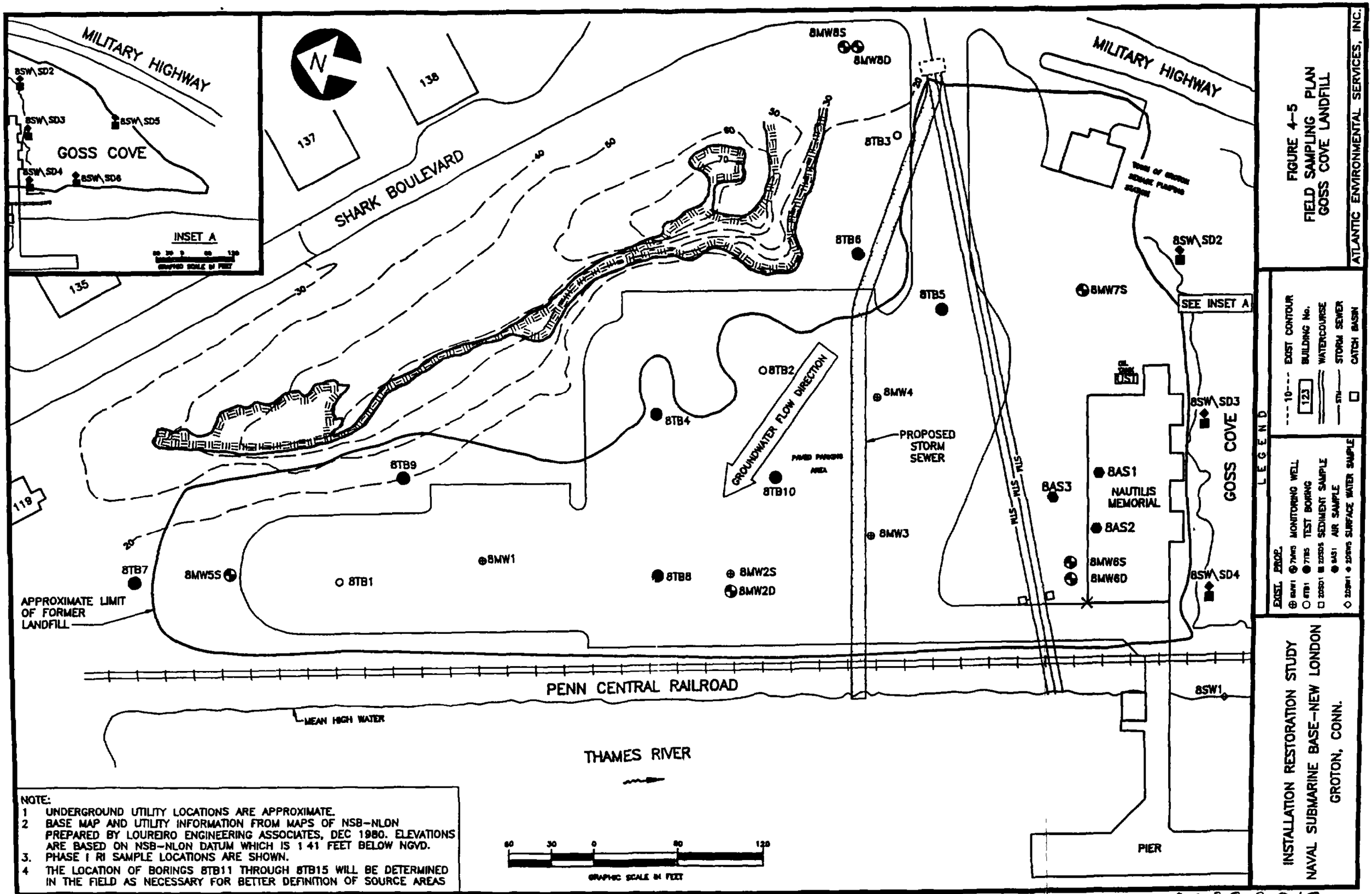
TABLE 4-11 (continued)
GOSS COVE FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil	Water	Air	VOC	SVOC	Inorganics	Pesticides	PCB	TCLP	RAD[4]	Dioxin	Engineering
8SW4	Surface water	Provide chemical data for surface water and sediments in Goss Cove area near shore of landfill.	8SW4		•		•	•	•	•	•				•
8SD4	Sediment		8SD4	•			•	•	•	•	•				•
8SW5	Surface water	Provide chemical data for surface water and sediments in Goss Cove away from the immediate influence of landfill material.	8SW5		•		•	•	•	•	•				•
8SD5	Sediment		8SD5	•			•	•	•	•	•				•
8SW6	Surface water	Provide chemical data for surface water and sediments in Goss Cove away from the immediate influence of landfill material.	8SW6		•		•	•	•	•	•				•
8SD6	Sediment		8SD6	•			•	•	•	•	•				•
			Subtotal Sediments	5	0	0	5	5	5	5	5	1	0	0	5
			Subtotal Surface Water	0	5	0	5	5	5	5	5	0	0	0	5
			Air Sampling												
8AS1	Air/Tenax tube	Located in basement of building in the boiler room where contaminants are likely to enter the building through foundation walls.	8AS1			•	•								
8AS2	Air/Tenax tube	Located in main exhibition room where workers and visitors are likely to be exposed for the longest duration.	8AS2			•	•								
8AS3	Air/Tenax tube	Outside building to represent background conditions at the site.	8AS3			•	•								
			Subtotal Air/Round	0	0	3	3	0	0	0	0	0	0	0	0
			Total Soils[3]	**30**	**0**	**0**	**30**	**30**	**30**	**30**	**30**	**10**	**0**	**2**	**13**
			Total Water[3]		**27**		**27**	**27**	**27**	**5**	**5**	**0**	**4**	**0**	**7**
			Total Air[3]			**6**	**6**								

PROPOSED

14 Primary test borings (including well borings)
5 Supplemental test borings
7 Wells
- 1 Bedrock
- 4 Shallow overburden
- 2 Deep overburden

Notes:
1. Bedrock well will be installed into first significant water bearing unit and to a minimum depth of 20 feet.
2. One round of ground water sampling.
3. Total includes two rounds of sampling.
4. RAD means gamma spectrum analysis and gross alpha/beta analysis.


MILITARY HIGHWAY
SHARK BOULEVARD
GOSS COVE
INSET A
SEE INSET A
8SW\SD2
8SW\SD3
8SW\SD4
8SW\SD5
8SW\SD6
8SW1
8MW8S
8MW8D
8TB3
8TB6
8TB5
8MW7S
8TB2
8TB4
8MW4
8TB9
8TB10
8MW3
8AS1
8AS3
8AS2
8MW6S
8MW6D
8TB7
8MW5S
8TB1
8MW1
8TB8
8MW2S
8MW2D
GROUNDWATER FLOW DIRECTION
PROPOSED STORM SEWER
NAUTILUS MEMORIAL
GOSS COVE
APPROXIMATE LIMIT OF FORMER LANDFILL
PENN CENTRAL RAILROAD
MEAN HIGH WATER
THAMES RIVER
PIER
135
137
138
118
GRAPHIC SCALE IN FEET
NOTE:
1 UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2 BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980. ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1 41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.
4 THE LOCATION OF BORINGS 8TB11 THROUGH 8TB15 WILL BE DETERMINED IN THE FIELD AS NECESSARY FOR BETTER DEFINITION OF SOURCE AREAS
LEGEND
EXIST. PROP.
EXIST CONTOUR
BUILDING No.
WATERCOURSE
STORM SEWER
CATCH BASIN
MONITORING WELL
TEST BORING
SEDIMENT SAMPLE
AIR SAMPLE
SURFACE WATER SAMPLE
FIGURE 4-5
FIELD SAMPLING PLAN
GOSS COVE LANDFILL
ATLANTIC ENVIRONMENTAL SERVICES, INC.
INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE-NEW LONDON
GROTON, CONN.

00232012

Thames River. Single well hydraulic conductivity tests will be run in wells 8MW2S and 8MW2D.

A total of five surface water samples will be collected from Goss Cove to assess the quality of water in the cove for risk assessment purposes.

Two rounds of air sampling will be conducted in and around the Nautilus Museum Building. Three samples will be collected: two from inside the building (one on the ground floor in the main exhibition area and one in the boiler room in the basement), and a third background air sample from outside the building during the same time period. In addition, methane monitoring in soil gas around the museum and during installation at wells 8MW6S and 8MW6D will be performed.

4.2.2.4 Spent Acid Storage and Disposal Area

The constituents to be analyzed for at this site, and the rationale for their selection, are provided in Table 4-12. The rationale for the Field Sampling Program is provided in Table 4-13. Sample locations are shown in Figure 4-6.

A total of ten test borings (including monitoring wells) will be drilled at this site. Each boring will be advanced to a depth of 15 feet or 4 feet below any evidence of contamination based on XRF field screening analyses, whichever is greater, to characterize overburden stratigraphy and assess contamination associated with former acid management activities. Two borings (15MW2S, 15MW4S) will be advanced to refusal (e.g., bedrock contact) to better define the overburden/bedrock interface. Continuous core samples will be collected from each boring for geologic logging and subsurface soil sample collection. A 5-foot long core sample at bedrock will be collected at location 15MW2S. Borings will be drilled in a radial sequence commencing within the vicinity of the former acid tank, and progressing outward. This sequence is intended to delineate the extent of battery acid contamination; five additional test borings may be used to further define the contaminated area, if necessary. Implementation of these borings, and their ultimate locations, will be determined on the basis of soil screening analyses, discussed below.

One subsurface soil sample will be collected from each boring for chemical analysis to determine the nature, extent, and degree of soil contamination associated with the former acid tank. Continuous soil samples (2-foot intervals) will be collected from each boring. One sample will be collected from each 2-foot interval for field screening. Screening will be performed using XRF analysis for lead. In order to validate this field method, soil samples covering a range of lead concentrations (by XRF analysis) will be collected for laboratory chemical analysis. A minimum of two samples from soils exhibiting each of the following concentration ranges will be selected for laboratory analysis: >1,000 ppm, 500 ppm, and not detected. All other samples will be collected from the sample interval yielding the highest evidence of lead contamination by XRF analysis. In borings yielding no evidence of lead contamination, the sample will be collected at a depth of 0-1 foot. As discussed above, five supplemental test borings are planned to further define the extent of soil contamination in the vicinity of the former acid tank, if necessary. Decisions to use these borings will be based upon a combination

TABLE 4-12
SPENT ACID STORAGE AND DISPOSAL AREA
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	●	Detected in one soil sample during Step I. Study area not adequately characterized for this parameter.
SVOC[2]	●	Detected in one soil sample during Step I. Study area not adequately characterized for this parameter.
Inorganics[3]	●	Detected in one soil sample during Step I. Heavy metals (especially lead) are significant constituents of spent battery acid.
Pesticides	●	Study area not adequately characterized for this parameter during Step I.
PCB[4]	●	Study area not adequately characterized for this parameter during Step I.
TCLP[5]	●	Determine hazardous characteristics for selected samples. Four previous soil samples from study area failed TCLP for lead.
Dioxin[6]		Historically, neither petroleum products nor chlorinated compounds have been burned at this site and dibenzofuran was not detected during Step I investigations.
Engineering Characteristics[7]	●	Feasibility Study data requirements for select samples.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).

TABLE 4-13
SPENT ACID STORAGE AND DISPOSAL AREA FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis						
				Soil	Water	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Engi-neering
Monitoring Wells												
15MW1S	Overburden/20±' (advance to bedrock)	Provide chemical data for shallow and deep ground water and subsurface soils in source area, immediately downgradient of the former acid storage tank; determine depth to bedrock.	15MW1S (depth)	●		●	●	●	●	●	●	●
15MW1D	Bedrock/50±'		15GW1S		●	●	●	●	●	●		●
15MW2S	Overburden/20±'	Monitor quality of shallow ground water and test for soil contamination upgradient of the former acid storage tank.	15MW2S (depth)	●		●	●	●	●	●		
			15GW2S		●	●	●	●	●	●		
15MW3S	Overburden/20±'	Monitor quality of shallow ground water and subsurface soils downgradient of the former acid storage tank.	15MW3S (depth)	●		●	●	●	●	●		
			15GW3S		●	●	●	●	●	●		
15MW4S	Overburden/20±' (advance to bedrock)	Monitor quality of shallow ground water and subsurface soils downgradient of the former acid storage tank; determine depth to bedrock.	15MW4S (depth)	●		●	●	●	●	●		
			15GW4S		●	●	●	●	●	●		
Test Borings												
15TB4	NA/15±'	Determine stratigraphy/nature of fill immediately north of the former acid storage tank. Further determine nature, extent and degree of soil contamination.	15TB4 (depth)	●		●	●	●	●	●	●	●
15TB5	NA/15±'	Further define extent of subsurface soil contamination (within 35' southeast of former acid tank).	15TB5 (depth)	●		●	●	●	●	●	●	
15TB6	NA/15±'	Further define extent of subsurface soil contamination (within 35' west of former acid tank).	15TB6 (depth)	●		●	●	●	●	●	●	
15TB7	NA/15±'	Further define extent of subsurface soil contamination (within 50' south of former acid tank).	15TB7 (depth)	●		●	●	●	●	●		
15TB8	NA/15±'	Further define extent of subsurface soil contamination (within 50' northwest of former acid tank).	15TB8 (depth)	●		●	●	●	●	●		
15TB9	NA/15±'	Determine nature and extent of subsurface soil contamination within 50' east of former acid tank.	15TB9 (depth)	●		●	●	●	●	●		
15TB10-15TB14	NA/15±'	Optional borings to be installed to determine extent of soil contamination, if required, based on the field screening results.	15TB10 (depth)-15TB14 (depth)	● (5)		● (5)	● (5)	● (5)	● (5)	● (5)		
			Subtotal Soils	15	0	15	15	15	15	15	4[1]	2
			Subtotal Water[2]	0	4	4	4	4	4	4	0	1

TABLE 4-13 (continued)
SPENT ACID STORAGE AND DISPOSAL AREA FIELD SAMPLING PLAN

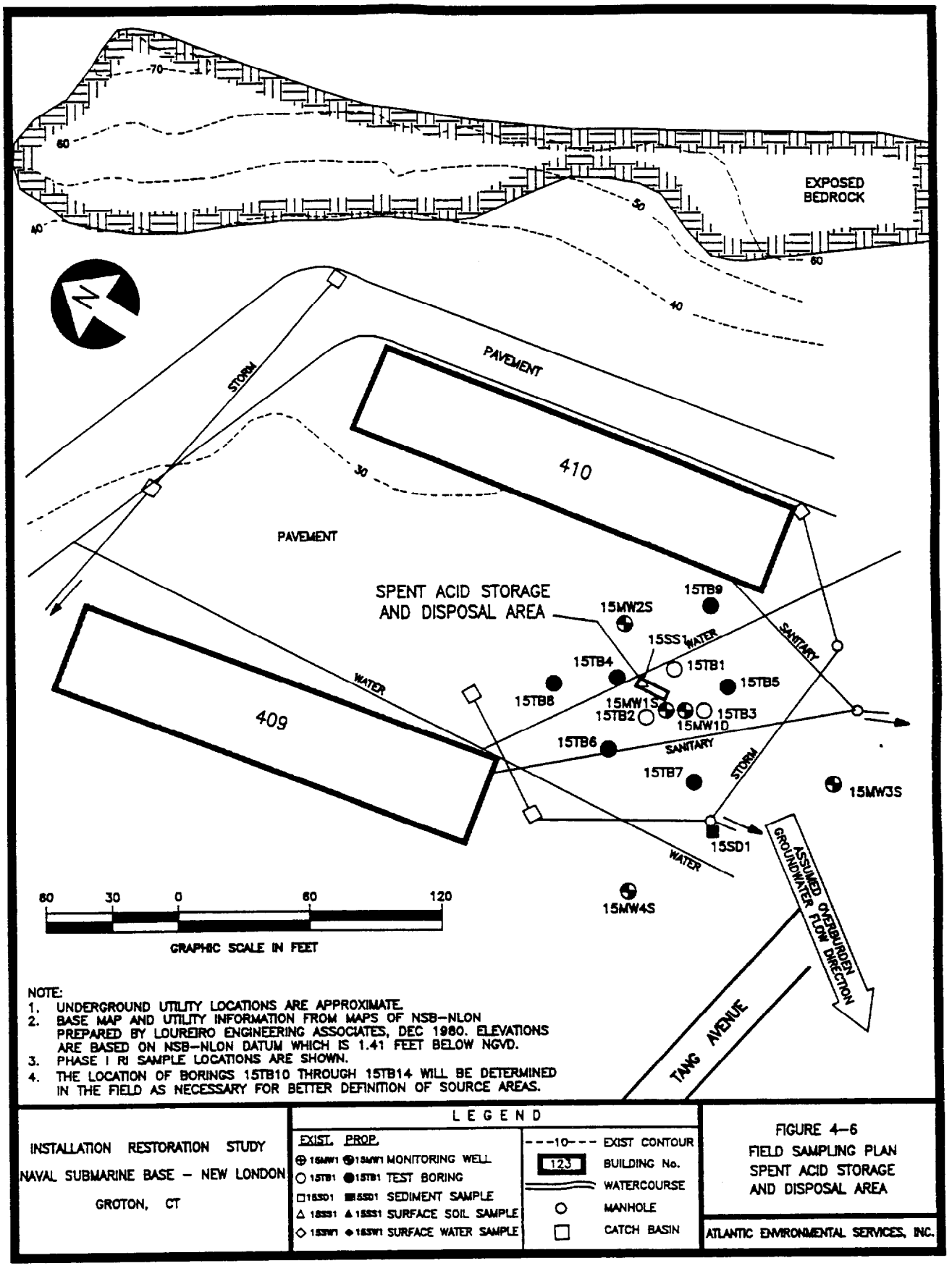
Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis						
				Soil	Water	VOC	SVOC	Inor-ganics	Pest-cides	PCB	TCLP	Engi-neering
Sediment Sampling												
15SD1	-	Provide chemical data for sediment from downgradient, stormwater location to determine whether site contaminants are being transported offsite by these mechanisms.	15SD1	•		•	•	•	•	•		•
			Subtotal Sediments	1	0	1	1	1	1	1	0	1
			Total Soils	**16**	**0**	**16**	**16**	**16**	**16**	**16**	**4[1]**	**3**
			Total Water[3]	**0**	**8**	**8**	**8**	**8**	**8**	**8**	**0**	**2**

PROPOSED

10 Primary test borings (including well borings)
5 Supplemental test borings
4 Wells

Notes:

[1] Four TCLP inorganic analyses will be conducted based on field screening for lead; one of the four will be selected for full TCLP analysis.
[2] Total includes 1 round of sampling only.
[3] Total includes 2 rounds of sampling.


EXPOSED BEDROCK
PAVEMENT
STORM
410
409
PAVEMENT
SPENT ACID STORAGE AND DISPOSAL AREA
15TB9
15MW2S
15SS1
WATER
SANITARY
15TB4
15TB1
15TB5
15TB8
15MW1S
15TB2
15TB3
15MW1D
15TB6
SANITARY
STORM
15TB7
15MW3S
15SD1
WATER
WATER
15MW4S
ASSUMED OVERBURDEN GROUNDWATER FLOW DIRECTION
TANG AVENUE
60 30 0 60 120
GRAPHIC SCALE IN FEET
NOTE:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980. ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.
4. THE LOCATION OF BORINGS 15TB10 THROUGH 15TB14 WILL BE DETERMINED IN THE FIELD AS NECESSARY FOR BETTER DEFINITION OF SOURCE AREAS.
INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT
LEGEND
EXIST. PROP.
MONITORING WELL
TEST BORING
SEDIMENT SAMPLE
SURFACE SOIL SAMPLE
SURFACE WATER SAMPLE
EXIST CONTOUR
BUILDING No.
WATERCOURSE
MANHOLE
CATCH BASIN
FIGURE 4-6
FIELD SAMPLING PLAN
SPENT ACID STORAGE AND DISPOSAL AREA
ATLANTIC ENVIRONMENTAL SERVICES, INC.

of XRF screening results and professional engineering judgement. Detection of lead concentrations at or above 500 ppm (preliminary lead cleanup level) in any or all of the outer borings (15TB7, 15TB8, and 15TB9) will prompt the initiation of supplemental boring(s) to better delineate the outermost extent of contamination. Decisions to utilize additional borings for detection of lead concentrations below 500 ppm will be addressed on a case by case basis.

TCLP samples will be collected from the four most contaminated samples identified during the boring program (test borings and wells). Three of the four samples will be analyzed for TCLP metals. Full TCLP will be run for the fourth sample. In addition to sample collection for chemical analysis, two soil samples (15MW1S and 15TB4) will also be collected from the screened interval for engineering characteristic evaluation; ground water sample 15GW1S will be analyzed for engineering characteristic parameters.

One sediment sample will be collected from the stormwater drainage system located immediately south of the former acid storage tank to determine whether site contaminants may be transported offsite by this mechanism. The sample will be collected from the westernmost manhole serving the drainage system, located between Building 409 and Tang Avenue.

A total of four shallow ground water monitoring wells will be installed at the site. One upgradient well will be installed north of the former acid tank location to characterize the quality of ground water entering the site (based on the presumed direction of flow). Three additional wells will be installed south of the former tank location to monitor downgradient water quality; the center well, 15MW1S, will be installed immediately downgradient of the former tank to characterize ground water in the contamination "source area." Final well depth will be determined on the basis of field observations; however, based upon boring information derived from Step I investigations, total depth is anticipated to range from approximately 15 to 20 feet. Wells will be installed with 10-foot screens, placed so that the top of the screen is located a minimum of 1 foot above the water table.

Two rounds of ground water sampling will be performed. The first round will be collected a minimum of two weeks after well development and the second round approximately three months following completion of the first round. Water table measurements will be taken for each well during both sampling rounds. Additional water table measurements may be collected from adjacent offsite monitoring wells (e.g., ERM-9, ERM-10, ERM-11, and/or ERM-12) to supplement site ground water gradient determinations. These wells are located in the ball field to the southwest. Single well hydraulic conductivity tests will be run in wells 15MW1S and 15MW3S.

4.2.3 Supplemental Step II Investigations

4.2.3.1 Area A

Soil, sediment, ground water, and surface water will be sampled and analyzed and ecological studies will be conducted during the field sampling portion of the Step II investigation of Area A. The rationale for selection of constituents to be analyzed is shown in Table 4-14. The Field Sampling Plan for this site is summarized in Table 4-15. Sample locations are shown in Figure 4-7 (Field Sampling Plan, Area A Landfill, Wetland, and Weapons Center), Figure 4-8 (Field Sampling Plan, Area A Downstream/OBDA) and Plate 1.

TABLE 4-14
AREA A
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	●	Detected in soil, sediment, and water samples collected during Step I.
SVOC[2]	●	Detected in soil, sediment, and ground water samples collected during Step I.
Inorganics[3]	●	Detected in soil, sediment, and water samples collected during Step I.
Pesticides	●	Detected in sediments, surface water, and surface soil samples collected during Step I, but not detected in ground water. Not included in proposed ground water analysis.
PCB[4]	●	Detected in sediments and surface soil samples collected during Step I but not detected in surface or ground water except at one well location. Not included in proposed ground water analysis.
TCLP[5]	●	Determine hazardous waste characteristics for selected samples.
Radiological Analyses[6]	●	Alpha and beta radiation above screening levels detected in ground water samples collected during Step I.
Dioxins[7]	●	Dibenzofuran detected in soils and sediment samples collected during Step I.
Engineering Characteristics[8]	●	Feasibility study data requirements for select samples.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total). At this site, all sediment samples will be analyzed for TOC and grain size.

TABLE 4-15
AREA A FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil (No. of Samples)	Sediment (No. of Samples)	Water (No. of Samples)	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Dioxin	RAD	Engi-neering
Monitoring Wells															
26 Existing wells	Existing	Sample all existing wells. Only well 2LMW18S analyzed for PCBs to confirm previous analysis.	Existing			● (26)	● (26)	● (26)	● (26)		● (1)				
2LMW7S 2LMW9D 2LMW13D 2LMW18S 2WMW3D 2WMW4D 2DMW11S 2DMW11D 3MW12S 3MW12D	Bedrock and overburden	Existing wells where radiological parameters exceeded screening levels.	2LGW7S 2LGW9D 2LGW13D 2LGW18S 2WGW3D 2WGW4D 2DGW11S 2DGW11D 3GW12S 3GW12D			● (10)								● (10)	
2LMW19D[1] 2LMW19S 2LMW20D[1] 2LMW20S	Bedrock/100' below bedrock surface Overburden/20±'	Further assessment of the ground water flow directions between the southeast portion of Area A Landfill and homes served by private wells near NSB-NLON east gate; evaluate ground water quality.	2LGW19D 2LGW19S 2LGW20D 2LGW20S			● (4)	● (4)	● (4)	● (4)						
2WMW21S 2WMW21D[1] 2WMW22D[1] 2DMW23D	Bedrock/100' below bedrock surface Overburden/20±'	Further assessments of the ground water flow directions between Area A Wetland and homes serviced by private wells near the east and north NSB-NLON boundaries. Evaluate ground water quality potentially upgradient of affected site areas.	2WGW21S 2WGW21D 2WGW22D 2DGW23D			● (4)	● (4)	● (4)	● (4)						
2WMW5D	Bedrock/20' (minimum penetration of bedrock)	Better define bedrock ground water flow direction within Area A Wetland; evaluate ground water quality.	2WGW5D			● (1)	● (1)	● (1)	● (1)						
2DMW24D 2DMW24S 2DMW25D 2DMW25S 2DMW26D 2DMW26S 2DMW27D 2DMW27S 2DMW28D 2DMW28S 2DMW29S 2DMW30S	Bedrock/20' (minimum penetration of bedrock) Overburden/20±'	Further evaluate extent of ground water contamination downgradient of Area A Landfill; further evaluate ground water quality/hydrology near North Lake.	2DGW24D 2DGW24S 2DGW25D 2DGW25S 2DGW26D 2DGW26S 2DGW27D 2DGW27S 2DGW28D 2DGW28S 2DGW29S 2DGW30S			● (12)	● (12)	● (12)	● (12)						

TABLE 4-15 (continued)
AREA A FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil (No. of Samples)	Sediment (No. of Samples)	Water (No. of Samples)	VOC	SVOC	Inorganics	Pesticides	PCB	TCLP	Dioxin	RAD	Engineering[4]
2WCMW1S 2WCMW2S 2WCMW3S	Overburden/20±'	Define ground water flow directions and hydraulic gradients near Weapons Center; evaluate ground water quality.	2WCGW1S 2WCGW2S 2WCGW3S			● (3)	● (3)	● (3)	● (3)						
2WCMW1S 2WCMW2S 2WCMW3S	Overburden/20±'	Provide chemical data for soils collected from the Weapons Center.	2WCMW1S (depth) 2WCMW2S (depth) 2WCMW3S (depth)	● (3)			● (3)	● (3)	● (3)						● (1)
2LPW1S	Overburden pump test/ base of saturated thickness	Located in an area considered to represent the average hydrogeologic conditions of Area A Landfill.	2LPW1S			● (3)	●[5] (7)	● (3)	● (3)		● (3)				● (3)
		Test Borings													
2LTB8 through 2LTB27	NA/15'	Define lateral and vertical extent and degree of contamination identified around Area A concrete pad. Ten soil samples will be collected for analysis based on GC field screening for PCB and organic vapor analyzer screening for VOCs.	2LTB8 (depth) through 2LTB27 (depth)	● (10)			● (10)	● (10)	● (10)	● (10)	● (10)	● (2)			● (2)
2LTB13 2LTB23	NA/15'	Located in landfill area where dibenzofuran and ash have been detected.	2LTB13 (depth) 2LTB23 (depth)	● (2)									● (2)		
2LTB28 through 2LTB32	NA/15'	Optional borings at Area A concrete pad to be installed to determine the lateral extent of soil contamination (if contamination is detected during field screening). Three soil samples will be collected for analysis based on GC field screening for PCB and total organic vapor analyzer screening for VOCs.	2LTB28 (depth) through 2LTB32 (depth)	● (3)			● (3)	● (3)	● (3)	● (3)	● (3)				
2LC1 through 2LC4	NA/15'	Core samples of the pad to determine if it is contaminated.	2LC1 through 2LC4	● (4)							● (4)				
2WCTB1 2WCTB2 2WCTB3 2WCTB4 2WCTB5 2WCTB6 2WCTB7 2WCTB8	NA/15'	Provide chemical data for soils collected from the Weapons Center area.	2WCTB1 (depth) 2WCTB2 (depth) 2WCTB3 (depth) 2WCTB4 (depth) 2WCTB5 (depth) 2WCTB6 (depth) 2WCTB7 (depth) 2WCTB8 (depth)	● (8)			● (8)	● (8)	● (8)	● (4)	● (4)	● (1)			● (1)
2DTB1	NA/10'	Optional boring to be installed if soil gas survey indicates presence of VOCs in vicinity.	2DTB1 (depth)	●			●								
			Subtotal Soil Samples	31			25	24	24	17	21	3	2	0	4
			Subtotal Ground Water Sampling[2]			63	57	53	53	0	4	0	0	10	3

TABLE 4-15 (continued)
AREA A FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil (No. of Samples)	Sediment (No. of Samples)	Water (No. of Samples)	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Dioxin	RAD	Engi-neering
Sediment Sampling															
2WSD10 through 2WSD42	0-1' Below sediment surface	Provide additional pesticide analytical data in Area A wetland to confirm that elevated levels of pesticides are not present. Ten soil samples will be collected for analysis based on GC field screening for pesticides.	2WSD10 (0-1') through 2WSD42 (0-1')		• (10)					• (10)		• (1)			• (1)
2DSD14 through 2DSD29 3SD3A 3SD4A 3SD5A 3SD7	0' to base of sediments at the following intervals 01', 1-3', and 3-5'	Define lateral and vertical extent and degree of pesticides in Area A downstream pond sediments. Ten soil samples will be collected for analysis based on GC field screening for pesticides. Full CLP analysis to be performed on samples 2DSD24 through 2DSD29.	2DSD14 (depth) through 2DSD29 (depth) 3SD3A 3SD4A 3SD5A 3SD7		• (10)		• (6)	• (6)	• (6)	• (10)	• (6)	• (1)			• (5)
2DSD30	0-1'	At ground water seep into North Lake.	2DSD30		• (1)		• (1)	• (1)	• (1)	• (1)	• (1)				
2DSD31	0-1'	At ground water seep into North Lake.	2DSD31		• (1)		• (1)	• (1)	• (1)	• (1)	• (1)				
2DSD32	0-1'	At ground water seep into North Lake.	2DSD32		• (1)		• (1)	• (1)	• (1)	• (1)	• (1)				
2WCSD1 through 2WCSD15	0-1'	Provide chemical data for sediments collected from areas of surface water flow from the Weapons Center; samples for VOC, PCB, and pesticide analysis selected at culvert outlets and upgradient locations within Weapons Center.	2WCSD1 through 2WCSD15		• (15)		• (6)	• (15)	• (15)	• (6)	• (6)	• (1)			• (2)
2WCSD11	0-1'	Located in area where dibenzofurans have been detected.	2WCSD11		• (1)								• (1)		
3SD6	0' to base of sediments	Located in area where dibenzofurans have been detected.	3SD6 (depth)		• (1)								• (1)		
			Subtotal Sediment Sampling	0	40	0	15	24	24	29	15	3	2	0	8
Surface Soil Sampling															
2DSS1 through 2DSS18	0-6" below grade	Provide chemical data for surficial soil samples from Area A downstream watercourse. Four surface soil samples will be collected for analysis based on GC field screening for pesticides.	2DSS1 (0-6") through 2DSS18 (0-6")	• (5)						• (5)					

TABLE 4-15 (continued)
AREA A FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil (No. of Samples)	Sediment (No. of Samples)	Water (No. of Samples)	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Dioxin	RAD	Engi-[4] neering
2DSS19 through 2DSS23	0-6" below grade	Optional sample locations to be installed (if required) to determine the lateral extent of soil contamination. If additional contamination is detected during field screening, two surface soil samples will be collected for analysis based on GC field screening for pesticides.	2DSS19 (0-6") through 2DSS23 (0-6")	● (2)						● (2)					
			Subtotal Surface Soil	7	0	0	0	0	0	7	0	0	0	0	0
			Surface Water												
2WSW1	Existing	Upgradient adjacent to wetland.	2WSW1			● (1)	● (1)		● (1)	● (1)					
2WSW2	Existing	At wetland outlet.	2WSW2			● (1)	● (1)	● (1)	● (1)	● (1)	● (1)				
2WCSW3		Upgradient of wetland at stormwater under drain outlet from Weapons Center.	2WCSW3			● (1)	● (1)	● (1)	● (1)	● (1)	● (1)				
2WCSW4		Upgradient of wetland at outlet from Weapons Center storm drain.	2WCSW4			● (1)	● (1)	● (1)	● (1)	● (1)	● (1)				
2WCSW5		Upgradient of wetland at outlet from Weapons Center storm drain.	2WCSW5			● (1)	● (1)	● (1)	● (1)	● (1)	● (1)				
2WSW6		Northeast section of wetland.	2WSW6			● (1)	● (1)		● (1)	● (1)					
2WSW7		Upgradient of wetlands in small drainage swale from Route 12.	2WSW7			● (1)	● (1)		● (1)	● (1)					
2WSW8 2WSW9		Upgradient of wetland at stormwater outlets from "urban areas".	2WSW8 2WSW9			● (2)	● (2)		● (2)	● (2)					
2WSW11		From pond in Area A wetland.	2WSW11			● (1)	● (1)		● (1)	● (1)					
2WSW10 2WSW12		Upgradient of wetland at stormwater outlet.	2WSW10 2WSW12			● (2)	● (2)		● (2)	● (2)					
4SW1 4SW2		Upgradient and downgradient, respectively of Rubble Fill at Bunker A-86 (tabulated under Rubble Fill at Bunker A-86).	4SW1 4SW2												
2DSW2-5 2DSW7 2DSW9-11	Existing	Surface water sample locations previously sampled during Phase I which were located to measure water quality at various locations in Area A downstream surface waters; 2DSW9 and 2DSW11 analyzed for SVOCs and PCBs.	2DSW2-5 2DSW7 2DSW9-11			● (8)	● (8)	● (2)	● (8)	● (8)	● (2)				

TABLE 4-15 (continued)
AREA A FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type			Analysis								
				Soil (No. of Samples)	Sediment (No. of Samples)	Water (No. of Samples)	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Dioxin	RAD	Engi-[4] neering
2DSW14		Upgradient of Area A downstream at stormwater outfall.	2DSW14			● (1)	● (1)		● (1)	● (1)					
2DSW15		Upgradient of Area A downstream at outfall from Torpedo Shops.	2DSW15			● (1)	● (1)		● (1)	● (1)					
7SW1	Existing	At downgradient location in Torpedo Shops. (Tabulated under Torpedo Shops.)	7SW1												
2DSW30-32		At ground water seep into North Lake.	2DSW30-32			● (3)	● (1)	● (1)	● (1)	● (1)	●				
		Subtotal Surface Water				25	25	7	23	23	7	0	0	0	0
		Total Solids		78			40	48	48	48	36	6	4	0	12
		Total Water[3]				151	139	113	129	23	15	0	0	20	6

PROPOSED

56 Primary test borings (including well borings)
5 Supplemental test borings
28 Wells
- 11 Deep bedrock wells
- 17 Shallow overburden wells

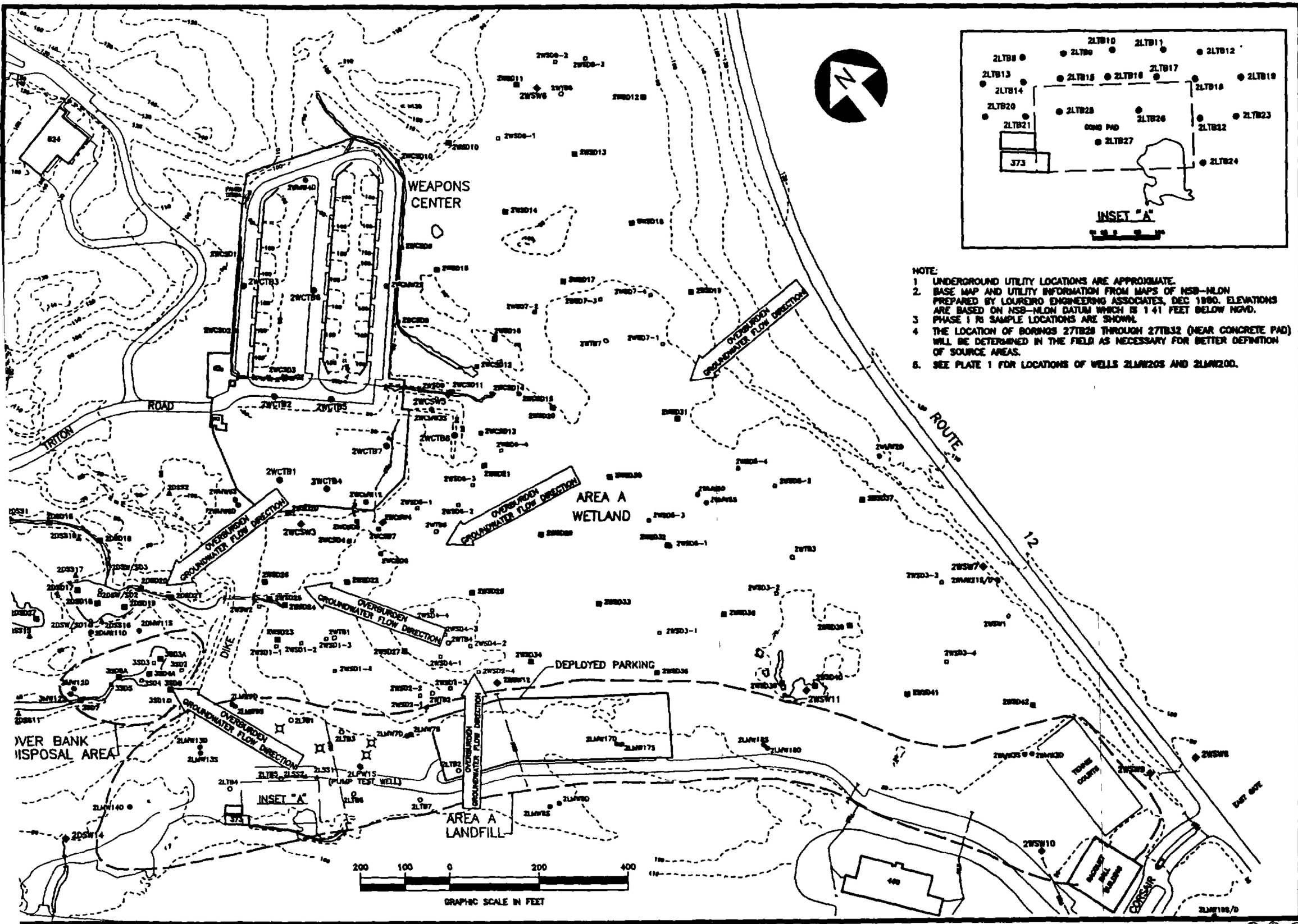
Notes:

[1] 100 feet penetration of bedrock to be representative of offsite residential well construction.
[2] Total includes one sampling round.
[3] Total includes two sampling rounds.
[4] All sediment samples will be analyzed for grain size and TOC.
[5] VOC samples should be collected at the following pump test intervals: start, 1 hour, 2 hours, 4 hours, 8 hours, 16 hours, and conclusion.

TABLE 4-15 (continued)
AREA A FIELD SAMPLING PLAN

ECOLOGICAL SAMPLING						
Sample Type	Location	Sample Quantity				Analysis
		Tissue	Soil	Sediment	Bioassays	
Area A - Qualitative Survey						
Qualitative soil invertebrate survey	Wetland, Downstream, OBDA					Qualitative
Fish	Downstream ponds	●[1] (3)				Qualitative/Pesticides
Area A - Quantitative Survey						
Native earthworms and soils	Downstream	● (5)	● (5)[3]			Pesticides
In situ earthworm bioassays in soils/wetland sediment	Wetland, Downstream, OBDA				● (15-20)	---
Introduced earthworms from bioassays and soils/wetland sediment	Wetland, Downstream, OBDA	● (5)	● (5)[3]			Pesticides
Earthworm bioassays in pond sediment	Downstream watercourses			● (6)[3]	● (9)[2]	Pesticides (sediment only)
Introduced earthworms from bioassays	Downstream watercourses	● (3)				Pesticides
Frogs	Downstream ponds and streams	● (9)				Pesticides
Benthic Invertebrates and reference location	Downstream ponds and streams	● (18)		● (18)[3]		Quantitative benthic analysis, reference area sediments for pesticides

Notes:
[1] If larger fish are found, separate analysis will be conducted for tissue and liver for a total of six analyses.
[2] Includes three reference locations.
[3] Analysis included in Area A field sampling plan.



NOTE:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB–NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1990. ELEVATIONS ARE BASED ON NSB–NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.
4. THE LOCATION OF BORINGS 27TB29 THROUGH 27TB32 (NEAR CONCRETE PAD) WILL BE DETERMINED IN THE FIELD AS NECESSARY FOR BETTER DEFINITION OF SOURCE AREAS.
5. SEE PLATE 1 FOR LOCATIONS OF WELLS 2LMW20S AND 2LMW20D.

FIGURE 4–7
FIELD SAMPLING PLAN
AREA A LANDFILL, WETLAND AND WEAPONS CENTER

ATLANTIC ENVIRONMENTAL SERVICES, INC.

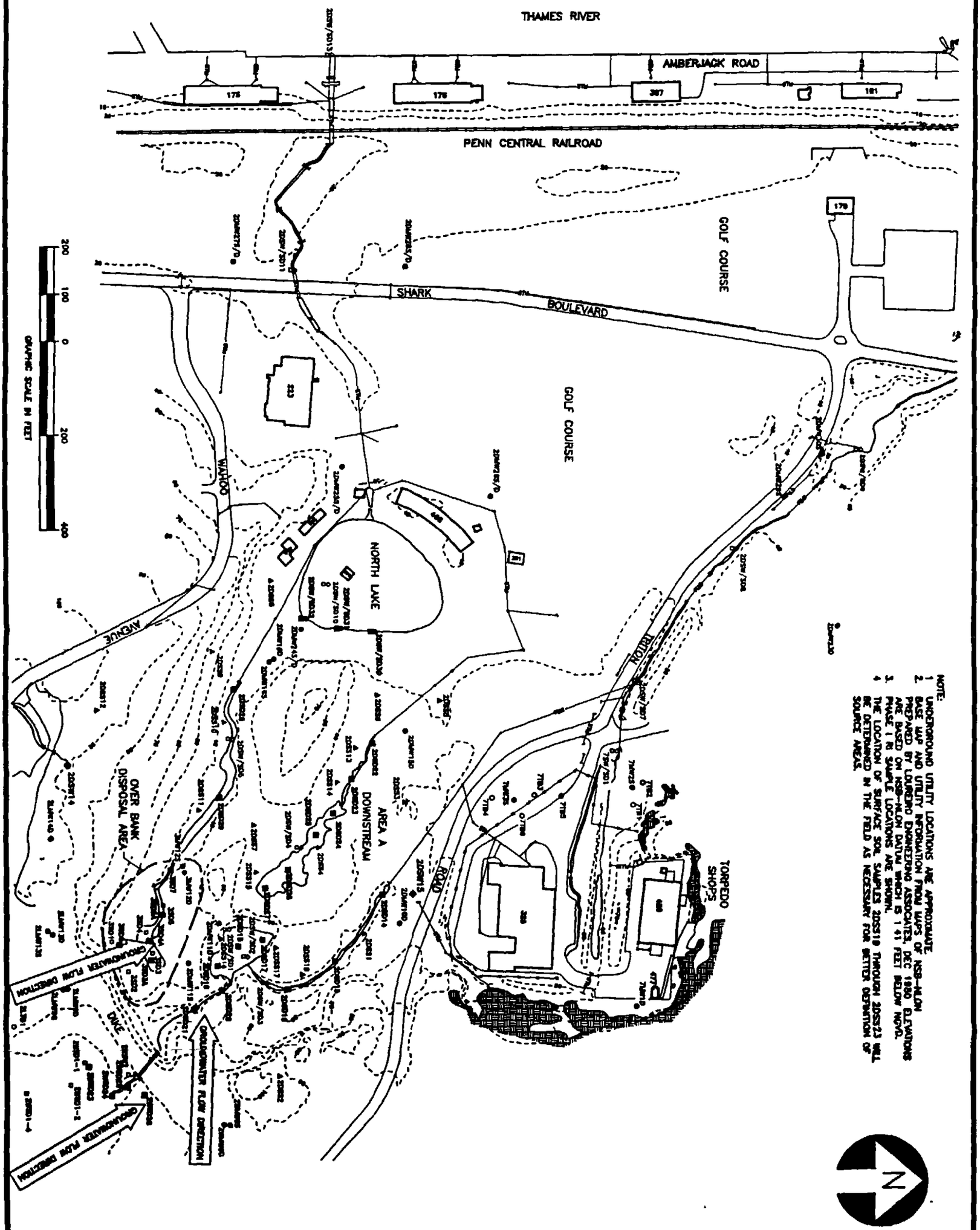
LEGEND

EXIST.	PROP.	
⊕ 6MW1	⊕ 7MW5	MONITORING WELL
○ 6TB1	● 7TB5	TEST BORING
□ 2DSD1	■ 2DSD5	SEDIMENT SAMPLE
△ 6SS1	▲ 7SS5	SURFACE SOIL SAMPLE
◇ 2DSW1	◆ 2DSW5	SURFACE WATER SAMPLE
	⌑	DRAWDOWN OBSERVATION WELL

---10--- EXIST CONTOUR
123 BUILDING No
WATERCOURSE
—STM— STORM SEWER
CATCH BASIN

INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE–NEW LONDON
GROTON, CONN.

00232022



INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE-NEW LONDON
GROTON, CONN.

LEGEND

EXIST.	PROP.	
6MW1	7MW5	MONITORING WELL
6TB1	7TB5	TEST BORING
20SD1	20SD5	SEDIMENT SAMPLE
6SS1	7SS5	SURFACE SOIL SAMPLE
20SW1	20SW5	SURFACE WATER SAMPLE

---10--- EXIST CONTOUR
123 BUILDING No.
WATERCOURSE
—STM— STORM SEWER
CATCH BASIN

FIGURE 4-8
FIELD SAMPLING PLAN
AREA A DOWNSTREAM/OBDA

ATLANTIC ENVIRONMENTAL SERVICES, INC

00232032

Area A Landfill

A total of 20 primary test borings will be drilled at the Area A Landfill. Proposed boring locations are described below, and illustrated in Figure 4-7 and Plate 1. Seventeen borings will be drilled around the Area A concrete pad (former hazardous waste storage area), two of which will be located in an area where dibenzofuran and ash have been detected. Three borings will be drilled inside the pad in areas where cracks are evident. Due to the fact that the storage area was aboveground, and that contamination is expected to be encountered at relatively shallow depths, borings will be advanced to a depth of 15 feet or the water table or 4 feet below any evidence of contamination based on GC field screening analyses, whichever is greater. Four core samples from the concrete pad will be analyzed for PCBs. These samples will either be collected from oil-stained areas of the pad or randomly if no such areas are evident. In addition to the primary test borings, a maximum of five supplemental borings may be required to define the full lateral extent of contamination.

Continuous soil samples will be collected from each borehole during drilling to determine the nature, extent and degree of soil contamination associated with the former hazardous waste storage area. An Atlantic geologist will log the lithology and structural characteristics of each subsurface soil sample, identify intervals of contamination by visual evidence, and screen each sample for volatile organic compounds using a total organic vapor analyzer and PCBs using a portable gas chromatograph. Ten subsurface soil samples will be selected for laboratory chemical analysis based on field screening and two subsurface soil samples will be collected for laboratory analysis for chlorinated dioxins. The details of sample selection and selection of supplemental borings is discussed below. If supplemental borings are necessary, no more than three additional samples will be selected for laboratory chemical analysis. Samples for engineering analysis will be selected based on representative aquifer materials and/or contaminated soils that may require remediation.

In order to validate the field screening method, soil samples covering a range of PCB concentrations will be collected for laboratory chemical analysis. A minimum of two samples will be analyzed offsite from soil exhibiting each of the following concentration ranges: >500 ppm, 2 ppm, and not detected. The remainder of samples will be collected from the portion of the core sample yielding the highest evidence of PCB contamination. In borings yielding no evidence of PCB contamination, the sample will be collected at a depth of 0-1 foot. As discussed above, a minimum of five supplemental test borings will be drilled if required to further define the extent of soil contamination in the vicinity of the former hazardous waste storage area. The decision to drill these borings will be based upon a combination of gas chromatograph and total organic vapor analyzer screening results and professional engineering judgement. Detection of PCB concentrations at or above 2 ppm (preliminary PCB cleanup level) in any or all of the borings drilled around the concrete pad will prompt the initiation of supplemental boring(s) to better delineate the outermost extent of contamination. Decisions to utilize additional borings for detection of PCB concentrations below 2 ppm will be addressed on a case by case basis.

Four monitoring wells (two bedrock and two overburden wells) will be installed at or near Area A Landfill. Proposed monitoring well locations are illustrated in Figure 4-7 and

Plate 1. The primary objectives of these monitoring wells are to provide access to ground water for sampling at discrete stratigraphic horizons, and to further assess ground water flow direction between the southeast portion of the Area A Landfill and homes served by private wells near NSB-NLON East Gate. Other ground water wells are proposed for other areas within Area A to further assess ground water quality and flow direction. Overburden wells will be installed to a depth of approximately 20 feet, and will be screened in the uppermost portion of the overburden aquifer. The exact placement and length of screen will be determined in the field by the site geologist, based on the position of the water table, thickness of the capillary fringe, depth to bedrock and contamination encountered. Screen lengths will not exceed 10 feet. Bedrock wells will be installed to a minimum depth of approximately 100 feet below the surface of bedrock. This depth was chosen so that samples collected from these wells would be representative and comparable to those collected from residential wells. Bedrock core samples (5 feet long) will be collected at locations 2WMW21D, 2WMW22D, 2DMW24D, and 2DMW27D.

Subsequent to monitoring well installation, the potentiometric surface of select Area A Landfill monitoring wells (newly installed and existing wells) and residential wells will be measured on a monthly basis for one year, as specified in Section 4.1.16 of this plan.

One ground water pump-test well will be installed in the northwest section of the Area A Landfill site (Figure 4-7 and Plate 1). This well will be used to conduct an aquifer pumping test to help evaluate the feasibility of a pump-and-treat ground water remediation system. The well will be constructed of 6-inch PVC screen and solid casing. The pump well will be installed to a depth of approximately 40 feet (i.e., to the top of the bedrock surface), and will be screened through the entire saturated thickness of the overburden aquifer. Four 2-inch drawdown observation wells will be installed at different distances from the pilot well. The pumping test will be conducted by pumping the pilot well at a constant rate, and measuring the changes in water levels in the piezometers.

Ground water samples will be collected twice from the proposed and existing monitoring wells. The second sampling round will be conducted three months after the first round has been completed. Ground water samples will also be collected from the pump-test well three times during the pumping test. Laboratory analytical procedures which will be performed on these samples have been identified in Table 4-15. The four existing monitoring wells that exhibited high alpha and beta levels during the Phase I RI will each be sampled one time, and ground water will be analyzed for radiological parameters.

Area A Wetland

A total of 33 sediment samples will be collected from the Area A Wetland site. The proposed sample locations are illustrated in Figure 4-7 and Plate 1. These locations were established on a map grid where the linear distance between sample points is approximately 200 feet. Samples are not proposed at grid points near Phase I sample locations. The primary objective of these samples is to provide additional pesticide analytical data to confirm the Phase I RI results that elevated sediment pesticide concentrations do not exist in the wetland. One sediment sample will be collected from each location at a depth of approximately 0-1 foot below

the sediment surface. Each sample will be screened for pesticides in the field using a portable gas chromatograph. Ten sediment samples will be selected for laboratory chemical analysis for pesticides based on gas chromatograph field screening. In order to validate the field screening method, soil samples covering a range of DDT concentrations will be collected for laboratory chemical analysis. A minimum of two samples will be analyzed from soils exhibiting each of the following concentration ranges: > 100 ppm (if detected), 25 ppm, and not detected. For the remainder of the samples, the sample for offsite laboratory analysis will be collected from the sediment samples yielding the highest evidence of DDT contamination. Samples for engineering analysis will be collected from sediments that may require remediation.

Four monitoring wells (three bedrock and one overburden well) will be installed at the site. Proposed monitoring wells are illustrated in Figure 4-7 and Plate 1. The primary objectives of these monitoring wells are to provide access to ground water for sampling at discrete stratigraphic horizons and to further assess ground water flow direction between the Area A Wetland and homes serviced by private wells near the east and north NSB-NLON boundaries. The overburden wells will be screened in the uppermost portion of the overburden aquifer. The exact placement and length of the screen will be determined in the field by the site geologist, based on the positions of the water table, thickness of the capillary fringe, depth to bedrock, and contamination encountered. Screen length will not exceed 10 feet. Bedrock wells will be installed to a minimum depth of approximately 100 feet below the surface of bedrock except for 2WMW5D. This well will be installed to the depth of the first water bearing zone of fracture concentrations and will penetrate the bedrock a minimum depth of 20 feet. Bedrock core samples (5 feet long) will be collected at locations 2WMW21D, 2WMW22D, 2DMW24D, and 2DMW27D.

Subsequent to monitoring well installation, the potentiometric surface of select Area A Wetland wells (newly installed and existing wells) and residential wells will be measured on a monthly basis for one year as specified in Section 4.1.16. The residential wells are at property recently acquired by the Navy.

Ground water samples will be collected twice from the proposed and existing monitoring wells. The second sampling round will be conducted three months after the first round. Laboratory analytical procedures which will be performed on these samples have been identified in Table 4-15. Two existing monitoring wells that exhibited high alpha and beta levels during the Phase I RI will each be sampled one time, and ground water will be analyzed for radiological parameters.

A total of 13 surface water samples will be collected from the Area A Wetland. Proposed and existing sample locations are illustrated in Plate 1. In addition, one sample will be collected upstream of Rubble Fill at Bunker A-86. The primary objectives of these samples are to determine if there is a source of upgradient contamination and define temporal variation in surface water quality. Laboratory analytical procedures which will be performed on these samples include those identified in Table 4-15, hardness, temperature and pH.

To assess any potential ecological impacts due to site contamination a qualitative soil invertebrate survey will be performed, the extent of wetland will be delineated, and the

following quantitative assessments will be performed:

- *in-situ* earthworm bioassays
- pesticide analysis of introduced earthworms from bioassays

The earthworm bioassays and tissue analyses will be performed in this area to provide reference information for studies that will be conducted in Area A Downstream. The Wetland was chosen as a reference area because of the low pesticide concentrations detected in wetland sediment in the Phase I RI.

Area A Downstream/OBDA

A total of 18 primary surficial soil sample locations are proposed for the Area A Downstream and are illustrated in Figure 4-8 and Plate 1. One soil sample will be collected from each location at a depth of approximately 0-6 inches below grade. All samples will be screened for pesticides in the field using a portable gas chromatograph. The primary objectives of these samples are to further define the extent of pesticide contamination and collect additional health and ecological risk data. Four surface soil samples will be collected for laboratory chemical analysis for pesticides, based on field screening. In addition to the primary sample locations, a maximum of five supplemental locations may be required to determine the lateral extent of pesticide contamination. If supplemental sample locations are necessary, no more than two additional samples will be selected for laboratory chemical analysis for pesticides.

In order to validate the field screening method, soil samples covering a range of DDT concentrations will be collected for laboratory chemical analysis. A minimum of one sample will be analyzed from soils exhibiting each of the following concentration ranges: >100 ppm, 25 ppm, and not detected. The remainder of the samples will be collected from the sediment samples yielding the highest evidence of DDT contamination.

A total of 21 sediment sample locations are proposed for the Area A Downstream, and are illustrated in Figure 4-8 and Plate 1. Seventeen of the sample locations are proposed for downstream ponds (including OBDA). A maximum of three samples will be collected from each pond location: from 0-1 foot, from 1-3 feet, and from 3-5 feet. The exact number of samples collected from each location will be dependent upon the thickness of the sediments. Three samples (0-1 foot below grade) will also be collected from locations where ground water seeps into North Lake. Each sample will be screened for pesticides in the field using a portable gas chromatograph. Ten pond sediment samples will be selected for laboratory analysis for pesticides based on field screening in the same manner described above for soils. All three of the sediment samples collected from North Lake will be selected for laboratory chemical analysis. In addition, a sediment sample from location 3SD6 will be analyzed for chlorinated dioxins, since this location is in an area where dibenzofuran has been detected. Samples for engineering analysis will be collected from sediments that may require remediation.

Prior to any subsurface investigation, a soil gas survey will be conducted in the vicinity of 2DMW15D. The soil gas survey area is shown in Figure 4-8. Samples will be collected at grid points 25 feet on center from an area 150 feet x 150 feet centered around 2DMW15D. A

subsurface soil sample will be collected from within the area if any elevated VOCs are detected.

Thirteen monitoring wells (six bedrock and seven overburden wells) will be installed at the site. Proposed monitoring well locations are illustrated in Figure 4-8 and Plate 1. The primary objectives of these monitoring wells are to provide access to ground water for sampling at discrete stratigraphic horizons, and to further define ground water flow directions near North Lake and beyond. Overburden wells will be installed to a depth of approximately 20 feet, and will be screened in the uppermost portion of the overburden aquifer. The exact placement and length of the screen will be determined in the field by the site geologist, based on the positions of the water table, thickness of the capillary fringe, depth to bedrock, and contamination encountered. Screen lengths will not exceed 10 feet. Bedrock wells will be installed to the depth of the first water bearing zone of fracture concentrations and will penetrate the bedrock a minimum depth of 20 feet. In addition to monitoring wells, the addition of one supplemental test boring may be necessary to assess the presence of VOCs in soils adjacent to 2DMW15D. If installed, the test boring would be advanced to a depth of approximately 10 feet or bedrock, whichever is greater.

Subsequent to monitoring well installations, the potentiometric surface of select monitoring wells (newly installed and existing wells) will be measured on a monthly basis for one year as specified in Section 4.1.16.

Ground water samples will be collected twice from the proposed and existing monitoring wells. The second round will be conducted three months after the first round has been completed. The four existing monitoring wells, which previously showed high alpha and beta values, will each be sampled one time, and ground water will be analyzed for radiological parameters.

A total of 13 surface water samples will be collected from the Area A Downstream, three of which will be samples of ground water seeps into North Lake. These samples will be collected when the lake is drained preferably prior to filling in early spring or soon after draining in the fall. Proposed and existing sample locations are illustrated in Plate 1. In addition, one sample will be collected at a downstream location within the Torpedo Shops. The primary objectives of these samples are to define water quality in North Lake, determine if there is a source of upgradient contamination, and define temporal variations in surface water quality. Laboratory analytical procedures which will be performed on these samples include those identified in Table 4-15, temperature, hardness, and pH.

To assess any potential ecological impacts due to site contamination, a qualitative soil invertebrate survey and qualitative fish survey will be performed, the extent of wetland will be delineated. The qualitative soil invertebrate survey will consist of observations of soil invertebrates in Area A Downstream. It is intended to provide general information on the presence and condition of soil invertebrates, but is not meant to provide quantitative information on community parameters. The fish survey to be conducted in Area A Downstream ponds will consist of electroshocking in the ponds to evaluate the presence of fish and identify species, if fish are present.

The following quantitative ecological assessments will also be performed:

- *in-situ* earthworm bioassays
- earthworm bioassays with sediment
- pesticide analysis of native earthworms, introduced earthworms from bioassays, frogs, and fish if present
- quantitative benthic invertebrate survey

Earthworm bioassays will be conducted at 15 to 20 soil locations (including wetland sediment mentioned previously) and six sediment locations (plus three silica sand reference chambers). The earthworm bioassays consist of placing introduced earthworms into a chamber with site soil or sediment and observing the organism's response, including sub-lethal effects such as swelling and coiling. Pesticide analysis of soil and earthworms will be performed at five soil sampling locations and three pond sediment sampling locations to assess bioaccumulation of pesticides in exposed receptors. Pesticide analysis of five native earthworm samples, nine frogs, and, if present, up to three fish samples will provide information on transfer of these contaminants through the food chain.

The quantitative benthic invertebrate survey in the streams and ponds will provide information on benthic community structure in this area and the impact, if any, of site contaminants in this area. Five reference samples will be collected from a reference area to be identified prior to the field survey. Thirteen stream and pond locations will be sampled in Area A Downstream.

Weapons Center

A total of eight test borings will be drilled at the Weapons Center. Proposed boring locations are illustrated in Figure 4-7. The primary objectives of these borings is to identify and characterize areas of potential soil contamination associated with past and present Weapons Center activities. Borings will be advanced to a minimum depth of 15 feet below grade or to the water table, or 4 feet below any evidence of contamination based on OVA field screening analyses, whichever is greater. OVA analyses will be made of the headspace of a subsample that has been heated to 80°C. Borings may be advanced below 15 feet if contamination is identified and/or if the borehole has not advanced through all surficial fill material. Continuous soil samples will be collected from each borehole during drilling. An Atlantic geologist will log lithology and structural characteristics of each subsurface soil sample, identify intervals of organic contaminations by visual evidence, and screen each sample with an organic vapor analyzer. Samples for engineering analysis will be selected based on representative aquifer materials and/or contaminated soils, or sediments that may require remediation. Samples to be collected at a non-specified depth (e.g., 2WCTB1 (depth)) will be selected based upon field screening with an organic vapor analyzer, visual observations, water table elevation or presence of fine-grained soil layer. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observation will be selected for analysis. If no such contamination is evident, a sample will be collected from either the elevation of ground water or from any fine-grained soil layer encountered above the water table.

Three overburden monitoring wells will be installed at the Weapons Center to supplement the existing wells. Proposed monitoring well locations are illustrated in Figure 4-7 and Plate 1. Overburden wells will be installed to a depth of approximately 20 feet, and screened in the uppermost portion of the overburden aquifer. The exact placement and length of the screen will be determined in the field by the site geologist, based on the positions of the water table, thickness of the capillary fringe, depth to bedrock, and contamination encountered. Screen lengths will not exceed 10 feet. Soil samples will be collected and analyzed from the three overburden well borings using the same procedures discussed for test borings.

Ground water samples will be collected twice from the proposed and existing monitoring wells. The second sampling round will be conducted three months after the first round has been completed.

A total of 15 sediment sample locations are proposed for this site and are illustrated in Figure 4-7 and Plate 1. One sediment sample will be collected from each location at a depth of approximately 0-1 feet below the sediment surface. Laboratory analytical procedures which will be performed on these samples have been included in Table 4-15. The objective of these samples is to identify and characterize sediment contamination in areas of surface water flow from the Weapons Center. Sediment sampled from location 2WCSD11 will also be analyzed for chlorinated dioxins, since this location is an area where dibenzofuran has been detected. The sediment samples to be analyzed for VOC, PCB and pesticides will be selected downstream at surface water outfalls and at upstream areas within the Weapons Center. Samples for engineering analysis will be selected based on representative aquifer materials and/or contaminated soils, or sediments that may require remediation.

Surface water sample locations near the Weapons Center are discussed in the above section regarding the Area A Wetlands.

4.2.3.2 Defense Reutilization and Marketing Office (DRMO)

A geologic survey of the site will be performed to supplement existing data collected during previous investigations. This will include mapping of bedrock fractures and field identification of bedrock type of the outcrop near the site.

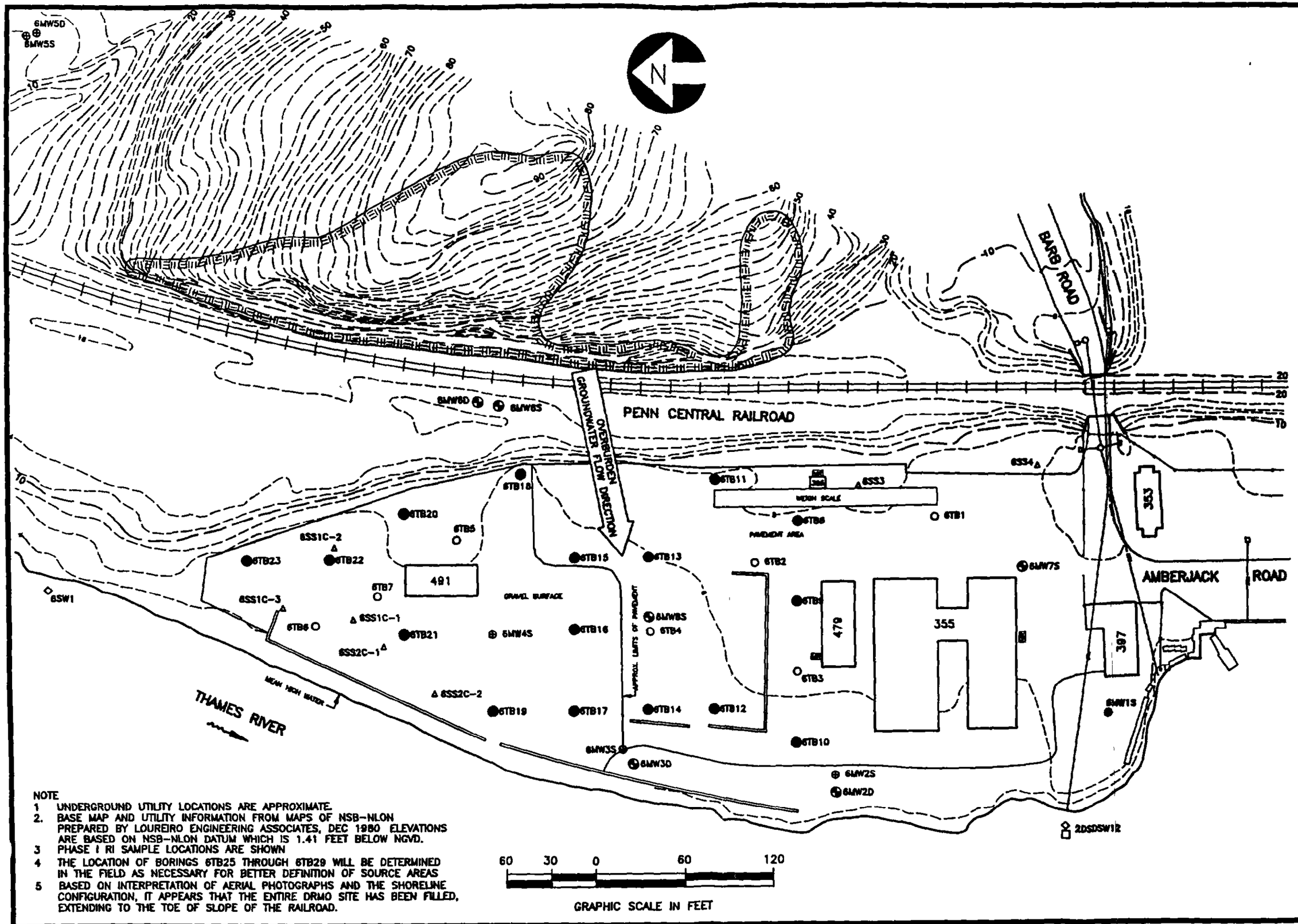
The rationale for selecting parameters to be sampled at the site is provided in Table 4-16. Sample locations are shown in Figure 4-9. The Field Sampling Plan for the site is summarized in Table 4-17. A total of 22 primary test borings will be drilled at this site. Most borings will be advanced to the base of the fill material (15± feet) or 4 feet below any evidence of contamination based on OVA and XRF field screening analyses, whichever is greater. Several well borings will be continued to greater depths as specified in the Field Sampling Plan and 5-foot long bedrock core samples will be collected at locations 6TB17 and 6TB18. In addition to the 22 primary test borings, five supplemental resolution borings may be installed, if necessary, to define the extent of contamination at the site. Supplemental resolution borings will only be installed if there are areas where additional information is necessary to define the extent of contaminants. The decision would be based on field screening organic vapor analysis, visual observations, and XRF analysis for lead.

TABLE 4-16
DRMO
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	Detected in soil and ground water samples collected during Step II.
SVOC[2]	•	Detected in soil and ground water samples collected during Step II.
Inorganics[3]	•	Detected in soil and ground water samples collected during Step II.
Pesticides	•	Detected in soil samples collected during Step II, but not ground water. Not included in proposed ground water analysis.
PCB[4]	•	Detected in soil samples collected during Step II, but not ground water. Not included in proposed ground water analysis.
TCLP[5]	•	Determine hazardous waste characteristics for select samples.
Dioxins[6]	•	Dibenzofuran detected in soil samples during Step II.
Radiological Analyses[7]	•	Detected in certain ground water samples collected during Step II. Analyze only for ground water samples exceeding action level in Step II.
Engineering Characteristics[8]	•	Feasibility study data requirements for select samples.

Notes:

1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).



NOTE
1 UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980 ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3 PHASE I RI SAMPLE LOCATIONS ARE SHOWN
4 THE LOCATION OF BORINGS 6TB25 THROUGH 6TB29 WILL BE DETERMINED IN THE FIELD AS NECESSARY FOR BETTER DEFINITION OF SOURCE AREAS
5 BASED ON INTERPRETATION OF AERIAL PHOTOGRAPHS AND THE SHORELINE CONFIGURATION, IT APPEARS THAT THE ENTIRE DRMO SITE HAS BEEN FILLED, EXTENDING TO THE TOE OF SLOPE OF THE RAILROAD.

FIGURE 4-9
FIELD SAMPLING PLAN
DRMO

ATLANTIC ENVIRONMENTAL SERVICES, INC

LEGEND

--- 10 --- EXIST CONTOUR
123 BUILDING No
WATERCOURSE
STORM SEWER
CATCH BASIN

EXIST. PROP.
6MW1 6MW5 MONITORING WELL
6TB1 6TB5 TEST BORING
2DSD1 2DSD5 SEDIMENT SAMPLE
6SS1 7SS5 SURFACE SOIL SAMPLE
2DSW1 2DSW5 SURFACE WATER SAMPLE

INSTALLATION RESTORATION STUDY
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GROTON, CONN.

00232042

TABLE 4-17
DRMO FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis								
				Soil	Water	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	TCLP	Dioxin	RAD[4]	Engi-neering
Monitoring Wells														
6MW1S	Existing	Existing	6GW1S		●	●	●	●					●	
6MW2S	Existing	Existing	6GW2S		●	●	●	●						
6MW2D[1]	Overburden/50±' (advance boring to determine bedrock contact)	Monitor quality of deep ground water discharging to river; existing shallow soil analytical data available from 6MW2S.	6GW2D		●	●	●	●						
			6MW2D (depth)	●		●	●	●	●	●				
6MW3S	Existing	Existing	6GW3S		●	●	●	●						●
6MW3D[1]	Overburden/50±' (advance boring to determine bedrock contact)	Monitor quality of deep ground water discharging to river; existing shallow soil analytical data available from 6MW3S.	6GW3D		●	●	●	●						
			6MW3D (depth)	●		●	●	●	●	●				●
6MW4S	Existing	Existing	6GW4S		●	●	●	●					●	
6MW5S	Existing	Replaced with new upgradient well 6MW6S												
6MW5D	Existing	Replaced with new upgradient well 6MW6D												
6MW6S	Overburden/20±'	Monitor quality of ground water upgradient of site.	6MW6S (depth)	●		●	●	●	●	●				
			6GW6S		●	●	●	●						
6MW6D[1]	Overburden/50±' (advance boring to determine bedrock contact)	Monitor quality of deep ground water upgradient of site.	6GW6D		●	●	●	●						
6MW7S	Overburden /20±'	Evaluate ground water quality in the southeast portion of the site; ground water elevation data.	6MW7S (depth)	●		●	●	●	●	●				
			6GW7S		●	●	●	●						
6MW8S	Overburden /20±'	Evaluate ground water quality in the vicinity of previously detected contaminants.	6MW8S (depth)	●		●	●	●			●			
			6GW8S		●	●								
Test Borings														
6TB8	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow sample from unpaved area.	6TB8 (0-1)	●		●	●	●	●	●				
			6TB8 (depth)	●		●	●	●	●	●				
6TB9	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB9 (depth)	●		●	●	●	●	●				
6TB10	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB10 (depth)	●		●	●	●	●	●				
6TB11	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB11 (depth)	●		●	●	●	●	●				
6TB12	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB12 (depth)	●		●	●	●	●	●				
6TB13	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow samples near area of contamination.	6TB13 (0-1)	●		●	●	●	●	●				
			6TB13 (depth)	●		●	●	●	●	●				
6TB14	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB14 (depth)	●		●	●	●	●	●				

TABLE 4-17 (continued)
DRMO FIELD SAMPLING PLAN

Sample Location	Well Type/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis								
				Soil	Water	VOC	SVOC	Inor-ganics	Pestl-cides	PCB	TCLP	Dioxin	RAD[4]	Engi-neering
6TB15	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB15 (depth)	●		●	●	●	●	●				
6TB16	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow sample from unpaved area.	6TB16 (0-1)	●		●	●	●	●	●				
			6TB16 (depth)	●		●	●	●	●	●				●
6TB17	NA/Base of fill (15±')	Further define the extent and degree of contamination.	6TB17 (depth)	●		●	●	●	●	●				
6TB18	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow sample from unpaved area.	6TB18 (0-1)	●		●	●	●	●	●				
			6TB18 (depth)	●		●	●	●	●	●				
6TB19	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow sample from unpaved area.	6TB19 (0-1)	●		●	●	●	●	●				
			6TB19 (depth)	●		●	●	●	●	●				
6TB20	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow sample from unpaved area.	6TB20 (0-1)	●		●	●	●	●	●				
			6TB20 (depth)	●		●	●	●	●	●	●	●		●
6TB21	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow surface soil data available at 6SS2C.	6TB21 (depth)	●		●	●	●	●	●		●		●
6TB22	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow surface soil data available at 6SS1C.	6TB22 (depth)	●		●	●	●	●	●				●
6TB23	NA/Base of fill (15±')	Further define the extent and degree of contamination. Shallow surface soil data available at 6SS1C.	6TB23 (0-10)	●		●	●	●	●	●				
6TB24-6TB28	NA/Base of fill (15±')	Optional resolution borings to be installed to determine extent of soil contamination, if required, based upon the field screening results.	6TB24-28 (depth)	● (5)		● (5)	● (5)	● (5)	● (5)	● (5)				
			Subtotal Soil	32		32	32	32	31	31	2	2	0	5
			Subtotal Ground Water[2]		10	10	9	9	0	0	0	0	2	1
			Total Soil	**32**		**32**	**32**	**32**	**31**	**31**	**2**	**2**	**0**	**5**
			Total Ground Water[3]		**20**	**20**	**18**	**18**	**0**	**0**	**0**	**0**	**4**	**2**

PROPOSED

22 Primary test borings (including well borings)
5 Supplemental test borings
5 Wells
- 2 - Shallow overburden
- 3 - Deep overburden or bedrock

Notes:

1. Bedrock well may be installed, see Field Sampling Plan for details.
2. One round of sampling.
3. Includes two sampling rounds.
4. RAD means gamma spectrum analysis and gross alpha/beta analysis.

Soil samples will be collected at intervals indicated in Table 4-17. Sample intervals collected and analyzed from the 0- to 1-foot interval will be used for risk assessment data requirements. Samples to be collected at unspecified depths will be grab samples selected based on field screening with an organic vapor analyzer and XRF, visual observations, water table elevation or the presence of any fine-grain soil layer location. The sample which appears to be the most contaminated based on organic vapor analysis and/or visual observations will be selected for analysis. If no such contamination is evident, a sample will be collected from either the elevation of ground water or from any fine-grained soil layers encountered above the water table. Discrete samples for engineering analysis will be selected based on representative aquifer materials and or contaminated soils that may require remediation.

A total of six monitoring wells will be installed during the supplemental Step II investigation, which include three shallow overburden wells and three deep overburden or bedrock wells. These additional monitoring wells will further assess onsite ground water quality and water quality of ground water discharging into the Thames River (ecological risk data). An upgradient bedrock well will be installed to determine background levels of the various analytes.

Well screens in the shallow overburden wells will be no greater than 10 feet in length and will be placed so that the base of the screen is set above the sand and silt layer, and the top of the well screen is a minimum of 1 foot above the elevation of the mean high tide ground water level. The decision to select a deep overburden well or bedrock well is as follows. If a water bearing unit of sufficient thickness to install a well exists below the fine sand and silt unit, then the deep wells will be installed in the overburden and will be screened on top of bedrock or the first confining layer below the fine sand and silt unit, whichever is encountered first. Screen lengths for the deep overburden wells will not exceed 10 feet. If no such unit is encountered, then a bedrock well will be installed. In any case, deep overburden well borings will extend to bedrock surface to determine depth. If a bedrock well is required, it will be installed to intercept the first significant water bearing zone and extend a minimum of 20 feet below the bedrock surface, whichever is greater.

Ground water samples will be collected twice; the first round will be collected a minimum of two weeks after well development, and a second round three months later. Sampling events will be conducted during low tide when ground water is flowing toward the Thames River. Single well conductivity tests will be conducted in wells 6MW4S and 6MW3D.

4.2.3.3 Lower Subase

The constituents to be analyzed for at this site and the rationale are provided in Table 4-18, and the Field Sampling Plan is summarized in Table 4-19. Sample locations are shown in Figure 4-10.

One monitoring well will be installed at the location east of the power house (Building 29) where oil was observed in an excavation. If recoverable free product is detected in this well, seven additional wells will be installed to determine the extent of free product.

TABLE 4-18
LOWER SUBASE
RATIONALE FOR SELECTION OF CONSTITUENTS FOR ANALYSIS

Parameter	Selected	Rationale
VOC[1]	•	Detected in soil and ground water samples during Step II.
SVOC[2]	•	SVOCs could be present in ground water; not previously analyzed.
Inorganics[3]	•	Detected in soil and ground water during Step II.
Pesticides		Not suspected to be present.
PCB[4]		Not suspected to be present.
TCLP[5]	•	Determine hazardous waste characteristics for select soil samples.
Radiological Analyses[6]		Radiological constituents are not suspected at this site.
Dioxin[7]		Historically, volatile organic compounds have not been burned at this site.
Engineering Characteristics[8]	•	Feasibility study data requirements for select samples.
TPH[9]	•	Useful in determining extent of petroleum contamination.

Notes:

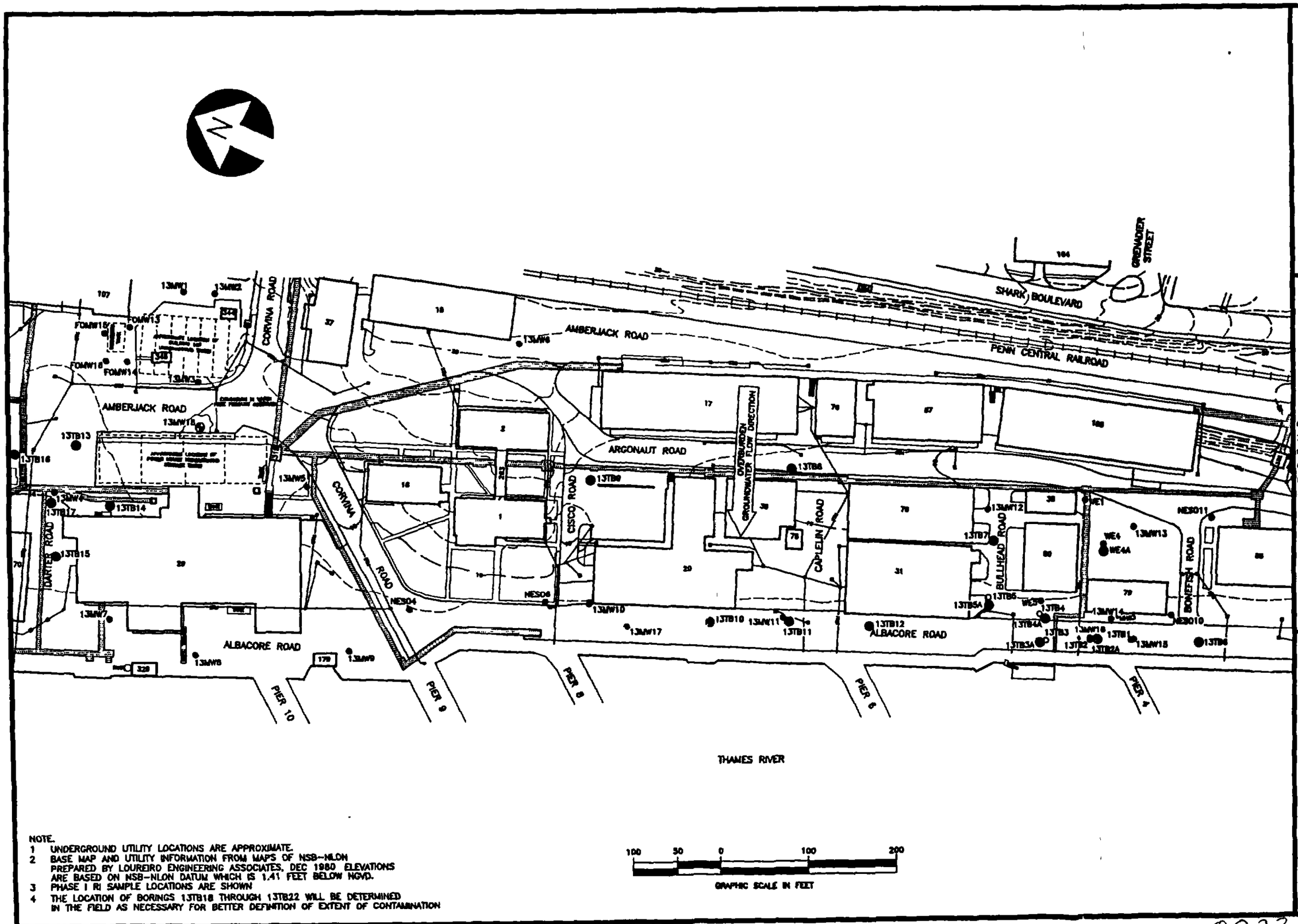
1. VOC means volatile organic compound listed in the CLP TCL.
2. SVOC means semi-volatile organic compound listed in the CLP TCL.
3. Inorganics include total and dissolved inorganics for ground water samples and dissolved inorganics for surface water. All CLP TAL compounds and boron are included in this category.
4. PCB means polychlorinated biphenyl. All arochlors in the CLP TCL will be analyzed.
5. TCLP means toxicity characteristic leaching procedures.
6. Radiological analyses include gross alpha and beta and a complete gamma spectrum analysis.
7. Dioxin analysis includes dioxins and dibenzofurans as specified in U.S. EPA CLP SOW DFLM01.0.
8. Engineering characteristics for soils include grain size distribution, moisture content, specific gravity, organic content, cation exchange capacity, pH, and total organic carbon content; and for ground water includes biochemical oxygen demand (5-day), chemical oxygen demand, total organic carbon, oil and grease (hydrocarbon fraction), total suspended solids, hardness, ammonia (as nitrogen) and phosphorus (total).
9. TPH means total petroleum hydrocarbons.

TABLE 4-19
LOWER SUBASE FIELD SAMPLING PLAN

Sample Location	Well Depth/ Proposed Depth (ft)	Rationale	Sample Designations	Sample Type		Analysis								
				Soil	Water	VOC	SVOC	Inor-ganics	Pesti-cides	PCB	Lead	TCLP[1]	TPH	Engi-neering
13TB2A-5A	15 feet or bottom of sand and gravel fill layer, whichever is deeper	At and around 13MW11 and 13MW16 where high TCLP lead was detected during the Phase I RI.	13TB2A-5A (depth)	• (4)							• (4)	• (4)	• (4)	• (1)
13TB6-12	15 feet or bottom of sand and gravel fill layer, whichever is deeper	At and around 13MW11 and 13MW16 where high TCLP lead was detected during the Phase I RI.	13TB6-12 (depth)	• (7)							• (7)	• (7)	• (7)	• (1)
13TB13-13TB17	15 feet or bottom of sand and gravel fill layer, whichever is deeper	At and around 13MW4 where high TCLP lead was detected during Phase I RI	13TB13-17 (depth)	• (5)							• (5)	• (5)	• (5)	
WE-4A	15 feet or bottom of sand and gravel fill layer, whichever is deeper.	At and around 13MW11 and 13MW16 where high TCLP lead was detected during the Phase I RI.	WE-4A (depth)	•							•	•	•	
13TB18-22	15 feet or bottom of sand and gravel fill layer, whichever is deeper.	Optional resolution borings to be installed to determine full extent of soil contamination if detected based upon field screening.	13TB18-22 (depth)	• (5)							• (5)	• (5)	• (5)	
24 existing monitoring wells	NA	Existing wells			• (24)	• (24)	• (24)	• (24)					• (24)	• (1)
13MW18	15 feet or 10 feet below ground water elevation, whichever is deeper.	At location where oil was observed in an excavation.	13GW18		•	•	•	•					•	
13MW19-25	15 feet or 10 feet below ground water elevation, whichever is deeper.	Optional wells to be installed to determine extent of recoverable product if detected in 13MW18.	13GW19-25		•	•	•	•					•	
			Subtotal Soil	22		0	0	0	0	0	22	22	22	2
			Subtotal Ground Water[2]		26	26	26	26	0	0	0	0	26	1
			Total Soils	**22**		**0**	**0**	**0**	**0**	**0**	**22**	**22**	**22**	**2**
			Total Water[3]		**52**	**52**	**52**	**52**	**0**	**0**	**0**	**0**	**52**	**2**

PROPOSED
17 Primary test borings
5 Supplemental test borings

Notes:
1. Of the 22 TCLP analyses, 16 will only include metals and two will include all TCLP constituents. These two samples will be selected from samples that appear to have high levels of contamination based on field screening results.
2. Total is per one round of sampling.
3. Total includes all rounds of sampling.



NOTE.
1 UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2 BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980 ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3 PHASE I RI SAMPLE LOCATIONS ARE SHOWN
4 THE LOCATION OF BORINGS 13TB18 THROUGH 13TB22 WILL BE DETERMINED IN THE FIELD AS NECESSARY FOR BETTER DEFINITION OF EXTENT OF CONTAMINATION

FIGURE 4-10
FIELD SAMPLING PLAN
LOWER BASE

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LEGEND

	EXIST. CONTOUR
123	BUILDING No.
	WATERCOURSE
STM	STORM SEWER
	CATCH BASIN

EXIST.	PROP.	
⊕ 8MW1	⊕ 7MW5	MONITORING WELL
○ 6TB1	● 7TB5	TEST BORING
□ 22SD1	■ 22SD4	SEDIMENT SAMPLE
△ 6SS1	▲ 7SS3	SURFACE SOIL SAMPLE
◇ 22SW1	◆ 22SW5	SURFACE WATER SAMPLE

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GROTON, CONN.

0023205Z

A total of 17 primary test borings will be drilled at this site to determine the extent and degree of lead contamination. Each boring will be advanced to a depth of 15± feet or the base of the sand and gravel fill layer or 4 feet below any evidence of contamination based on XRF field screening analyses, whichever is greater, and continuously sampled. The actual location may vary due to potential utility conflicts. In addition to the 17 primary test borings, up to five supplemental resolution test borings may be conducted as necessary to define the full extent of lead contamination. Application of these borings and their ultimate locations will be determined on the basis of soil screening analyses, discussed below.

Soil samples will be collected at the intervals depicted in Table 4-19. The two samples to be tested for engineering characteristics will be selected based upon representativeness of the sand and gravel fill layer. Samples to be collected at a non-specified depth (i.e., 13TB14 (depth)) will be made on the basis of field screening using XRF analysis for lead. In order to validate this method, soil samples covering a range of lead concentrations (by XRF analysis) will be collected for offsite laboratory analysis. A minimum of two samples from soils exhibiting each of the following concentration ranges will be selected for laboratory analysis: > 1,000 ppm, 500 ppm, and not detected. All other samples will be collected from the portion of the core sample yielding the highest evidence of lead contamination by XRF analysis. In borings yielding no evidence of lead contamination, the sample will be collected at a depth of 0 to 1 foot. As discussed above, five supplemental test borings are planned to further define the extent of soil contamination, if necessary. Decisions to use these borings will be based upon a combination of XRF analyses and professional engineering judgement. Detection of lead concentrations at or above 500 ppm (preliminary lead cleanup level) will prompt the initiation of supplemental boring(s) to better delineate the outermost extent of contamination. Decisions to utilize additional borings for detection of lead concentrations below 500 ppm will be addressed on a case by case basis.

No new wells will be installed; however, two more rounds of ground water samples will be collected from all 24 existing monitoring wells to confirm Phase I RI results; conduct additional chemical analysis; and define any temporal variations in ground water quality: one initial round, and the second round three months thereafter. Samples will be collected during low tide when there is gradient toward the Thames River.

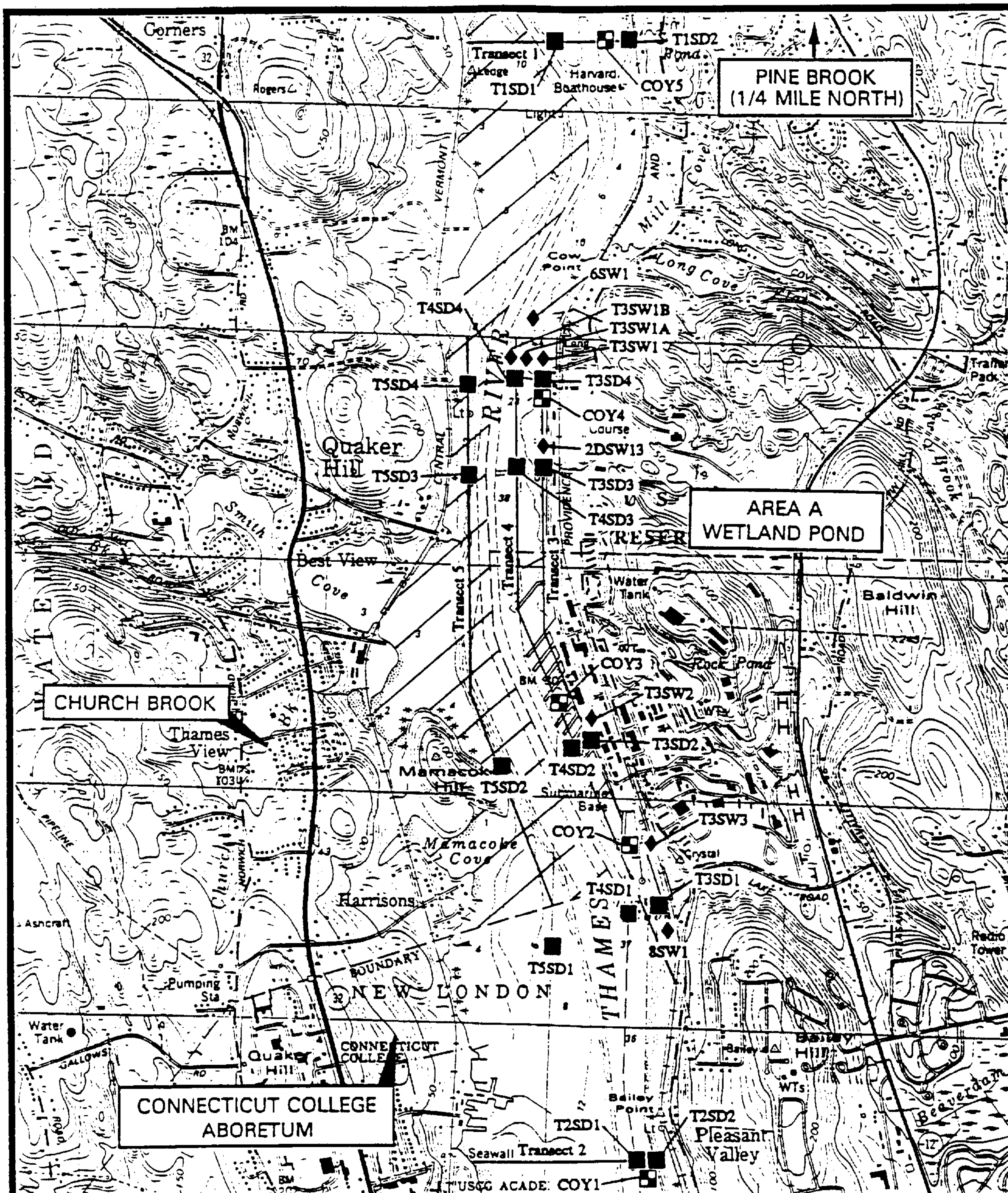
4.2.3.4 Thames River

The constituents to be analyzed at this site and the rationale are discussed in Section 5.0 of the Work Plan; the Thames River Field Sampling Plan is summarized in Table 4-20. Sample locations are shown in Figure 4-11.

A total of 16 sediment and 14 surface water samples will be collected to assess whether the investigation sites at NSB-NLON have had an impact on the Thames River. Surface sediment samples will be collected for chemical analysis. In addition, water samples will be collected at the surface and at approximately 1 foot from the river bottom. In addition to the parameters specified in the field sampling plan table, all water samples will also be analyzed for hardness, pH, temperature and salinity.

TABLE 4-20
THAMES RIVER FIELD SAMPLING PLAN

Sample Location	Proposed Depth	Rationale	Sample Designations	Sample Type: Sediment (No.)	Sample Type: Water (No.)	Analysis: VOC	SVOC	Inorganics	Pesticides	PCB	Quantitative Benthic Survey	Engineering
Sediments												
T1SD1-T1SD2	0-6"	One tidal excursion above Subase to measure upgradient quality along river transect.	T1SD1-T1SD2	● (2)			● (2)	● (2)	● (2)	● (2)	● (2)	● (2)
T2SD1-T2SD2	0-6"	One tidal excursion below Subase to measure sediment quality along river transect.	T2SD1-T2SD2	● (2)			● (2)	● (2)	● (2)	● (2)	● (2)	● (2)
T3SD1-T3SD4	0-6"	Along bulkhead at stormwater outfalls at DRMO, Lower Subase, and Goss Cove to measure any impacts from these sites.	T3SD1-T3SD4	● (4)		●[1] (1)	● (4)	● (4)	● (4)	● (4)	● (4)	● (4)
T4SD1-T4SD4	0-6"	Along pier line at stormwater outfalls from DRMO, Lower Subase, and Goss Cove to measure any offshore impacts from these sites.	T4SD1-T4SD4	● (4)			● (4)	● (4)	● (4)	● (4)	● (4)	● (4)
T5SD1-T5SD4	0-6"	At Subase to measure sediment quality along river transect.	T5SD1-T5SD4	● (4)			● (4)	● (4)	● (4)	● (4)	● (4)	● (4)
		Sediment Totals		16			16	16	16	16	16	16
Water												
6SW1	Surface bottom	Upgradient sample location.	6SW1S 6SW1B		● (2)	● (2)	● (2)	● (2)	● (2)			
T3SW1-T3SW3	Surface bottom	To measure impacts of stormwater and ground water discharge from sites.	T3SW1S-3S T3SW1B-3B		● (6)	● (6)	● (6)	● (6)	● (6)			
T3SW1A-T3SW1B	Surface bottom	To measure area of influence/dilution from DRMO outfall.	T3SW1AS-1BS T3SW1AB-1BB		● (4)	● (4)	● (2)	● (4)	● (4)			
8SW1	Surface bottom	Downgradient sample location.	8SW1S 8SW1B		● (2)	● (2)	● (2)	● (2)	● (2)			
2DSW13	Surface bottom	To measure impacts at outfall from Area A.	2DSW13S 2DSW13B		● (2)	● (2)	● (2)	● (2)	● (2)			
		Water Totals			16	16	14	16	16			
Ecological Sampling												
COY1-COY5	Water column	To assess potential uptake and exposure effects of water column contaminants from both surface or ground water discharges.	COY1-COY5	Oyster tissue (5) plus replicates (5) (10)		● (10)	● (10)	● (10)	● (10)	● (10)		
West side of Thames River	Sediment	To assess potential exposure effects of water column contaminants on Thames River and to assess whether contaminants may enter the food chain via this mechanism.	BV1-BV6	Tissue from bivalve species (6)			● (6)	● (6)	● (6)	● (6)		
East side of Thames River (between bulkhead and pier)	Sediment		MU1-MU3	Tissue from mussel species (3)			● (3)	● (3)	● (3)	● (3)		
1. Sample T3SD1			Totals	19		10	19	19	19	19		



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NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT

LEGEND

- ■ Sediment Sample Locations
- Indicates Caged Oyster Locations
- ◆ Surface Water Sample Locations
- Commercial Shellfish Beds
- PINE BROOK Potential Reference Areas For Benthic Sampling

Shading indicates Conditionally Restricted Shellfishing area
Locations are approximate; exact locations will be chosen in the field
SOURCE: U.S.G.S. Topographic Map, 1984 Uncasville, Ct.

N

FIGURE 4-11
THAMES RIVER ECOLOGICAL
SAMPLING LOCATIONS

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Biological samples will also be collected from the Thames River. These will include a quantitative benthic survey at the 16 sediment sampling locations to evaluate benthic conditions in the river and potential impacts of the Subase. Five oyster cages (with replicates) will be deployed along the shore at the Subase. Chemical analysis of the oysters after 28 days deployment will provide data to assess biological uptake of water column contaminants. Three bivalve species resident in the Thames River will also be sampled (three tissue samples per species) for chemical analysis to evaluate the potential effect of the Subase on body burdens of these organisms.

5.0 SAMPLE PRESERVATION AND SHIPPING

All sampling glassware will be pre-cleaned by the analytical laboratory prior to shipment to Atlantic's Connecticut office. Preservatives will be added to the pre-cleaned containers prior to shipment. Sample preservation standards for solid and liquid matrices are outlined in the laboratory QA/QC plan (Appendix A of the QA/QC Plan).

Preservation method will be noted on the sample container and reported with the designated sample number in a sampling log book. Preservative amounts will be determined as specified in notes of Addendum 4 to the laboratory QA/QC Plan (Appendix A of the QA/QC Plan). The chain-of-custody form (Atlantic Procedure No. 1041) will serve as final documentation of the preservation condition of all samples prior to shipment to the analytical laboratory. All samples and appropriate QA/QC samples will be shipped via Federal Express or courier to the analytical laboratory.

6.0 RECORD KEEPING AND DOCUMENTATION

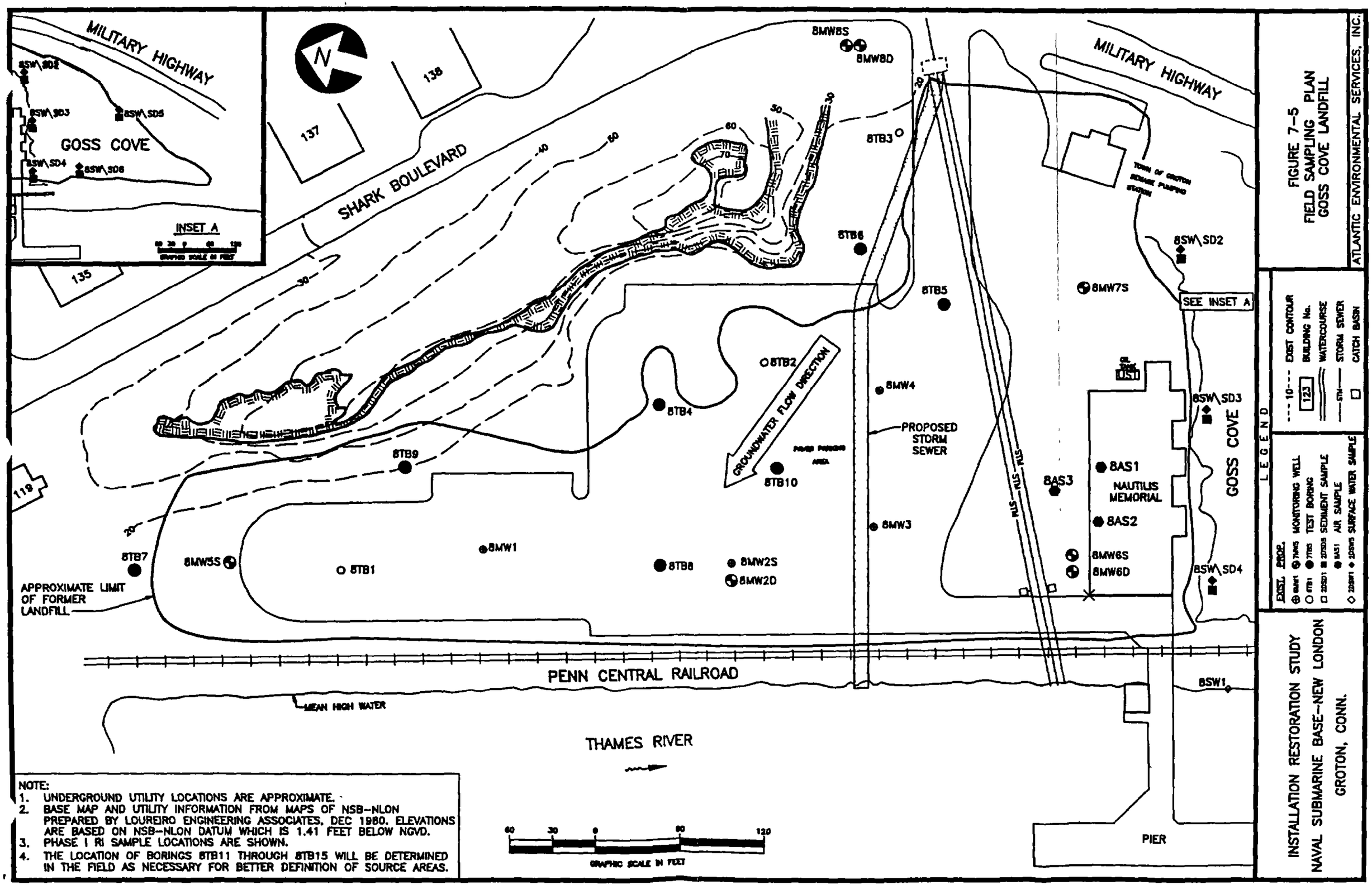
The following documents will be utilized for record keeping during field operations:

DOCUMENT	PURPOSE
Field Notebook	A designated field notebook will be issued to each field technician and used during field activities.
Master Sample Log	A laboratory notebook will remain in the site office to record every sample collected. The field operations manager will log in all samples and those sent to the analytical laboratory with waybill number at the end of each day.
Chain-of-Custody Record	A COC form will document custody of all samples from field to laboratory.
Waybills	A waybill receipt is obtained at the time of accepted sample shipment by Federal Express or courier and will be attached to the Master Sample Log.
Accident Report/Daily First Aid Report/Employer's First Report of Injury/OSHA 200 Forms	These data sheets will document any accident occurring onsite during field activities. The sheets are attached to the HASP and located in the site trailer.

At the conclusion of each field sampling effort, site field logs and the master sample log will be photocopied and stored in the project file at Atlantic's Connecticut office.

7.0 SCHEDULE

The schedule to begin the field sampling plan will commence upon contract approval by the Navy. Factors that may result in modifications to the schedule include: availability of drilling equipment, analytical laboratory turn-around time, and weather conditions. The project schedule is summarized below in Figure 7-1, which shows the overall operations, sampling, and report preparation schedules.


MILITARY HIGHWAY
SHARK BOULEVARD
GOSS COVE
INSET A
GRAPHIC SCALE IN FEET
137
138
135
119
8SW\SD2
8SW\SD3
8SW\SD4
8SW\SD5
8SW\SD6
8MW8S
8MW8D
8TB3
8TB6
8TB5
8MW7S
SEE INSET A
8TB2
8TB4
8TB9
8TB10
8MW4
GROUNDWATER FLOW DIRECTION
PROPOSED STORM SEWER
8AS1
8AS3
NAUTILUS MEMORIAL
8AS2
8MW6S
8MW6D
8MW3
8TB7
8MW5S
8TB1
8MW1
8TB8
8MW2S
8MW2D
APPROXIMATE LIMIT OF FORMER LANDFILL
PENN CENTRAL RAILROAD
MEAN HIGH WATER
THAMES RIVER
8SW1
PIER
NOTE:
1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON PREPARED BY LOUREIRO ENGINEERING ASSOCIATES, DEC 1980. ELEVATIONS ARE BASED ON NSB-NLON DATUM WHICH IS 1.41 FEET BELOW NGVD.
3. PHASE I RI SAMPLE LOCATIONS ARE SHOWN.
4. THE LOCATION OF BORINGS 8TB11 THROUGH 8TB15 WILL BE DETERMINED IN THE FIELD AS NECESSARY FOR BETTER DEFINITION OF SOURCE AREAS.
LEGEND
EXIST. CONTOUR
BUILDING No.
WATERCOURSE
STORM SEWER
CATCH BASIN
EXIST. PROP.
MONITORING WELL
TEST BORING
SEDIMENT SAMPLE
AIR SAMPLE
SURFACE WATER SAMPLE
FIGURE 7-5
FIELD SAMPLING PLAN
GOSS COVE LANDFILL
ATLANTIC ENVIRONMENTAL SERVICES, INC.
INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE-NEW LONDON
GROTON, CONN.

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APPENDIX A

ATLANTIC STANDARD OPERATION PROCEDURES

TECHNICAL PROCEDURES	
Procedure Number	**Atlantic Procedure**
1020	Field Procedures for Collection of Surface Soil Samples
1021	Field Procedures for Collection of Subsurface Soils
1022	Field Procedures for Collection of Surface Water and Sediment Samples for Hazardous Waste Determination
1023	Field Procedures for Collection of Ground Water Samples for Hazardous Waste Determination
1024	Field Procedures for Collection of TCDD Samples
1030	Field Procedures for Logging Subsurface Conditions During Test Borings and Well Logging
1041	Sample Chain-of-Custody Procedure
1042	Shipping Procedures for Environmental Field Samples
1051	Operation and Calibration of the HNu Systems Photoionizer Model PI-101
1052	Operation of the Photovac 10S50 Portable Gas Chromatograph
1053	Soil Gas Screening for Volatile Organics
1060	Cleaning Procedure for Sampling Devices Used in Environmental Site Investigations
1070	Well Development Procedures for Small Diameter Monitoring Wells
1071	Field Procedures for Determination of *In Situ* Hydraulic Conductivity with Single Well Hydraulic Tests
1256A	Gas Chromatography Analysis Using External Standard Calibration
1256B	Microscale Extraction
1256C	PCB and Pesticide Analysis by Gas Chromatography
1256D	The Determination of Volatile Organic Compounds in Ambient Air Using Tenax® Adsorption
GTP002	Operation of the Scitec Map Analyzer Model 310 for Lead in Soil Analyses
Standard Number	**ASTM Standards**
D422[1]	Standard Practice for Particle-size Analysis of Soils
D854[1]	Standard Test Method for Specific Gravity of Soils
D2216[1]	Standard Method for Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures
D2217[1]	Standard Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
D2974[2]	Standard Test Methods for Moisture, Ash, and Organic Matter of Peat Materials
Method Number	**U.S. EPA Method (SW 846)**
9040	pH Electrometric Measurement (SW 846)
9045[1]	Soil pH (SW 846)

TECHNICAL PROCEDURES	
9050	Specific Conductance (SW 846)
9081[2]	Cation Exchange Capacity of Soils (SW-846)
Method Number	**U.S. EPA Method (Methods for the Determination of Toxic Organic Compounds in Ambient Air)**
TO1[2]	Determination of Volatile Organic Compounds in Ambient Air Using Tenax® Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS)
Method Number	**APHA Standard Methods for Examination of Water and Wastewater**
2580	Oxidation - Reduction Potential (Eh)
2340[2]	Hardness - Total as $CaCO_3$

[1] At the discretion of the project manager, these methods may be performed in a field laboratory or an offsite laboratory.

[2] These methods will be performed in an offsite laboratory.

SITE SPECIFIC MODIFICATIONS TO ATLANTIC FIELD PROCEDURES		
QA Procedure	**Section Number**	**Modification/Clarification**
1020 1021 1023	6.2 and 6.4 6.2 and 6.3 6.2 and 6.4 6.2 and 6.3	Sample volume, container and preservatives should be as specified in Table 6.1 of the Laboratory Quality Assurance Plan. CME or Waterloo samples may be used in lieu of split-spoons for collection of soils. Samples will not be composited unless necessary to obtain sufficient sample volume to allow chemical analyses specified.
1022	6.41	The samples will be immediately preserved after filtration.
	6.2.2 and 6.4.2	All sediment samples will be collected with a core sampler provided with a core catcher. Sample depth will be as indicated in the Field Sampling Plan.
1023	6.2 and 6.4	Samples to be analyzed for dissolved metals should be field filtered with a 0.45 micron filter prior to the addition of sample preservatives.
1023	6.3	Well purging will be considered complete when three consecutive measurements differ by less than five percent for pH, conductivity, and temperature, and a minimum of three well volumes have been purged. Purging rates will not exceed those used for well development. Samples for VOA analysis will only be collected with a Teflon® or stainless steel bailer.
1042	6.0	Sample packaging, marking, labeling, and shipment shall comply with Department of Transportation Hazardous Materials Regulations (49CFR).
1053	5.1	Soil gas surveys will not be conducted after rainfall events when the ground appears to be saturated.
1060	6.2 and 6.3	The decontamination procedure for sampling equipment shall be as presented below: 1. scrub with a brush in Alconox detergent 2. rinse in clean tap water 3. 10% nitric acid rinse or, for carbon steel, 1% (only for metals analysis) 4. distilled/deionized water rinse (only for metals analysis) 5. rinse with methanol 6. rinse with hexane 7. rinse with distilled water 8. allow to air dry The decontamination procedure for heavy equipment shall be as presented below: 1. scrub with a brush 2. steam clean
1070	6.0	For this project the air development method and the jetting development method will not be used. Well development will proceed until turbidity is less than 50 NTU, or for the greater between a maximum of four hours or seven well volumes. Pumping rates will be measured and recorded during well development.
1070	6.1 and 6.2	A minimum of two weeks must elapse between well development and the commencement of ground water sampling. At a minimum, 3 to 5 well volumes, plus the volume of water lost to the formation during drilling must be removed.

ATLANTIC PROCEDURE NO. 1020

FIELD PROCEDURES FOR COLLECTION OF SURFACE SOIL SAMPLES

Prepared By: John A. Ripp — Principal
JOHN A. RIPP — TITLE

Reviewed By: Edmund J. Burke — QA. Manager
EDMUND J. BURKE, P.E. — TITLE

Approved By: Paul Burgess — Chief Engineer
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SECTION 1.0: PURPOSE

To insure a standard procedure for collection of surface soil samples for the identification of chemical parameters.

SECTION 2.0: SCOPE

The following procedure describes the logistics, chain-of-events, collection techniques and documentation requirements for collecting surface soil samples designated for chemical analysis.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Chemist, Geologist or Engineer - Second

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1041 Sample Chain-of-Custody Procedure

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington

SECTION 6.0: PROCEDURE

6.1 Selection of Sampling Locations

The selection of sampling locations in and around a project site will be based on a review of existing site data, the site topography and surface features, results of preliminary site surveys using portable geophysical and air monitoring equipment and the initial estimates as to the extent of and migration pathways of the waste present. At the start of the investigation, a number of surface soil samples are usually allocated. Only after initial field reconnaissance are the final locations selected. At a minimum, the following should be included as sampling points:

- Upgradient soil surfaces to determine background levels.
- Soil surfaces within the immediate area of contamination.
- Downgradient soil surfaces to determine any spread of contamination resulting from storm water runoff.

Sampling locations may be selected in the following areas at the site:

- Areas where chemicals may have been stored, handled or disposed.
- Areas where motor vehicles hauling chemicals may have traveled on the site.
- Areas where water may have ponded during storm events.

6.2 Equipment List

The following is to be considered a minimum listing of required field equipment for collecting soil samples. Other tools required for accessing soils beneath paved area, etc. should be included when necessary.

- Boots, latex gloves, chemical resistant gloves, appropriate level of protection.
- Sample container - 1 each 1 liter glass jar with a teflon lined cap.
- Teflon coated or stainless steel sample spoons.
- Wooden stakes and spray paint (highly visible)
- Field notebook
- Sample bottle labels
- Chain-of-custody forms

6.3 Order of Samples

Surface soil samples should be taken in all locations prior to all other site sampling events. This is to prevent the possibility of cross-contamination between sampling points by site personnel or equipment (backhoe, drill rigs, equipment vehicles, etc. . .). For consistency with other sampling programs, the upgradient samples should be collected first.

6.4 Location and Collection of Samples

Surface soils, depending upon the contaminants of interest, can be either individual or composite samples. Composites represent samples taken from a number of individual locations which are equally blended to form a sample representing a larger area. Certain state agencies are discouraging the use of composite samples when looking for aromatic volatile and halogenated volatile organic compounds because of dilution and the difficulty of forming a "true" composite. Therefore prior to sampling, the use of composites should be checked with the agency which will have final approval of actions regarding a site in which surface soil samples are used in developing certain actions regarding clean up.

If statistical techniques are to be employed in collecting surface soil samples using a random grid, the procedure provided in Chapter 5 of Methods of Soil Analysis, Part I by C.A. Black et al, American Society of Agronomy, Academic Press, N.Y. 1965 and Section I of EPA-SW 846 Test Methods for Evaluating Solid Waste. Physical Chemical/Methods are suggested protocols.

Once the general locations have been chosen, sampling can begin. Normally a sample representing the top 3 to 6 inches of soil is taken. Samples are collected using a dedicated, precleaned stainless steel or Teflon spoon and immediately stored in the glass jar. Organic debris (ie.

leaves, twigs, bark) along with large pieces of gravel should be avoided. The sample should be representative of the area soil; it is best represented by the finer grains of the topsoil. The jars must be filled completely so as to avoid creating a head space where volatiles may escape. After each jar is filled the threads should be wiped clean so that the cap can be threaded on without creating an air gap.

Latex or rubber gloves should be worn to protect the sampling person and to avoid cross contamination through handling.

All filled jars must be labelled with the following as a minimum:

- project number
- sampling time and date
- sample number
- analysis
- collector's initials

The sample chain-of-custody form is then immediately filled out and kept with the sample. The sample is then stored in a refrigerated container until delivery to the analytical lab.

The location, depth of sample, sample type, time of sample, and other associated data (ie. organic vapor readings, color of the ground, odors, texture, etc.) will be documented in the field notebook when the sample is taken. If sampling is performed under a paved area or in fill, a description of these unique areas will also be included.

6.5 Sample Verification

After each sample of soil is taken, an indicator should be used to mark the location in the event it will be surveyed at a later time. Once all the surface soil samples are collected, the sample numbers and locations should be reviewed before leaving the site or progressing to other tasks in a program. All used sampling devices will be kept together, separate from clean tools, so that they can be cleaned according to appropriate decontamination and cleaning procedure. In no event will a used sampling device be used for two or more samples without full cleaning between samples.

ATLANTIC PROCEDURE NO. 1021

FIELD PROCEDURES FOR COLLECTION OF SUBSURFACE SOILS

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — Q.A. Manager — TITLE

Approved By: Paul Burgess — PAUL BURGESS, P.E. — Chief Engineer — TITLE

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SECTION 1.0: PURPOSE

To insure a standard procedure for collection of subsurface soil samples during site contamination studies for the determination of chemical parameters.

SECTION 2.0: SCOPE

The following procedure describes the method, materials and documentation requirements for collection of subsurface soils from test pits and split spoon samplers for eventual analysis by a chemical laboratory.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Operations Manager - Second

Field Staff - Third

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1041 Sample Chain-of-Custody Procedure

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington

SECTION 6.0: PROCEDURE

6.1 Introduction

During a site investigation where test pits, exploratory borings, monitoring wells, test trenches and other forms of excavation are performed it is often planned that soils or buried waste materials are to be collected. For most drilling operations split spoon samples are used to collect discrete samples from known depths using samplers ranging in length from 2 feet to 5 feet. Usually not all samples from these split spoons are designated for analysis, therefore the containerization and handling of samples from split spoons may be different depending on their ultimate purpose.

Samples from test pits and test trenches may also be collected for chemical analysis. These samples can only be taken using a remote sampler from the side walls of each pit. Samples taken from the bucket of the backhoe are harder to identify especially regarding their actual vertical position beneath the ground surface.

The following is to be used as a general guide in collecting samples from either test pits or split spoons.

6.2 Split Spoon Sampling

After logging a split spoon sample following Atlantic Procedure No. 1030 the sample is then identified for either analysis by a laboratory or storage until further decisions are made. If the sample is to be stored, a clean glass jar, preferably new one liter size, will be used to store the sample. In many cases the driller will provide these to the field team. However in no case shall used or dirty soils jars be used to hold samples. If the driller does not have the proper jars, new clean "Mason type" jars may be used. A label must be affixed to these storage jars identifying the boring number, sample depth, date of sample and project number on it for future reference. If soil samples are to be sent for analysis then only properly cleaned or laboratory supplied sample containers are to be used.

The collector must take the following steps when preparing the samples:

1. Always follow designated safety precautions in terms of level of protection. At a minimum samples must always be handled using latex or chemical resistant gloves. This protects the collector and prevents cross-contamination between samples.

2. Do not use the top one to two inches of recovered sample in the split spoon. This usually consists of washings and cave-in soils from higher in the boring that fell into the bottom of the augers.
3. Use a properly cleaned stainless steel spoon (tablespoon size) to remove the soils from the split spoon.
4. When possible, try to fill each sample container so that no air space is allowed. This will prevent volatiles from escaping. If a number of containers are to be used then evenly divide the sample between containers.
5. Avoid getting soils on the threads of the soils containers. Use a clean paper towel to wipe off the threads to insure a good seal.
6. Fill out the sample labels on each jar including the following:

   - sample number
   - sample depth
   - date and time of sample
   - analysis
   - preservation
   - initials of the sample collector

7. Fill in the chain-of-custody form (Atlantic Form No. 1041) for each sample. If a confining layer is to be sampled to determine whether contamination from a shallower zone is migrating down, care should be exercised in collecting these samples. In many instances ground water will fill the auger and the split spoon will travel through the water before being pushed into a deeper zone, there is no guarantee that soils in the split spoon haven't been contaminated with standing water in the auger. To insure a "pure" sample, the drilling procedure may have to be modified to seal off the upper zone from the lower zone using casing and washing the interior of the casing clean. These operations must be detailed in the site sampling plan.

After each spilt spoon sample is collected Atlantic personnel will maintain custody and keep it refrigerated (when necessary) until shipment to the laboratory. The stainless steel sampling spoon is then decontaminated in accordance with Atlantic Procedure No. 1060 before the next sample is taken.

6.3 Sampling Soils from Test Pits

As mentioned before, soils designated for analysis must be collected directly from the side walls of the test pits. A remote sampler is basically a stainless steel scoop that can swivel so that it can be pushed against the side wall and hold soils in a trap at its base. The

scoop is attached to a light weight telescoping aluminum rod which will have a maximum 10 foot reach.

The depth of sample must be noted in the field notebook. The sample is then handled the same as the split spoon samples following the same safety precautions. After the sample is taken, the remote sampling tool will be decontaminated before obtaining the next sample.

ATLANTIC PROCEDURE NO. 1022

FIELD PROCEDURES FOR COLLECTION OF SURFACE WATER AND SEDIMENT SAMPLES FOR HAZARDOUS WASTE DETERMINATION

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — Q.A. Manager — TITLE

Approved By: Paul Burgess — PAUL BURGESS, P.E. — Chief Engineer — TITLE

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1.0 PURPOSE

To insure a standard procedure for collection of surface water (streams, ponds, lakes, impoundments) and sediments for the identification of chemical composition.

2.0 SCOPE

The following procedure describes the logistics, chain-of-events, collection techniques and documentation requirements for collecting surface water and sediment samples designated for chemical analysis.

3.0 RESPONSIBILITY

Project Manager - First

Field Supervisor - Second

Field Sampling Technicians - Third

4.0 SUPPORTING PROCEDURES

Atlantic Procedure No. 1060 Decontamination Procedure for Sampling Devices

Atlantic Procedure No. 1041 Sample Chain-of-Custody Procedure.

5.0 REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington

6.0 PROCEDURE

6.1 Selection of Sampling Locations

The selection of sampling locations in and around an project site will be based on a review of existing site data, the site topography and surface features, results of preliminary site surveys using portable geophysical and air monitoring equipment and the initial estimates as to the extent of the waste. At the start of the investigation, a number of surface water and sediment samples are usually allocated. Only after initial field reconnaissance are the final locations selected. At a minimum the following should be included as sampling points.

- Upstream and upgradient of the waste site to determine background levels of pollutants.
- In leachate, runoff or intermittent flow paths passing through or from the site.
- In downgradient streams, swales, runoff channels or sewers draining the site to determine limits of surficial deposition.

6.2 Equipment List

The following lists are examples of equipment to be used for sampling. Site specific checklists of equipment should be designed based on the characteristics of each sample and location.

6.2.1 Surface Water Sampling

- Boots, latex gloves, chemical resistant gloves, appropriate level of protection.
- Sample containers (depending on sample requirements of the analytical laboratory) may include for each location:
  - 4 each 1 liter glass jars with teflon lined caps.
  - 8 each 40 ml. glass vials with teflon lined septas.
  - 1 each 500 ml. plastic containers for metals analysis.
  - 1 each 500 ml. plastic containers for mercury analysis.
- Wooden stakes and spray paint.
- Stainless steel Kemmerer bottle, Van Dorn bottle or sterile glass samplers (if required)
- Remote samplers
- Field Notebook
- Sample bottle labels
- Chain-of-custody forms

6.2.2 Sediment Sampling

- Boots, latex gloves, chemical resistant gloves, appropriate level of protection.
- Dedicated stainless steel spoons (tablespoon size)
- Dedicated teflon spoons (if required)
- Sample containers for each sample
  - 1 each 1 liter glass jars with teflon lined caps
- Wooden stakes and spray paint.

- Field Notebook
- Sample bottle labels
- Chain-of-custody forms

6.3 Order of Samples

If both stream sediment and water samples are to be collected concurrently, the water samples should be taken first in order to avoid introducing pollutants in the water column from sediment collection activities.

In flowing streams or runoff channels samples should be collected from the furthest downstream point first. The remaining samples will be taken progressing upstream.

6.4 Sample Collection

6.4.1 Surface Water Samples

Surface water samples are collected in a manner to be representative of the water column from which the samples are taken. A two man team is required for the collection as a safety precaution. The person collecting the samples in most cases will have entered the water body. For flowing streams this will necessitate the donning of boots or waders and wearing latex inner gloves and chemical resistant outer gloves. All samples in flowing water bodies will be taken facing upstream. Samples taken from small lakes or ponds should be taken from a

small boat using a Kemmerer or teflon lined Van Dorn bottle. Samples taken from standing puddles, pools, drainage ditches should be taken without disturbing the sediments. This may be accomplished by the use of a remote sampler, e.g. a sample bottle held on along pole with a gimballed yoke.

For pre-preserved sample containers the following procedure will be followed:

- Prior to collecting any water samples place a waterproof sample label on each container which specifies the following:

  Sample number
  Date
  Time
  Analysis
  Preservative
  Project number
  Initials of the collector

  Fill in the information with a waterproof ink pen. This will prevent difficulty in filling out the labels on a wet jar after it is filled.

- Face upstream, wearing gloves, take a 1 liter glass container with no preservative and submerge it closed to mid-depth.
- Open the jar with the mouth facing upstream; fill it and; close it while submerged.
- Take the filled jar and use it to fill the 40 ml. vials making sure no air is trapped in the vials.

- Repeat steps 1 and 2 with the same container and fill those containers having preservative avoiding any overflow since this will dilute the preservative.
- Repeat steps 1 and 2 with the same container and fill the remaining sample containers. The last container filled, will be the original container used to fill the other jars.
- If dissolved metals analysis are required, an extra bottle (no preservative) will be filled and the metals container (pre-preserved with nitric acid) will remain empty. Only after the water sample is field filtered will it be poured into the pre-preserved metals container.
- Place all sample containers into a sample shipping container, cool with ice packs and fill in the chain-of-custody form.
- Detail in the field notebook the following:
  - sample identification number
  - location of the sample (sketch of the sample point)
  - time and date sample was taken
  - personnel performing the task
  - visual or sensory description of the sample (color, odor, turbidity, etc.)
  - weather conditions during sampling
  - runoff conditions
  - other pertinent observations

- Place a wooden stake at the edge of the stream or near the sample point with sample number on it. The stake may be located by survey for inclusion on a site map.

Note:

- It is understood that all sample containers and collection devices will be cleaned prior to field use following the appropriate cleaning procedures depending on the type of analysis to be performed.
- If sampling devices are to be dedicated to a particular sample location, they will be placed in a plastic bag after its use and marked or tagged "DEDICATED TO PROJECT NO. _____ SAMPLE LOCATION NO. _____".

6.4.2 Sediment Samples

Stream sediment samples are collected in a manner to be representative of deposits of sediment carried off of a site. Again the use of protective boots, and gloves will be necessary. All priority pollutant and organic analysis of sediments can be performed on a 1 liter sample. The following procedure will be followed:

- Select a sample location that is representative of sediment depositional areas. This might mean a sandbar in the middle of a stream, the inside corner of a stream bed in a meander, or a deep pool where water velocities are reduced.

- Place a waterproof sample label on the glass container which specifies the following:

  Sample number
  Date
  Time
  Preservative
  Project number
  Initials of the collector

  Fill in the information with a waterproof ink pen prior to collecting the sample.

- Use either a pre-cleaned dedicated stainless steel spoon or teflon coated spoon, that will fit inside the sample jar, to collect a sample.

- All samples should be taken within the top 3 inches of the stream bed. Remove any vegetation debris (leaves, roots, bark) along with any large stones from the sample so that only the finer soil material is collected.

- Fill out the chain-of-custody form and place the sediment sample into the shipping container. Cool as required.

- Detail in the field notebook the following:

  - sample identification number
  - location of the sample (sketch of the sample point)
  - time and date sample was taken
  - personnel performing the task

- visual or sensory description of the sample
- brief sediment descriptions (color, texture, appearance)
- weather conditions during sampling
- runoff or flow conditions
- other pertinent observations

o Place a wooden stake at the edge of the stream or near the sample point with the sample number on it. This stake will be located by survey for inclusing on a site map.

6.4.3 General Site Rules

Surface water and sediment samples, depending on the particular site, can be collected from a variety of locations. Instead of having a procedure for each type of location, the following general rules should be used for any site.

o The sample must be representative of the water body or sediments deposited in an area.

o Avoidance of cross contamination between sampling points can be accomplished by the use of dedicated sampling devices.

o Care must be taken to not disturb the sample location conditions or chemistry, e.g. facing upstream in a river, collecting sediments from areas not stepped on by the collectors.

- In lakes or ponds, samples of the water column, at a minimum, will be a composite of surface, mid-depth and bottom (1 foot above floor) samples. Sediments need only be sampled by grab method.
- Only pre-cleaned sampling devices and sample containers are to be used.
- Proper field documentation and chain-of-custody procedures must be followed.

ATLANTIC PROCEDURE NO. 1023

FIELD PROCEDURES FOR COLLECTION OF GROUND WATER SAMPLES FOR HAZARDOUS WASTE DETERMINATION

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — Q.A. Manager — TITLE

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SECTION 1.0: PURPOSE

To insure a standard procedure for collection of ground water samples for the identification of chemical constituents.

SECTION 2.0: SCOPE

The following procedure describes the logistics, chain of events, collection techniques and documentation requirements for collecting ground water samples designated for chemical analysis.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Supervisor - Second

Field Sampling Technicians - Third

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1041 Sample Chain-of-Custody Procedure.

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351 published by J.L. Darling Corp., Tacoma, Washington

SECTION 6.0: PROCEDURE

6.1 Selection of Sampling Locations

Ground water sampling locations in and around a project site are typically obtained from existing domestic, production and monitoring wells, and newly installed ground water monitoring wells which were part of the site hydro-geological investigation. The location of new ground water monitoring wells will be based upon the review of existing site hydrogeological data, the results of preliminary site surveys, and the initial estimates of the extent of the waste. The ground water sampling locations will be chosen by the project manager. At a minimum one upgradient and three downgradient water samples from the uppermost aquifer will be taken.

6.2 Equipment List

The following is to be considered a guide for groundwater sampling preparation.

1. Latex gloves, and any other personal safety equipment specified in the site health and safety plan.

2. Sample containers (depending on sample requirements of the analytical laboratory) may include for each location:

   - 4 each 1 liter glass jars with Teflon lined caps
   - 8 each 40 ml. glass vials with Teflon lined septas
   - 1 each 500 ml. plastic containers for metals analysis
   - 1 each 500 ml. plastic containers for mercury analysis

3. Device to measure water levels in wells to within .01 feet. Typically a cloth tape with a "plopper" or an electronic water level indicator is used.

4. Field Notebook No. 351

5. Sample bottle labels

6. Chain-of-custody forms

7. A large volume bailer or pump to evacuate the wells.

8. Dedicated Teflon bailer with stainless steel cable, or a peristaltic pump with dedicated Teflon tubing.

6.3 Sample Collection

Prior to the extraction of any ground water, the depth to water shall be measured to the nearest .01 feet. A cloth tape with a "plopper", or an electronic water sensing device (i.e. Slope Indicator Water Mark) shall be used for this purpose. The device used must be clean to avoid contamination of the well. The depth to water is typically measured from a reference point established on the top of the well casing. This value is recorded in the field notebook along with the length of casing stick-up above the ground surface. If both an inner and outer casing are present, the one used as the measurement reference point shall be identified (normally the inner), and any distance between the two, measured and recorded. If the depth of the well is unknown the bottom shall be sounded and the depth recorded.

Ground water samples are to be collected in a manner to be representative of the formation from which the samples were taken. To insure against sampling stagnant water in a well, a minimum of four well volumes must be evacuated from the well prior to sampling. In the case of monitoring wells that will not yield water at a rate adequate to be effectively flushed, one of the two following procedures must be followed. The first procedure includes purging water to the top of the screened interval at a sufficiently slow rate to prevent the exposure of the gravel pack or formation to atmospheric conditions. The sample is then taken at a rate that would not cause rapid drawdown. The second procedure would be to pump the well dry and allowed it to recover. The samples should be collected as soon as a volume of water sufficient for the intended analytical scheme reenters the well. Exposure of water entering the well for periods longer than 2 to 3 hours may render samples unsuitable and unrepresentative of water contained within the aquifer system. In these cases, it may be desirable to collect small volumes of water over a period of time, each time pumping the well dry and allowing it to recover. Whenever full recovery exceeds 3 hours, samples should be collected in order of their volatility as soon as sufficient volume is available for a sample for each analytical parameter or compatible set of parameters. Parameters that are not pH-sensitive or subject to loss through volatilization should be collected last.

Evacuation is accomplished by bailing with a large volume (1.5 liter) bailer, or by pumping. Whichever method is used, it must be assured that any materials (hose, bailer, tubing, pumps, rope, etc.) entering the well must be clean. If the same device is being used to evacuate a number of wells, the device must be cleaned with the appropriate cleaners between each well to prevent cross-contamination.

For pre-preserved sample containers the following procedure will be followed:

1. Prior to collecting any water samples, place a waterproof sample label on each container which specifies the following:

   Sample Number
   Date
   Time
   Preservative
   Project Number
   Initials of the Collector

   Fill in the information with a waterproof ink pen. This will prevent difficulty in filling out labels on a wet jar after it is filled.

2. Extract the ground water sample using either a dedicated Teflon bailer or a peristaltic pump with dedicated Teflon tubing. Latex gloves shall be worn during this procedure.

3. When using the peristaltic pump or bailer first fill the 40 ml. vials making sure no air is trapped in the vials. This sample is normally taken for volatile analysis and therefore should be sampled prior to further disturbance of water in the well.
4. Fill all the remaining jars directly from the pump discharge or bailer. With the containers containing preservative, avoid overflow since this will dilute the preservative.
5. If dissolved metals analysis are required an extra bottle (no preservative) will be filled and the metals container (pre-preserved with nitric acid) will remain empty. Only after the water sample is field filtered will it be poured into the pre-preserved metals container. This will constitute a sample for dissolved metals.
6. Place all sample containers into a sample shipping container, cool with ice packs and fill out the chain-of-custody form.
7. Detail in the field notebook the following:

- sample identification number
- location of the sample
- time and date of sampling
- personnel performing task
- depth to water table, reference mark, casing(s) stick-up, and horizontal distance between inner and outer casing
- Amount evacuated from well and device used for evacuation
- Visual or sensory description of the sample (color, odor, turbidity, etc.)
- Weather conditions both present and previous to sampling
- Other pertinent observations

8. Make sure the well is secured after sampling.

Note:

1. It is understood that all sample containers and collection devices will be cleaned prior to field use following the appropriate cleaning procedures.
2. If sampling devices are to be dedicated to a particular sample location, they will be placed in a plastic bag after its use and marked or tagged

"DEDICATED TO PROJECT NO. _____

SAMPLE LOCATION NO. _____

ATLANTIC PROCEDURE NO. 1024

FIELD PROCEDURES FOR COLLECTION OF TCDD SAMPLES

Prepared By:	Curtis A. Kraemer CURTIS A. KRAEMER	Senior Hydrogeologist TITLE
Reviewed By:	John A. Ripp JOHN A. RIPP	Principal TITLE
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SECTION 1.0: PURPOSE

To insure the proper blending of soil samples for TCDD analysis. Proper blending assures that the laboratory results will be representative of the whole soil sample.

SECTION 2.0: SCOPE

The following procedure describes the collection of samples for TCDD (dioxin) analysis. TCDD is usually sampled as a contaminant in soil or sediment. Because it binds tightly with soil particles, it is often found in near-surface soils. The USEPA "A Compendium of Superfund Field Operations Methods"[1], dated December 1987, indicates that TCDD contamination might be found at greater depths if the contaminated material was used as fill or consists of transported sediments.

Atlantic personnel should be aware that the procedures for use in sampling TCDD are often revised by the USEPA. If there is any question, the USEPA Regional Sample Control Center should be contacted about any new sampling procedures.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Operations Manager - Second

Field Staff - Third

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1020 Field Procedures for Collection of Surface Soil Samples

Atlantic Procedure No. 1041 Sample Chain-Of-Custody Procedure

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington (or equivalent)

SECTION 6.0: PROCEDURE

As noted above, TCDD is usually sampled as a contaminant in near-surface soils or sediments. Sampling for TCDD in soils is similar to sampling for surface soil samples except that a thorough blending of the sample is of greater importance and that the sampling equipment must be rigorously cleaned. Because the "action levels" associated with TCDD contamination are very low, the Field Operations Manager should consider using sampling equipment that has been cleaned in a contract laboratory using CLP procedures. The sampling tools should not be used again until they have been decontaminated in a contract laboratory using CLP procedures.

The following procedure requires the use of a one quart stainless steel blender cup. The blender cup should not be filled more than 3/4 full. No gravel or stones should be placed into the cup and large clumps of soil should be broken

up as much as possible. The blending cup is then brought back to the blending station where the blender is placed on a plastic sample drop sheet. The blending procedure is as follows:

* Pulse blender five times.
* Invert blender cup several times and shake.
* Repeat this procedure six times for a total of 30 pulses.
* Allow the blender to sit for two to five minutes to allow all dust to settle. The blended sample is then dispersed into an amber jar that has been placed in a plastic bag or "baggie" with a rubber band closure at the neck to reduce the possibility of contamination outside of the sample jar.

The sample is removed from the blender cup by using scoopulas. The baggie and rubber band are removed and properly disposed. The sample jar may be spray rinsed with 1,1,1-trichloroethane to further reduce the possibility of contamination. The jar is rebagged in a clean baggie, tagged, and processed for shipping. Any material remaining in the blender cup should be properly disposed.

The blender is cleansed by filling it (1/4 to 1/2 full) with soapy water, agitate (blend) it for 30 seconds, and, if necessary, scrubbed with a brush. The cup is then rinsed with distilled water, alcohol, and 1,1,1-trichloroethane and allowed to drip dry.

Field personnel should note that the samples should be kept away from light and that field samples are not to be composited.

In the event a stainless steel blender is not available for use in the field, an undisturbed soil sample should be collected and sent to a contract laboratory for homogenization. The Field Operations Manager should make a special note to the laboratory that the sample requires homogenization in accordance with CLP protocol.

SECTION 7.0 REFERENCES

[1] United States Environmental Protection Agency, A Compendium of Superfund Field Operations Methods, OSWER Directive 9355.0-14, Washington, D.C., December, 1987.

ATLANTIC PROCEDURE NO. 1030

FIELD PROCEDURE FOR LOGGING SUB-SURFACE CONDITIONS DURING TEST BORINGS AND WELL LOGGING

Prepared By: John A. Ripp — JOHN A. RIPP — PRINCIPAL (TITLE)

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — QA MANAGER (TITLE)

Approved By: Paul Burgess — PAUL BURGESS, P.E. — CHIEF ENGINEER (TITLE)

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SECTION 1.0: PURPOSE

To insure a standard procedure for the documentation of sub-surface conditions encountered during test borings and well drilling.

SECTION 2.0: SCOPE

The following procedure details a method for recording sub-surface conditions in test borings and well drill holes during site contamination, hydrogeological, and geotechnical investigations. An optional procedure for photographing samples is included.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Supervising Field Geologist/Engineer - Second

SECTION 4.0: SUPPORTING PROCEDURES

ASTM Designation D 1586 - Standard method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM Designation D 2488 - Standard practice for Description and Identification of Soils (Visual-Manual Procedure)

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351 (published by J.L. Darling Corp., Tacoma, Wash.)

Atlantic Boring Log Form

SECTION 6.0: PROCEDURE

6.1 Predrilling Requirements

When conducting borings at any location, local or on-site buried utilities must be cleared through the appropriate engineering departments of each utility serving the area. At least a 48 hour notification shall be made to the utilities prior to drilling. The ticket number or call number given by the utility must be logged in the field notebook. This will protect the drilling supervisor from any liability associated with damaging a public utility.

The supervising geologist/engineer shall record the name of the drilling firm and the names of the driller and his assistant. The date, project location, project number, and weather conditions shall also be recorded.

An accurate time log of drilling activities shall be kept. This log shall be kept in the field notebook and shall include, at least the following:

- Time driller and rig on-site
- Time drilling begins
- Any delays in the drilling activities, and the cause of such delays.
- Time drillers leave the site.

6.2 Test Borings and Well Drilling Subsurface Sampling Methods

Test borings and monitoring well drilling can be conducted by a variety of drilling methods. The drilling method is not as critical to the documentation of the subsurface conditions as the soil and rock sampling techniques. However, the drilling method and type of drill rig shall be documented.

Where details of subsurface conditions are necessary, soil sampling shall be conducted using a split spoon penetration sampler driven with a 140 pound hammer at a height of 30 inches. The standard method of soil sampling as described in ASTM Designation D 1586 shall be used as a guide.

The supervising geologist/engineer shall record, at a minimum, the weight of the hammer, the length of the split spoon sampler, and the number of hammer blows on the spoon per 6 inches of penetration. Upon removal of the sampler the earth materials shall be logged in accordance with Section 6.3 of this document.

Rock sampling will be conducted using a double barrel core sampler. The supervising geologist/engineer shall record the length of the core barrel, the diameter of the barrel, the rate of penetration, and the down pressure torque and rotation of the sampler.

6.3 Logging of Unconsolidated Deposits

Vertical measurements in a boring shall be made from the original ground surface. Split spoon samples are typically taken in 2-foot intervals, or at changes in lithology through unconsolidated materials. The supervising geologist/engineer shall monitor drill cuttings and maintain communication with the driller (Re: down pressures, drilling rates, resistance, etc.) to determine where changes in lithology occur.

During the sampling, the hammer blows per 6 inches of sampler penetration, and the depth at which the sample was taken shall be recorded. Blow counts over 50 per 6 inches of penetration shall constitute sampler refusal. Upon extraction of the sampler moisture conditions on the drill rods shall be noted. Upon opening the sampler the percent recovery shall be recorded as the length of sample retained over the length of sampler penetration. Changes in lithology, color, or moisture conditions in the spoon are measured and recorded prior to emptying the spoon. If the sample is to be retained, a sample number is assigned and recorded in the field log and on the sample container. The sample container will also include the project name, boring number, location, depth, date, and person collecting the sample.

The supervising geologist/engineer will log the soil sample in the field notebook. The soil description shall include, at a minimum, the following information:

o Color

o Mineral or rock content

o Grain size, in order from most predominant to least predominate using the proportions;

- Trace = 0 to 10%
- Little = 10 to 20%
- Some = 20 to 35%
- And = 35 to 50%

o Density, descriptions based upon blow counts as follows:

- Cohesionless Soils (primarily sand and gravel)

0 - 10 blows = Loose
10 - 30 blows = Medium Compact
30 - 50 blows = Dense
50 plus blows = Very Dense

- Cohesive Soils (primarily silt and clay)

0 - 2 blows = Very soft
2 - 4 blows = Soft
4 - 8 blows = Medium
8 - 15 blows = Stiff
15 - 30 blows - Very stiff
30 plus blows = Hard

o Moisture Content

o Structure

o Other (mottling, odor, instrument readings, etc.)

A sample soil log is shown in Figure 6-1.

When the technical specifications of a soil sampling program require soil descriptions to conform to the "Unified Soils Classification" the soils shall also be classified according to ASTM Standard Designation D 2488. Figure 6-2 shows this classification.

6.4 Logging Bedrock Cores

The supervising geologist/engineer on a drilling program is responsible for logging and recording geologic and geotechnical information from rock cores. The following information shall be included in a rock core run log:

- The depth and length of the core run.
- The coring rate, down pressure, torque and rotation speed. This information can be obtained from the driller.
- The color of the core wash water. Any changes or loss of return water will be noted.
- The recovery of the core run recorded as length of rock recovered over the length of the core run.
- The Rock Quality Designation (RQD) of the run. RQD is reported as the sum of inches of all rock core pieces larger than four inches over the total number of inches in the run.
- The rock type(s) and their location in the core run, rotating color, minerology, texture, fossil content, effervescence in HCL and any other data of geologic significance.
- Any structure in the core, including fractures, clay seams, vuggs, bedding, fissility and any other data of geologic or geotechnical significance.

Tuesday 2/14/84
General Power Corp, 1243-01-01
Middletown, U.S.A. Power
Weather: Cold (~35°F) light rain
ATLANTIC Personnel on-site 0700
T. Brooks & J. Ripp
Drillers (Conn Borings) on-site 0650
Joe Smith and Bob Jones

Boring B-1 -
20' so. of pumphouse started 0730
using Mobile B-61
and 6 3/4" ID H.S.A.

Sample B-1-A 0-2'
Blows: 1, 1, 3, 7
Recovery: 1'9" / 2'
0-6" Dark br. topsoil and roots
6-12" Light br. fine-med.
sand with some silt,
little organic loam
very loose, dry, slight rust
mottles at 1' 10"
OVA - < 1 ppm benzene

Figure 6-1
Example Boring Log

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

* Based on the material passing the 3-in. (75-mm) sieve.

Figure 6-2
Unified Soils Classification

Rock cores shall be stored in a core box in the exact sequence they were removed from the ground. Core runs will be separated by wooden blocks clearly marked with the depth of the run. The core box shall be marked with the project name, location, project number, boring number, data and the depths of the core runs in that box.

6.5 Photographing Rock and Soil Samples from Borings

Soil samples should be photographed while still in the split spoon sampler. If smearing of the sample has occurred a fresh exposure can be made by scrapping with a pen knife or other similar object. The spoon and sample should be placed in a good light preferable against a solid colored background. A ruler for scale, and a tag identifying the sample number, depth and project name or number written so as to be legible in the photograph. Any photographs taken must be recorded in the field notebook.

Rock core samples are photographed in the wooden core box. The rock should be wetted to enhance the color and textual changes in the rock. Due to the relatively large size of most core boxes the photographer (when possible) should stand up on a chair, tail gate, car bumper or other perch in order to photograph the box from directly above, and get the entire box in the camera's field view. Somewhere in the photograph must be an identifier tag indicating the project name or number, the boring number, the date, and the depths of the various core runs.

ATLANTIC PROCEDURE NO. 1041

SAMPLE CHAIN-OF-CUSTODY PROCEDURE

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — QA Manager — TITLE

Approved By: Paul Burgess — PAUL BURGESS, P.E. — Chief Engineer — TITLE

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1041	Atlantic's Chain-Of-Custody Form	5

SECTION 1.0: PURPOSE

To provide the project manager with a record of the custody of any environmental field sample from time of collection to final analysis. Once a sample has been submitted to the laboratory, internal laboratory chain-of-custody will take over in the form of "Request for Analysis" forms, analytical notebooks, and "Reports of Analysis" forms.

SECTION 2.0: SCOPE

This procedure details how a sample is traced through the Chain-of-Custody-Form.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Supervisor - Second

Field Technician - Third

SECTION 4.0: SUPPORTING PROCEDURES

None

SECTION 5.0: REQUIRED FORMS

Atlantic Chain-of-Custody Form No. 1041

SECTION 6.0: PROCEDURE

This procedure describes the use of a Chain-of-Custody Form to accompany all sample containers from the time of collection to submission to the analytical laboratory.

For sampling programs where a large number of samples are to collected or where various laboratories will be receiving the samples, a Chain-of-Custody Form is to accompany each group of samples (see attached form). This form presents general sample information in tabular form listing sample number, date and time of sampling, whether the sample was a composite or grab and information regarding the number of containers, size of container and preservative used for each. If for instance a sample consisted of two 40 ml. vials with no preservation and one 500 ml vial preserved with nitric acid, the number of containers box would designate three while the first diagonal box would list 40 ml vial/PRSV.-NONE and the box beneath listing two and the second diagonal box listing 500 ml glass jar/PRSV.-HNO_3 and the box beneath listing one.

The bottom of the form is the chain-of-custody with dates and times of transfer indicated with the appropriate signatures. The sample collector is always the first signature while the analytical laboratory is the final. Theoretically all individuals handling the samples between collection and laboratory should sign the form. However if a common carrier (ie. Federal Express, Purolator) are used for shipping only one signature is required.

This form can be used as a legal document to guarantee samples were not mishandled and that they were delivered to the laboratory within the time frame necessary to start analysis.

On occasion, the analytical laboratory will provide their own Chain-of-Custody form. Usually the same information is included but in a different format from the Atlantic form. Chain-of-Custody forms from the analytical laboratories are acceptable documentation.

Since these forms are basically sample transmittal documents a copy of the form should remain with the sampling personnel. Upon completion of the analysis the laboratory will provide a complete set of all Chain-of-Custody forms for inclusion with analytical reports.

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CHAIN OF CUSTODY FORM

FORM NO. 1041

PROJECT NO:	PROJECT NAME:				NO OF CONTAINERS	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	PRSV.	REMARKS
SAMPLERS (SIGNATURE):												
SAMPLE NO.*	DATE	TIME	COMP	GRAB								

*SOURCE CODES: Test Pit Soil...(TP) Boring Hole Soil...(BH) Surface Soil...(SS) Waste...(W) Ground Water...(GW) Surface Water...(SW) Sediment...(SD) Waste Water...(WW)

RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):	RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):
RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):	RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):
RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED FOR LABORATORY BY (SIGNATURE):	DATE/TIME:	REMARKS:	

Distribution Original accompanies shipment, copy to coordinator field files

ATLANTIC PROCEDURE NO. 1042

SHIPPING PROCEDURES FOR ENVIRONMENTAL FIELD SAMPLES

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — Q.A. Manager — TITLE

Approved By: Paul Burgess — PAUL BURGESS, P.E. — Chief Engineer — TITLE

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SECTION 1.0: PURPOSE

To insure a standard procedure for shipment of water, soil and other environmental samples that are controlled by chain-of-custody and strict analytical starting times.

SECTION 2.0: SCOPE

The following procedure is established to avoid mishandling, delays and mislabeling of samples normally collected and shipped from a field site to a designated analytical laboratory.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Supervisor - Second

Field Technicians - Third

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1040 Sample Preservation for Solid and Liquid Matrices

Atlantic Procedure No. 1041 Sample Chain-Of-Custody Procedure

SECTION 5.0: REQUIRED FORMS

Receipt of Airweigh Bill or Weighbill Forms

Chain-of-Custody Form Standard Form No. 1041

SECTION 6.0: PROCEDURE

6.1 Prior to mobilization to a field site, the field operations manager or his designee will select a shipper based on proximity to the site and ability to ship overnight.

6.2 Upon selection of a shipper the following information will be gathered before any samples are shipped. This can be done over the phone or by correspondence.

1. Location of the shipping depot or local pickup office in case samples are to be delivered directly to the depot by the field team.
2. Name and phone number of a contact at the shipper.
3. Rates of shipping per package size and weight
4. Special instructions as to container sizes and weights.
5. A set of weighbills for the field team.
6. A copy of the shipper's brochure which will provide information on the format for the various types of weigh bills.
7. Times for calling in a pickup from the job site and normal pickup times.

6.3 The Atlantic field manager will give the shipper a street address where samples can be picked up by the courier near the job site.

6.4 Once all samples have been collected, preserved and containerized for shipment, the field supervisor will call the shipper to arrange for pick up.

6.5 All samples, unless so designated for ground transportation, will be shipped by air express for overnight delivery. This is the standard method since samples collected for Method 625 organics have only a 72-hour holding time between collection and the start of analysis.

6.6 The following steps will be followed in the field to prepare the sample shipping containers for pick up.

1. A standard chain-of-custody form will be filled-out, signed by the courier as a custodian, and placed inside each shipping container before final sealing.
2. The Atlantic field supervisor or his designee will insure that all weighbills have been filled-in properly for air express. If the contract laboratory is within ground transportation distance for overnight delivery, then the weighbills should reflect guaranteed overnight delivery.
3. A copy of all weighbills must be kept by the field supervisor and the weighbill number associated with each group of samples logged into the Master Sample Log. The name of courier must be written in this log also in case there is a problem in tracing samples.
4. If possible, to save shipping fees, the sample shipping containers can be strapped together.

5. An estimated time of delivery for the samples will be logged in the Master Sample Log, (e.g., ETA 12 noon 3/14/83).

6.7 Once the samples have been shipped, the field supervisor will call the analytical laboratory and provide a listing of samples to be delivered, the shipping company's name, and the weighbill numbers. As soon as the samples are delivered, the contract laboratory will inform Atlantic of their arrival and report, any damage associated with the samples or whether any sample containers are missing.

ATLANTIC PROCEDURE NO. 1051

OPERATION AND CALIBRATION OF THE HNu SYSTEMS PHOTOIONIZER MODEL PI-101

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: Edmund J. Burke — EDMUND J. BURKE, P.E. — Q.A. Manager — TITLE

Approved By: Paul Burgess — PAUL BURGESS, P.E. — Chief Engineer — TITLE

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SECTION 1.0: PURPOSE

To insure a standard procedure for the calibration and operation of the HNu Systems Photoionizer Model PI-101.

SECTION 2.0: SCOPE

The following procedure details those steps necessary for the collection and operation in the survey mode of the HNu Photoionizer. A listing of calibration data needed for proper documentation is supplied at the end of this procedure.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Operations Manager - Second

Field Staff - Third

SECTION 4.0: SUPPORTING PROCEDURES

None

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington (or equivalent), or a conventional paper, bound laboratory notebook (Nalge 6301 or equivalent).

SECTION 6.0: PROCEDURE

6.1 General Description

The HNu Photoionizer is a survey tool for determining general levels of organic vapors in air. The instrument is comprised of a readout module which contains all controls and the battery power supply and a photoionizer probe which contains the photo-cell. The readout module also contains terminals for connection to a recorder. This module is carried by a strap held across the shoulder while the probe is held by hand.

6.2 Instrument Startup

First connect the probe unit to the readout module by attaching and turning the connector terminal. Note this fitting is "keyed" and must be attached in only one orientation.

Second turn the main switch to battery. The needle should deflect to the upper end of the green scale. If it doesn't deflect into the green area or is at the low end of the scale, the instrument needs to be charged. A battery charger is located in the instrument cover and it plugs into the side of the readout module. For a full day's operation the battery should be charged overnight.

Third turn on the main switch to any range (ie. 0-2,000 ppm, 0-200 ppm or 0-20 ppm). Look into the probe through the sample tube and observe the violet light of the photo cell. If the light is not on, check the following:

1. Make sure the probe is attached properly to the readout module.
2. An etch mark should be scribed on the probe where it can be unscrewed to replace the photo cell. This mark shows the exact position that the top of the probe takes so that the air inlet ports are lined up. If not lined up,unscrew the probe and assemble it properly.
3. Check the photo cell lamp and replace it if necessary.

Once the battery and photo cell are operating, perform a calibration.

6.3 Calibration

The PI 101 Analyzer is designed for trace gas analysis in ambient air and is calibrated at HNu with certified standards of benzene, vinyl chloride and isobutylene.

Some general points to consider when calibrating the PI 101 are that the analyzer is designed for operation at ambient conditions and therefore the gas standards used for calibration should be delivered to

the analyzer at ambient temperatures and pressure and at the proper flow rates. The PI 101 is a non-destructive analyzer; calibrations using toxic or hazardous gases must be done in a well ventilated area.

The frequency of calibration should be twice daily as a minimum. The instrument should be calibrated at the beginning of the day (or when the instrument is first turned on) and at the end of the day (or when use of the instrument is completed). If the instrument is turned off during the day for any significant length of time, it should be calibrated when turned on. An accurate and reliable method of calibration check is to use analyzed gas cylinders of "hydrocarbon-free" air and isobutylene (prepared by HNu).

Step 1. Zero set - Turn the function switch to STANDBY. In this position the lamp is OFF and no signal is generated. Set the zero point with the ZERO set control. The zero can also be set with the function switch on the X1 position and using a "Hydrocarbon-free" air. In this case "negative" readings are possible if the analyzer measures a cleaner sample when in service.

Step 2. 0-20 or 0-200 range - For calibrating on the 0-20 or 0-200 range only one gas standard is required. Turn the function switch to the range position and note the meter reading. Adjust the SPAN control setting as required to read the ppm concentration of the standard. Recheck the zero setting (Step 1). If readjustment is needed, repeat Step 2. This gives a two-point calibration; zero and the gas standard point.

6.4 Documentation

In the field notebook, or in the bound laboratory notebook, at the start of the project (or if there is a change in instruments), record the following:

1. Site name
2. Instrument model and serial number S/N
3. Types of calibration gases
4. Note the size of the photo cell lamp used in the particular probe. This is useful to know which organic compounds the HNu is sensitive toward.

In the field notebook, or in the bound laboratory notebook, at the start of each calibration, record the following:

1. Date
2. Time
3. Name of person performing the calibration
4. Span setting before beginning calibration
5. That the instrument was zeroed, and whether the instrument was on standby or if "hydrocarbon-free" air was used.
6. The new span setting, if necessary, to calibrate instrument reading
7. Repeat Step 5 if span was adjusted during Step 6
8. Note that the second calibration reading was correct

ATLANTIC PROCEDURE NO. 1052

OPERATION OF THE PHOTOVAC 10S50 PORTABLE GAS CHROMATOGRAPH

Prepared By:	FRANCIS DUMONT	Chemist TITLE
Reviewed By:	DENNIS F. UNITES, P.G.	TITLE
Approved By:	JOHN A. RIPP	TITLE

REVISIONS

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SECTION 1.0: PURPOSE

To establish a standard procedure for the operation of the Photovac 10S50 Portable Gas Chromatograph.

SECTION 2.0: SCOPE

This procedure details the steps necessary for the operation of the Photovac 10S50 in regard to performing soil gas surveys.

SECTION 3.0: RESPONSIBILITY

First - Project Manager

Second - Field Team Leader

Third - Photovac Operator

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1053 *Soil Gas Screening for Volatile Organics*

SECTION 5.0: PROCEDURE

5.1 Introduction

The Photovac 10S50 is a portable gas chromatograph (GC) which can be used in the performance of soil gas surveys. This procedure describes the necessary equipment needed for GC operation, the method for setting up the GC, and the method for introducing samples into the GC system.

5.2 Equipment Required

Equipment needed for GC operation includes:

- Photovac 10S50 portable gas chromatograph with CPSIL5 capillary column and isothermal oven;
- cylinder of zero or ultra-zero grade air with regulator;
- glass gas-tight syringes;
- sample standards;
- gas standard of 1 or 10 ppm benzene in air;
- AC power supply;
- AC/DC converter;
- flowmeter (two channel); and
- Photovac owner's manual.

5.3 Instrument Set-Up

The GC requires that certain "running" parameters be inputted into its computer memory prior to operation. Parameters which should be entered include:

- electronic gain - 50;
- slope sensitivity - 18, 14, 6 mV/second;
- chart speed - 0.5 cm/minute;
- window +/- 10 percent;
- minimum area - 100 mV seconds
- timer delay - 10.0 seconds;
- cycle time - 0 minutes;

- analysis time - dependent on compounds of interest but should be at least three times greater than Event 3 (backflush);
- Event 1 (sample pump) on at 8.0 seconds, off at 10.0 seconds;
- Event 3 (backflush) on at 0.0 seconds, off at 160.0 seconds;

Once set, the GC computer memory should retain these running parameters.

The "use" function is utilized to set the date and time. The "info" function is utilized to input information the operator wishes to have printed out with each chromatogram (i.e., site name, location, etc.).

Once the parameters are set up, the carrier gas reservoir is filled with air (zero or ultra-zero grade). The flow meter is attached to the detector "out" and auxiliary "out" fittings. The detector outflow should be adjusted to approximately 10 ml/minute using the column flow adjustment knob. The auxiliary outflow should be adjusted to approximately 12 ml/minute using the auxiliary out valve knob. The oven is then turned on to 40° C. The instrument is then allowed to warm up and stabilize for 30 to 45 minutes.

After allowing for warm up, the "Start/Stop" and "Enter" keys should be pressed. This causes the GC to perform a run without the injection of a sample. This is done to ensure that a stable electronic baseline is being drawn. An unsteady baseline can be due to insufficient warm up or a leak in the GC system. A baseline with peaks can be due to a contaminated GC column. If a stable baseline is not obtained after sufficient warm up, refer to the Operation's Manual for probable causes and repair procedures.

While the baseline sample is running, the "chart" mode is set to "on with set-up". This setting activates the chart recorder to print set-up information at the end of the run, including the offset.

The offset is a measure of how much the instrument must adjust the baseline to compensate for background noise and is checked after each run. The offset should not exceed 50 mV. A high offset is usually the result of a contaminated column or the use of an unsuitable carrier gas. Refer to the Operation's Manual if the offset is greater than 50 mV.

5.4 Sampling Introduction

Analysis of standards and samples can be performed once the machine is properly set up. Standards (refer to Procedure 1053) and samples can be introduced into the GC by the following steps:

- push "Start/Stop" followed by "Enter" keys
- allow pump to buzz on for two seconds and shut off
- immediately inject the standard or sample utilizing a gas tight syringe

SECTION 6.0: STORAGE

While the GC is not in use, a low flow rate (approximately 1 ml/minute) should be maintained through the column. This is done by allowing the carrier gas reservoir to run out or by hooking up the external carrier gas fitting to an outside tank regulated to 40 psi. This is done in order to prevent the buildup of contamination in the column during downtime.

Long-term storage of the GC can cause low battery power. Low battery power can result in the loss of the GC's memory and would necessitate re-inputting running parameters. Sufficient battery charge to ensure memory retention can be maintained by occasionally plugging the GC in and turning it on overnight.

SECTION 7.0: REFERENCES

Photovac 10S Operations Manual

ATLANTIC PROCEDURE NO. 1053

SOIL GAS SCREENING FOR VOLATILE ORGANICS

Prepared By:	FRANCIS DUMONT	Chemist TITLE
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SECTION 1.0: PURPOSE

To establish standard procedures for screening study sites for volatile organic compound (VOC) contaminants using soil gas sampling, and subsequent analysis using Photovac 10S50 gas chromatograph (GC).

SECTION 2.0: SCOPE

This procedure details steps necessary for the collection and interpretation of soil gas data.

SECTION 3.0: RESPONSIBILITY

First - Project Manager

Second - Field Team Leader

Third - Photovac Operator

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1052 *Operation of the Photovac 10S50 Portable Gas Chromatograph*

SECTION 5.0: PROCEDURE

5.1 Introduction

The objective of this field procedure is to provide a method for screening sites for VOC contamination prior to any subsurface investigation. This procedure can be used to estimate the lateral extent and relative concentration of VOCs in soil or ground water (shallow, unconfined, first

water bearing zone only) across a site. This is accomplished by collecting and analyzing soil vapors for selected constituents that are produced by the volatilization of VOCs from in-situ product, waste, contaminated soils, or ground water.

The primary objective of soil gas surveying is to provide cursory information on locations and relative concentrations of site contamination. These data permit more effective planning of the quantitative sampling and analytical phases of the investigation. Soil gas procedures are not intended for evaluating contamination located beneath the water table. These procedures cannot be used to quantify contamination. Subsurface soil/water sampling and analysis by standard laboratory procedures are required to verify soil gas survey results.

5.2 Equipment Required

The following is a list of equipment and supplies that would be required to implement the soil gas procedure:

- Photovac 10S50 portable gas chromatograph with CPS1L5 capillary column and isothermal oven;
- 1/4" ID stainless steel tubing (5 feet long);
- plastic line which fits snugly in tubing (5-1/2 feet long);
- various Swagelok fittings;
- flow meter (two channel);
- cylinder of Zero or Ultra Zero gas with regulator;
- glass gas-tight syringes (10, 100, 500 and 1000 ul);
- sample standards (i.e., benzene in air, BTX headspace, chlorinated solvents headspace, etc.);

- AC power supply (i.e., generator, access to power outlet, etc.);
- modeling clay sufficient to cover soil gas sample hole once stainless steel tube is inserted; and
- gas transfer line (Photovac internal tank).

5.3 Instrument Start-Up and Calibration

The following is a list of suggested initial instrument settings:

- carrier gas flow - 10 ml/min;
- electronic gain - 50;
- oven temperature - 40°C;
- backflush - 160 seconds;
- run time - 1000 seconds;
- data management parameters - see Atlantic Procedure No. 1052;
- sample event times - see Atlantic Procedure No. 1052.

The Photovac GC requires a 30-45 minute warm-up period for the oven temperature and gain settings to stabilize. The electronic baseline should be checked by initiating the GC run without injecting sample.

Next, the Photovac is calibrated by injecting qualitative and quantitative standard mixtures. Stock standards ranging from 25 to 500 ml/l of the target analytes are prepared by diluting the neat (pure) compound in pesticide-grade methanol. Headspace standards are prepared daily by adding a measured (3 - 100 ul) volume of stock standard to 30 ml of distilled water in a 40 ml volatile organic analysis (VOA) vial. The vial is shaken by hand for two minutes and then allowed to

equilibrate for an additional three minutes. Between 10 and 100 ul of the headspace vapor is injected into the GC for analysis. The headspace standard provides the relative retention times (time required to elute through the column) of the target analytes.

A standard of 1 part per million (ppm) benzene in air is used to evaluate chromatogram peak variation resulting from fluctuation in instrument sensitivity and as a quality control check on the headspace standards.

Finally, a sample of ambient air (system blank) is collected through the sampling apparatus (see Section 5.5 and 5.7) to ensure that the system is free from contamination.

5.4 Sampling Grid Layout

Soil gas sampling should be performed on a grid at sites where little or no history and/or geologic information is available. The grid spacing may range from 25 to 100 foot centers, depending on the size of the area to be screened and the time and cost constraints of the investigation.

If sources of soil contamination are better known and documented, then the choice of sampling locations can be tailored to that information. The approach for those better documented sites would be to sample in and around areas of known/suspected contamination first to ensure that the subsurface contaminants can be detected at those locations. Areas where no contamination is expected are sampled next. If nothing is detected at these background locations, then subsequent sampling points can be located approximately one-half the distance to the known source. This procedure is followed until soil contamination is defined to the degree that is consistent with project objectives.

5.5 Soil Gas Collection

Soil gas samples are obtained by the following procedure.

- A plunger bar is used to drive a 1/2 inch diameter hole in the ground to a desired depth*. If the sample location is covered by hard pavement or cement, then a hammer drill is used to break through this material.

- A pre-purged, 4 foot long, 1/4 inch O.D. stainless steel tube is used to collect the sample. To prevent soil from plugging the tube as it is lowered into the cavity, a section of plastic line is inserted into the tube and held in place. After the tube is placed in the ground, the line is pulled out. Clay is placed around the tube at the soil surface creating a seal that prevents surface air from mixing with the gas from the soil.

- A 3-way Swagelok fitting is placed on the open end of the steel tube at the ground surface. One end of the fitting is connected to a teflon tube leading to a small personal sampler air pump. A small teflon-coated septum is secured over the remaining opening of the fitting. The pump is switched on and allowed to run for 3 minutes at a flow rate of 100 to 150 milliliters per minute (ml/min). The soil gas sample is collected by inserting a pre-rinsed 500 ul syringe through the septum and withdrawing 300 ul of air.

- The sampling apparatus is removed from the hole and flushed with high flows of ambient air to remove any soil gas contaminants.

Flow rates and purge volumes may have to be adjusted depending on subsurface conditions. Tightly packed soils may necessitate the use of smaller purge volumes and slower flow rates. Sample volumes injected into the GC may need refinement based on the chromatographic responses obtained.

5.6 Analysis and Data Collection

The gas sample obtained is injected directly into the Photovac instrument. The chromatogram that is generated contains peaks that represent constituents in the sample. The retention times of

* Depth is generally four feet but may be changed based on site conditions such as depth of contamination or depth to ground water.

these peaks are compared to the headspace standard to qualitatively identify the compound. Relative concentrations can be calculated by comparing the integrated peak areas that are generated. Any major unknown peaks that cannot be immediately identified should be noted in the event further evaluation is necessary.

5.7 QA/QC Protocol

Standards are run at the beginning, middle and end of each sampling day, and to document, when necessary, any retention time shifts.

System blanks are run at the beginning and end of each day, and when possible cross-contamination between samples is suspected. A system blank is obtained by allowing the sample collecting system to draw in ambient air for 3 to 5 minutes, drawing 300 ul of sample, and injecting it into the GC. If the GC demonstrates contamination in the system, the soil gas sampling tube should be decontaminated in the following way:

- flush stainless steel tube with methanol;
- purge stainless steel tube with high pressure zero air until dry; and
- purge syringe and septa fitting with high pressure zero air.

If contamination persists after this treatment, a different sampling tube and syringe should be used.

A syringe blank is run when it is suspected that the syringe has become contaminated. This is done by drawing 300 ul of ambient air into the syringe and injecting it into the GC. The syringe should be purged with zero air if it is found to be contaminated. If contamination persists after this treatment, a different syringe should be used. Contaminated syringes can be cleaned in the

laboratory by flushing with methanol and drying under a UV lamp.

5.8 Interpretation

Integrated area counts can be obtained for individual peaks produced on the chromatograms. This information can be used to outline generalized areas of contamination and locate specific "hot spots" of high soil gas concentrations. It is possible to relatively quantitate soil gas concentrations at a particular site by establishing varied ranges of peak area.

In addition to identifying single peaks, the chromatographic patterns or "signatures" can be evaluated. For example, coal tar exhibits a different chromatographic signature from that of gasoline. The interpretation of these signatures is to a large extent dependent upon the experience and knowledge of the GC operator.

One method that may be useful for interpreting soil gas results involves collecting a known sample of onsite contamination from a sludge pit or boring, and producing a chromatographic "signature" of the headspace vapor to compare to soil gas chromatograms from samples taken elsewhere on the site.

Other methods of distinguishing between contamination sources using chromatographic signatures are presented in a recent topical report available through the Gas Research Institute (see references). Examples of coal tar related data are compared and contrasted with data derived from petroleum related products.

A number of factors can significantly influence the correlation between the soil gas results and the actual conditions present at a particular site. These include soil porosity and composition, soil heterogeneities, and local climatic conditions such as temperature and humidity. Thus, a soil gas

sample result should only be compared to results of other soil gas samples from the same site (assuming similar geology) taken under similar climatic conditions.

SECTION 6.0: DOCUMENTATION

The following information is recorded in a laboratory notebook during the implementation of this procedure:

- project title and date of investigation;
- personnel involved;
- instrument parameters used;
- sketch of all soil gas locations (along with measurements necessary to accurately position later on a scale drawing);
- description of collection parameters (e.g., depth, purge rate and volume, etc.);
- meteorological parameters and site geological information; and
- any variation or adjustment of the above procedure that is used.

In addition to the laboratory notebook documentation, each soil gas chromatogram is pasted on an Atlantic soil gas point description sheet which includes the following information:

- project number;
- sample number;
- date of sample collection;
- weather conditions;

- depth to sample;
- comments associated with sample;
- contaminant identification;
- retention time; and
- peak area.

Original chromatograms are saved in the project file and a set of copies are saved in a separate Photovac/Soil Gas file.

SECTION 7.0: REFERENCES

Gas Research Institute (GRI) Topical Report #GRI-89/0166. *Soil Gas Investigations at MGP Sites: An Evaluation of Alternative Compounds*. Chicago, Illinois. 1989.

ATLANTIC PROCEDURE NO. 1060

CLEANING PROCEDURE FOR SAMPLING DEVICES USED IN ENVIRONMENTAL SITE INVESTIGATIONS

Prepared By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

Reviewed By: James E. Gould — JAMES E. GOULD — Engineer — TITLE

Approved By: Paul Burgess — PAUL BURGESS, P.E. — Principal — TITLE

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REVISIONS

1. Revision 1 was incorporated to delete the use of acetone from field cleaning operations.

SECTION 1.0: PURPOSE

To insure a standard procedure for cleaning sampling devices for use on site investigations.

SECTION 2.0: SCOPE

This procedure is to be used during site investigations for the cleaning of split spoons, sampling spoons, well bailers, remote samplers, sampling dredges and all devices used to collect a sample or transfer a sample of soil or liquid into its shipping container. Following this general procedure will prevent the likelihood of cross-contamination between samples.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Operations Manager - Second

Field Staff - Third

SECTION 4.0: SUPPORTING PROCEDURES

None

SECTION 5.0: REQUIRED FORMS

None

SECTION 6.0: PROCEDURE

6.1 Materials Selection

All field sampling equipment that contacts the solid or liquid media being collected for eventual chemical analysis should be made of stainless steel or teflon. These materials are easily cleaned and relatively inert when containing the sample. Materials such as neoprene fittings, tygon tubing, silicon rubber bladders, PVC, polyethylene and viton are not acceptable. Also, stainless steel aircraft cable should be used for raising and lowering bailers into monitoring wells. Sampling equipment should be cleaned beforehand and dedicated to individual samples taken in the field. If this is not possible, a cleaning procedure must be followed between each sample. The following presents the procedures for the sampling of organic and inorganic constituents:

6.2 Procedure for Materials in Contact with Media to be Analyzed for Organics

1. Scrub the device with nonphosphate/low sudsing detergent in a stainless steel basin. This type of basin is easily cleaned and thus prevents the buildup of organic contaminants.
2. Rinse it thoroughly with tap water to remove all suds.
3. Rinse it three times with distilled water using a plastic squeeze bottle.

4. Finally rinse it three times with chromatograph grade methanol using a teflon squeeze bottle to remove nonpolar compounds. Allow to air dry and wrap in aluminum foil until use.

Note: Solvent resistant gloves should be worn when rinsing with organic solvents to prevent contamination of the equipment and for personal safety. Use aluminum foil to provide a clean surface if the equipment is set down during the cleaning procedure.

6.3 Procedure for Materials in Contact with Media to be Analyzed for Inorganics

1. Scrub the device with nonphosphate/low sudsing detergent in a HDPE (high density polyethylene) basin using a plastic brush.
2. Rinse it thoroughly with tap water to remove all suds.
3. Rinse it with dilute (0.1N) HCl and/or HNO_3 using prerinsed plastic squeeze bottles.
4. Rinse three times with deionized distilled water. Air dry and wrap in plastic. Note: Any acid resistant disposable gloves can be used in this cleaning procedure. Plastic sheeting should be available to provide a clean surface if the equipment is set down during the cleaning procedure.

ATLANTIC PROCEDURE NO. 1070

WELL DEVELOPMENT PROCEDURES FOR SMALL DIAMETER MONITORING WELLS

Prepared By:	Curtis A. Kraemer CURTIS A. KRAEMER	Senior Hydrogeologist TITLE
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Approved By:	Paul Burgess PAUL BURGESS, P.E.	Principal TITLE

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SECTION 1.0: PURPOSE

To insure the natural hydraulic conductivity of the subsurface materials have been restored and all foreign sediment removed to ensure turbid-free ground water samples.

SECTION 2.0: SCOPE

The following procedure describes the methods for monitoring well development and the conditions for which the methods are best suited. The procedure also includes a method for determining whether the development is sufficient for monitoring wells used for RCRA ground water monitoring programs.

SECTION 3.0: RESPONSIBILITY

Project Manager - First

Field Operations Manager - Second

Field Staff - Third

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure No. 1030 Field Procedures for Logging Subsurface Conditions During Test Boring and Well Logging

Atlantic Procedure No. 1060 Cleaning Procedure for Sampling Devices used in Environmental Site Investigations

Atlantic Procedure No. 1071 Field Procedures for Determination of In-Situ Hydraulic Conductivity with Single Well Hydraulic Tests

SECTION 5.0: REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington (or equivalent)

SECTION 6.0: PROCEDURE

Well development is a means to restore the natural hydraulic conductivity of the subsurface materials surrounding a monitoring well and ensure a turbid-free ground water sample. There are a variety of well development techniques, all of which require reversals or surges in flow to avoid bridging by particles, which is common when flow is continuous in one direction. The in-situ ground water should be used for surging the well. If the well yields an insufficient quantity of water to use, an outside source of water (preferably tap water) may be used. If the source of the outside water is unknown (not tap water), a sample should be chemically analyzed to determine whether the water may have an impact on the in-situ water quality.

The following applies to all methods described below:

* All materials including submersible pumps, suction lines, surge blocks, and lines used to pump water or compressed air into a well should be decontaminated in accordance with Atlantic Procedure No. 1060.

* Field notes should be kept to record the following information;

initial static water level

method of well development

average discharge rate and corresponding drawdown

any measureable recovery or information regarding yield of monitoring well

any noticeable changes in ground water quality resulting from well development

* The well development should continue until the discharge runs sediment free after 20 strokes of the surge block. A clear glass jar of distilled water should be used as a reference. Discharge from the pump should be checked periodically by collecting some of the discharge in a clear glass jar and comparing to the distilled water reference.

6.1 Surge Block Method

This method is best suited for monitoring wells that will yield at least 1/2 gallons per minute (gpm) while being pump with a vacuum lift pump (centrifugal pump). It can be used on wells with yields of less than 1/2 gpm, but may require the introduction of water from an outside source.

A surge block is a piston-like device with an outside diameter that is just smaller than the inside diameter of the well and used with by stroking the block up and down in the well. On the downstroke water is forced outward into the subsurface materials, and on the upstroke water, silt and fine sand are pulled in through the screen. This results in sediment filling in the well screen, which must be periodically removed.

The surge block for 2-inch wells consists of two rubber stoppers with a 1/2-inch pipe passing through the rubber stoppers. The stoppers are held in place with washers and nuts; the nuts can be tightened or loosened to expand the stoppers to get a good fit inside the well. The surge block is attached to either 3/4-inch or 1-inch rigid polypropylene tubing. This tubing is rigid enough that it can be used to stroke the surge block. This tubing is then attached to a centrifugal pump with a valve on the discharge side to control the pumping rate from the well.

The surge block should be kept above the screen if sufficient water is above the well screen. If necessary, the block may be stroked in the well screen, however, care should be exercised so not to damage the well screen and the slot sizing. Periodically the surge block should be lowered to the bottom of the well to remove the sediment that has accumulated at the bottom.

The same methodology applies to wells with yields less than 1/2 gpm except that water may have to be introduced occasionally because the well may dewater. The discharged water from the well should be used if at all possible, if not, tap water is the next choice of an outside source of water. When developing the low yielding wells, keep the discharge rate to a minimum, and if necessary, stop pumping for a short period of time while stroking the surge block.

6.2 Overpumping/Backwashing Development Method

This method can be used for wells that yield either less than or more than 1/2 gpm. Any number of pieces of equipment can be used to develop wells with this method. In general, the method involves overpumping a well so that it dewaters the well and then introducing a slug of water back into the well. As

mentioned at the beginning of the procedure, it is preferred to use the discharge water when backfilling into the well. If that is not available, tap water is the next preferred source of water.

Any means of pumping water quickly out of a well may be used to overpump the well, however, there should be some means of removing the sediment that has flowed into the well. To this end a centrifugal pump will both pump quickly (will lift water up to about 25 feet of head) and remove the sediment from the bottom of a well. Most forms of submersible pumps are not designed to pump solids and will quickly become inoperative.

Backwashing the well is performed either by pumping the water back into the well quickly or pouring the water back into the well.

6.3 Air Development Method

The air development method consists of lowering a line (usually solid pvc pipe) down into a well and, using compressed air, blowing air into the well that literally lifts the water up and out of the well. This method is not well suited for low yielding wells since one has to wait for the well to recover before purging more water. The one major disadvantage to this method is that most air compressors have trace amounts of petroleum mixed in the air to keep the equipment lubricated. These trace amounts of petroleum can easily compromise the quality of the water in the well. There are some compressors which filter the air so there is no petroleum mixed in, however, these are not commonly available.

There should be a "U" shaped fitting at the bottom of the line placed in the well. This will direct the air in an upward direction, rather than blowing the air down and, subsequently, out into the subsurface materials. Without this U-shaped fitting, fine-grained materials may be pushed into the well screen producing the opposite of the desired affect. It is important that the air compressor be adequately sized so that it will produce sufficient pressure to lift the column of water out of the well (the longer the column, the more pressure that is required).

6.4 Jetting Development Method

This method can be used for both high and low yielding wells. It involves the pumping of water into the well through "jetting" nozzles (pointed directly at the well screen) and simultaneously pumping the well. The pumping pulls water into the well, and the jetting pushes water out through a small length of screen at a high velocity. This provides both a reversal and surge of water through the well screen. This may require the use of an outside source of water, particularly in low yielding wells. If an outside source is required, it preferably should be tap water.

ATLANTIC PROCEDURE NO. 1071

FIELD PROCEDURE FOR DETERMINATION OF IN-SITU HYDRAULIC CONDUCTIVITY WITH SINGLE WELL HYDRAULIC TESTS

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Reviewed By: James E. Gould — for DENNIS F. UNITES, P.G. — PRINCIPAL — TITLE

Approved By: John A. Ripp — JOHN A. RIPP — Principal — TITLE

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ATLANTIC ENVIRONMENTAL SERVICES, INC.
COLCHESTER, CONNECTICUT

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SECTION 1.0 PURPOSE

To insure the use of standard procedures for determining in-situ hydraulic conductivity values of subsurface materials for hazardous materials site investigations. These are single well hydraulic methods which yield order-of-magnitude hydraulic conductivity values. These should not be considered the same as multiple well aquifer tests which are commonly used for water resources investigations and which yield greater information about more of the aquifer.

SECTION 2.0 SCOPE

The following procedure describes first, how to select a field method for determining in-situ hydraulic conductivity based on site conditions and assumed hydraulic conductivity ranges; second, the logistics, chain-of-events, and documentation requirements; and third, the appropriate method to evaluate the field data.

SECTION 3.0 RESPONSIBILITY

Project Manager - First

Field Operations Manager - Second

Field Staff - Third

SECTION 4.0 SUPPORTING PROCEDURES

Atlantic Procedure No. 1030 Field Procedures for Logging Subsurface Conditions During Test Boring and Well Logging

Atlantic Procedure No. 1060 Cleaning Procedure for Sampling Devices used in Environmental Site Investigations

Atlantic Procedure No. 1071 Well Development Procedures for Small Diameter Monitoring Wells

SECTION 5.0 REQUIRED FORMS

Field Notebook No. 351, published by J.L. Darling Corp., Tacoma, Washington (or equivalent)

SECTION 6.0 PROCEDURE

6.1 Test Method Selection

The in-situ (within a monitoring well) hydraulic conductivity of subsurface materials can be determined by:

* single well pump tests
* slug tests (injection or extraction tests)
* constant head test

Figure 1 is a decision flow chart developed by Kraemer, Hankins, and Mohrbacher [1] for selecting the most appropriate in-situ hydraulic conductivity test method. There are several factors which influence

the selection of the test method. The expected hydraulic conductivity value can be based on observed subsurface conditions and from text books like Groundwater by Freeze and Cherry [2] which give ranges for a variety of soil and bedrock descriptions. The placement of the well screen is critical for some test methods. If the top of the screen is above the water table, water can not be added into the well because some of it will flow into the vadose zone, and the test methods assume the flow is only in the saturated zone. If the ground water is known, or expected, to be contaminated, all water discharged from the well should be containerized (drummed in 55-gallon containers or into larger vessels if appropriate). If the water quality in the monitoring well is of a long term concern or will require subsequent sampling, no water should be introduced into the well.

Water levels can be measured with an electronic water level indicator, however this slows down the measurement and recording procedure. It is also the primary source of error in the test procedure. A pressure transducer hooked to a direct readout can also be used. This requires the field personnel to record the data as it happens. A pressure transducer hooked to a data logger can be used. This allows the field personnel to monitor other ongoing operations while the test is proceeding. The only problem with data loggers is that sometimes the data can not be retrieved, and a well, or group of wells, may require a second test. If a pressure transducer is used, a calibration check will be required. The calibration check is made by lowering the transducer about two feet into the water and allowing the transducer to equilibrate (the water level readings stabilize). Then lower the transducer exactly 1.00 feet using a steel or

fiberglass surveying tape or wooden folding rule. Allow the water level readings to stabilize, the readings should show exactly 1.00 foot additional water. Repeat this procedure at least three times, at different depths, in one well at least once a day.

Single wells should not be hydraulically tested until the well has been developed as specified in Atlantic Procedure No. 1070. Notes will be taken as part of the development procedure that will provide some insight regarding the yield of individual wells. These notes will provide an approximate pumping rate, amount of drawdown and duration of pumping.

6.2 Slug Test Procedure

The slug test consists of two methods:

* slug extraction method
* slug injection method

Both methods are used in materials which have relatively low hydraulic conductivities. The major drawback to the slug test is that has a very small zone of influence and often reflects the hydraulic conductivity of the sand backfill around the well screen rather than the in-situ materials.

The slug extraction method involves the "instantaneous" withdrawal of a known volume of water from a well and recording the recovery of the water level back to its original static level. The slug injection method involves the "instantaneous" injection of a known volume of water into a well and recording the lowering of the water level back to its original static level. The slug injection method can not be used where the top of the well screen is above the water table.

6.2.1 Slug Extraction Test Procedure

Required Measurements

* length of well screen
* inside diameter of well screen
* inside diameter of well riser

Required Equipment

* steel or fiberglass surveying tape
* electronic water level indicator/pressure transducer (+ readout/data logger)
* bailer/displacement device
* watch with seconds hand (or digital)
* semi-log paper

1. Establish the static water level in the well by measuring and recording the depth to water to the nearest 0.01 foot from a stationary point (usually a point marked on the top of the well riser or protective casing). Preferably the static water level is measured every 10 minutes for at least 30 minutes prior to initiating the test.

2. Lower a bailer or device that will displace a known volume of water (a PVC pipe filled with sand) and allow the water level to reach the initial static water level. If a displacement device is used, it is best to wait until the following day (about 12 hours if the device is placed in the well toward the end of the day) before starting the test.

3. Measure and record the static water level just prior to initiating the test.

4. As quickly as possible, remove the bailer or displacement device. If a bailer is used, the volume of water in the bailer should be recorded (the water can be placed into a container initially and measured and recorded toward the end of the test)

5. Measure and record water levels as follows:

* 10, 20 and 30 seconds elapsed time
* 45, 60, 75 and 90 seconds elapsed time
* every 30 seconds elapsed time, up to 10 minutes
* every minute up to 30 minutes
* every two minutes up to 1 hour
* every five minutes up to 3 hours
* every ten minutes up to 6 hours
* every 30 minutes up to 12 hours

Measurements may cease once the water level has returned to at least 85 percent recovery.

6. Calculate the volume of water that was displaced by the displacement device, or measure the volume of water that was removed by the bailer and calculate the volume of the bailer materials to determine the total volume removed from the well.

7. Calculate the time zero drawdown in the well based on the volume of water displaced/removed and the radius of the inside well diameter. This should be noted as H_0.

8. Calculate a drawdown ratio for each measurement with the following equation:

$$\frac{\text{maximum drawdown } (H_0 \text{ in feet}) - \text{recovery (in feet)}}{\text{maximum drawdown } (H_0 \text{ in feet})}$$

This equation should equal 1.00 at time zero (maximum drawdown, but no recovery) and should equal 0.15 when 85 percent recovery has been reached.

9. Plot time versus the drawdown ratio on semi-log paper. The time should be plotted linearly on the X axis and the drawdown ratio should be plotted logrithmically on the Y axis.

10. The resulting plot should theoretically be straight; in reality it is not. The straightest portion of this line should be used for the hydraulic conductivity calculations. Generally, the beginning and end points are not on the line and should not be used.

11. Use the time and head values (t_1,H_1 and t_2,H_2) representing the two ends of the line in the equations that are presented in Figure 2. Figure 2, taken from Hvorslev's work [3], shows six different field situations in terms of subsurface strata and borehole/well placement. The most commonly used situations presented in Figure 2 are F and G. The slug extraction method would be calculated under the variable head equations.

6.2.2 Slug Injection Test Procedure

Required Measurements

* length of well screen
* inside diameter of well screen
* inside diameter of well riser

Required Equipment

* steel or fiberglass surveying tape
* electronic water level indicator/pressure transducer (+ readout/data logger)
* bucket/water container (graduated)
* watch with seconds hand (or digital)
* semi-log paper

1. Establish the static water level in the well by measuring and recording the depth to water to the nearest 0.01 foot from a stationary point (usually a point marked on the top of the well riser or protective casing). Preferably the static water level is measured every 10 minutes for at least 30 minutes prior to initiating the test.

2. Measure and record the static water level just prior to initiating the test.

3. As quickly as possible, pour a known volume of water into the well (be certain that the volume of water will not overflow the top of the well). The volume of water poured into the well should be recorded.

4. Measure and record water levels as follows:

* 10, 20 and 30 seconds elapsed time
* 45, 60, 75 and 90 seconds elapsed time
* every 30 seconds elapsed time, up to 10 minutes
* every minute up to 30 minutes
* every two minutes up to 1 hour
* every five minutes up to 3 hours
* every ten minutes up to 6 hours
* every 30 minutes up to 12 hours

Measurements may cease once the water level has returned to at least 85 percent recovery.

5. Calculate the time zero head in the well based on the volume of water added to the well and the radius of the inside well diameter. This should be noted as H_0.

6. Calculate a head ratio for each measurement with the following equation:

$$\frac{\text{maximum head } (H_0 \text{ in feet}) - \text{recovery (in feet)}}{\text{maximum head } (H_0 \text{ in feet})}$$

This equation should equal 1.00 at time zero (maximum head, but no recovery) and should equal 0.15 when 85 percent recovery has been reached.

7. Plot time versus the head ratio on semi-log paper. The time should be plotted linearly on the X axis and the head ratio should be plotted logrithmically on the Y axis.

10. The resulting plot should theoretically be straight; in reality it is not. The straightest portion of this line should be used for the hydraulic conductivity calculations. Generally, the beginning and end points are not on the line and should not be used.

11. Use the time and head values (t_1,H_1 and t_2,H_2) representing the two ends of the line in the equations that are presented in Figure 2. The most commonly used situations presented in Figure 2 are F and G. The slug injection method would be calculated under the variable head equations.

6.3 Constant Head Method

Required Measurements

* length of well screen
* inside diameter of well screen
* inside diameter of well riser
* discharge rate of water into well

Required Equipment

* steel or fiberglass surveying tape
* electronic water level indicator/pressure transducer (+ readout/data logger)
* bucket/water container (graduated)
* watch with seconds hand (or digital)
* semi-log paper

The constant head method involves the discharge of water into a well at a constant rate and allowing the increase in head to equilibrate. The constant head method can not be used where the top of the well screen is above the water table.

1. Establish the static water level in the well by measuring and recording the depth to water to the nearest 0.01 foot from a stationary point (usually a point marked on the top of the well riser or protective casing). Preferably the static water level is measured every 10 minutes for at least 30 minutes prior to initiating the test.

2. Measure and record the static water level just prior to initiating the test.

3. Discharge water into the well at a constant rate. The discharge rate must be known, but not necessarily prior to initiating the test. If necessary, the discharge rate can be measured at the end of the test. The field measurement of the discharge rate is usually made by discharging the water into a container of known volume and timed. The field measurement should be measured and recorded three times and the average recorded as the constant discharge rate.

4. Measure and record water levels as follows:

* 10, 20 and 30 seconds elapsed time
* 45, 60, 75 and 90 seconds elapsed time
* every 30 seconds elapsed time, up to 10 minutes
* every minute up to 30 minutes
* every two minutes up to 1 hour
* every five minutes up to 3 hours
* every ten minutes up to 6 hours
* every 30 minutes up to 12 hours

Measurements may cease once the rising water level increases no more than two percent of the total increase between water level readings. The increase in total head at the end of the test should be noted as H_c.

5. Use the constant discharge rate and H_c values in the equations that are presented in Figure 2. The most commonly used situations presented in Figure 2 are F and G. The constant head method would be calculated under the constant head equations.

6.4 Single Well Pump Test

Required Measurements

* length of well screen
* inside diameter of well screen
* inside diameter of well riser
* discharge rate of water into well

Required Equipment

* steel or fiberglass surveying tape
* electronic water level indicator/pressure transducer (+ readout/data logger)
* bucket/water container (graduated)
* watch with seconds hand (or digital)
* pump capable of maintaining constant discharge
* semi-log paper

A single well pump test consists of pumping water from a well at a constant discharge rate and measuring the change in water levels over a period of time. The largest advantage of single well pump tests is that it can involve a large volume of water which influences a greater effective area. Therefore, the test can effect a larger area which provides data more representative of the subsurface materials. The largest drawback is that this larger volume of water may require temporary storage and/or treatment before discharging to the ground or some other approved receptacle.

1. Establish the static water level in the well by measuring and recording the depth to water to the nearest 0.01 foot from a stationary point (usually a point marked on the top of the well riser or protective casing). Preferably the static water level is measured every 10 minutes for at least 30 minutes prior to initiating the test.

2. Lower a submersible pump or suction line for a peristaltic/centrifugal pump into the well and allow the water level to reach the initial static water level.

3. Measure and record the static water level just prior to initiating the test.

4. Begin pumping the well at a constant discharge rate. If using a peristaltic/centrifugal pump, there should be some means to control the discharge rate. On a centrifugal pump this can easily be accomplished by placing a valve (preferably a ball valve) on the discharge end of the pump (before the discharge line though). The discharge rate should be checked periodically and adjusted if necessary. The discharge rate should not vary more than ten percent.

5. Measure and record water levels as follows:

* 10, 20 and 30 seconds elapsed time
* 45, 60, 75 and 90 seconds elapsed time
* every 30 seconds elapsed time, up to 10 minutes
* every minute up to 30 minutes
* every two minutes up to 1 hour
* every five minutes up to 3 hours
* every ten minutes up to 6 hours
* every 30 minutes up to 12 hours

The test should be run as long as practical, however, typical budget restraints would indicate the test should be run for about one hour typically. If the discharge rate can not be maintained, the pumping should be terminated immediately.

6. Once the pumping has been terminated, measure and record the recovering water level as follows:

* 10, 20 and 30 seconds elapsed time
* 45, 60, 75 and 90 seconds elapsed time
* every 30 seconds elapsed time, up to 10 minutes
* every minute up to 30 minutes
* every two minutes up to 1 hour
* every five minutes up to 3 hours
* every ten minutes up to 6 hours
* every 30 minutes up to 12 hours

Measurements should be made and recorded until the water level has recovered at least 85 percent. If there is insufficient time, record the recovery as long as possible.

7. Plot time versus drawdown on semi-log paper. The time should be plotted logrithmically on the X-axis and drawdown should be plotted linearly on the Y-axis. If the drawdown is greater than ten percent of the saturated thickness of the subsurface materials (or, if the total saturated thickness is unknown, ten

percent of the water standing in the well), a corrected drawdown needs to also be plotted. The corrected drawdown for each measurement is calculated with the following equation:

$$s_c = s - s^2 / 2m$$

where s = measured drawdown

s_c = corrected drawdown

m = saturated thickness of subsurface materials (if unknown, length of standing water in the well)

8. A "best fit" straight line should be drawn through the plotted points.

9. Calculate the coefficient of transmissivity. This is done with the following equation:

$$T = \frac{264 \times Q}{\text{delta } s}$$

where T = coefficient of transmissivity (gallons per day per foot, gpd/ft)

Q = constant discharge rate (gallons per minute, gpm)

delta s = change in drawdown over one log cycle

If the drawdown was corrected, the change in corrected drawdown over one log cycle should be used.

10. Calculate the hydraulic conductivity with the following equation:

$$k = \frac{T\ (gpd/ft)}{m\ (ft)} \ / \ 7.48\ (\text{gallons per } ft^3)$$

where k = hydraulic conductivity (feet per day, ft/day)

T = coefficient of transmissivity

m = saturated thickness of subsurface materials (if unknown, length of standing water in well)

11. Plot time versus recovery on semi-log paper. The time should be plotted logrithmically on the X-axis and recovery should be plotted linearly on the Y-axis. If the recovery is greater than ten percent of the saturated thickness of the subsurface materials (or, if the total saturated thickness is unknown, ten percent of the water standing in the well), a corrected recovery needs to also be plotted. The corrected recovery for each measurement is calculated with the following equation:

$$s'_c = s' - s'^2 / 2m$$

where s' = measured recovery

s'_c = corrected recovery

m = saturated thickness of subsurface materials (if unknown, length of standing water in the well)

12. A "best fit" straight line should be drawn through the plotted points.

13. Calculate the coefficient of transmissivity. This is done with the following equation:

$$T = \frac{264 \times Q}{\text{delta } s'}$$

where T = coefficient of transmissivity (gallons per day per foot, gpd/ft)

Q = constant discharge rate (gallons per minute, gpm)

delta s' = change in recovery over one log cycle

If the recovery was corrected, the change in corrected recovery over one log cycle should be used.

14. Calculate the hydraulic conductivity with the following equation:

$$k = \frac{T \text{ (gpd/ft)}}{m \text{ (ft)}} \;/\; 7.48 \text{ (gallons per ft}^3\text{)}$$

where k = hydraulic conductivity (feet per day, ft/day)

T = coefficient of transmissivity

m = saturated thickness of subsurface materials (if unknown, length of standing water in well)

SECTION 7.0 REFERENCES

[1] Kraemer, Curtis A., Hankins, John B., and Carl J. Mohrbacher, "Selection of Single-Well Hydraulic Test Methods for Monitoring Wells," Ground Water and Vadose Zone Monitoring, ASTM STP 1053, D.M. Nielsen and A.I. Johnson, Eds., American Society for Testing and Materials, Philadelphia. 1989.

[2] Freeze, R.A., and J.A. Cherry, Groundwater, Prentice-Hall, Englewood Cliffs, NJ, 1979.

[3] Hvorslev, M.J., Waterways Experiment Station Bulletin 36, U.S. Army Corps of Engineers, Vicksburg, MS, 1951.

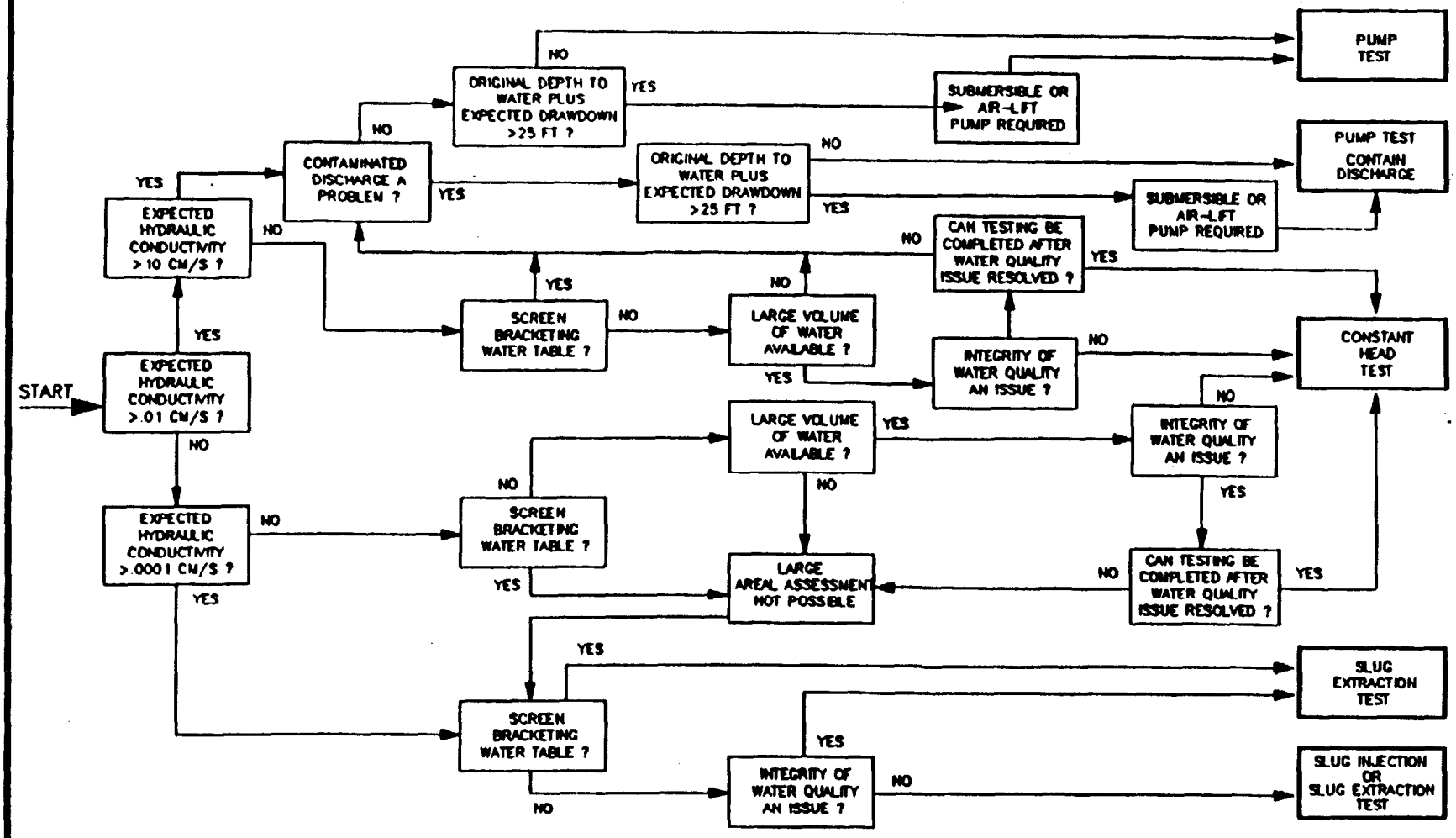
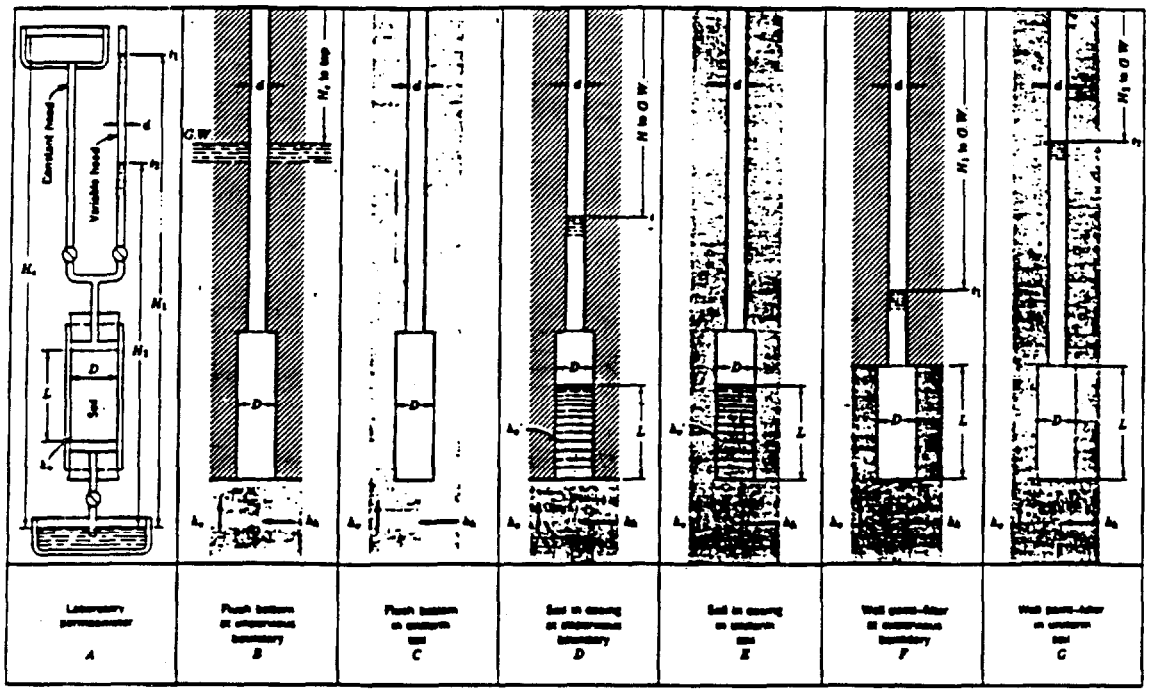


FIGURE 1
DECISION MAKING FLOWCHART FOR HYDRAULIC TESTS

ATLANTIC PROCEDURE NO. 1071
(FROM KRAEMER, HANKINS & MOHRBACHER, 1989)



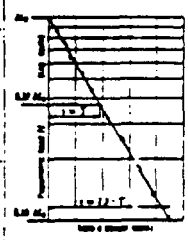
Case	Constant Head	Variable Head	Basic Time Lag	Notation
A	$k_v = \frac{4 \cdot q \cdot L}{\pi \cdot D^2 \cdot H_1}$	$k_v = \frac{d^2 \cdot L}{D^2 \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{L}{(t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $d = D$	$k_v = \frac{d^2 \cdot L}{D^2 \cdot T}$ $k_v = \frac{L}{T}$ for $d = D$	D = Diam. sample (cm) d = Diameter, standpipe (cm) L = Length, sample (cm) H_1 = Constant pert. head (cm) H_1 = Pert. head for $t = t_1$ (cm) H_2 = Pert. head for $t = t_2$ (cm) q = Flow of water (cm³/sec) t = Time (sec) T = Basic time lag (sec) k_v = Vert. perm. sample (cm/sec)
B	$k_v = \frac{q}{2 \cdot D \cdot H_1}$	$k_v = \frac{d^2}{8 \cdot D \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{d \cdot D}{8 \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $d = D$	$k_v = \frac{d^2}{8 \cdot D \cdot T}$ $k_v = \frac{d \cdot D}{8 \cdot T}$ for $d = D$	
C	$k_v = \frac{q}{2.75 \cdot D \cdot H_1}$	$k_v = \frac{d^2}{11 \cdot D \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{d \cdot D}{11 \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $d = D$	$k_v = \frac{d^2}{11 \cdot D \cdot T}$ $k_v = \frac{d \cdot D}{11 \cdot T}$ for $d = D$	
D	$k_v = \frac{4 \cdot q \left(\frac{1}{8} \frac{k_v}{k_h} \frac{D}{L} + 1 \right)}{\pi \cdot D^2 \cdot H_1}$	$k_v = \frac{d^2 \left(\frac{1}{8} \frac{k_v}{k_h} \frac{D}{L} + 1 \right)}{D^2 \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{\frac{1}{8} \frac{D}{L} + 1}{(t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $\frac{k_v}{k_h} = 1$, $\frac{L}{D} = D$	$k_v = \frac{d^2 \left(\frac{1}{8} \frac{k_v}{k_h} \frac{D}{L} + 1 \right)}{D^2 \cdot T}$ $k_v = \frac{\frac{1}{8} \frac{D}{L} + 1}{T}$ for $\frac{k_v}{k_h} = 1$, $\frac{L}{D} = D$	k_h = Vert. perm. ground (cm/sec) k_h = Horiz. perm. ground (cm/sec) k_m = Mean coeff. perm. (cm/sec) m = Transformation ratio $k_m = \sqrt{k_v \cdot k_h}$ $m = \sqrt{k_v/k_h}$ $\ln = \log_e = 2.3 \log_{10}$
E	$k_v = \frac{4 \cdot q \left(\frac{1}{11} \frac{k_v}{k_h} \frac{D}{L} + 1 \right)}{\pi \cdot D^2 \cdot H_1}$	$k_v = \frac{d^2 \left(\frac{1}{11} \frac{k_v}{k_h} \frac{D}{L} + 1 \right)}{D^2 \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{\frac{1}{11} \frac{D}{L} + 1}{(t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $\frac{k_v}{k_h} = 1$, $\frac{L}{D} = D$	$k_v = \frac{d^2 \left(\frac{1}{11} \frac{k_v}{k_h} \frac{D}{L} + 1 \right)}{D^2 \cdot T}$ $k_v = \frac{\frac{1}{11} \frac{D}{L} + 1}{T}$ for $\frac{k_v}{k_h} = 1$, $\frac{L}{D} = D$	
F	$k_v = \frac{q \ln \left[\frac{2mL}{D} + \sqrt{1 + \left(\frac{2mL}{D} \right)^2} \right]}{2 \cdot \pi \cdot L \cdot H_1}$	$k_v = \frac{d^2 \ln \left[\frac{2mL}{D} + \sqrt{1 + \left(\frac{2mL}{D} \right)^2} \right]}{8 \cdot L \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{d^2 \ln \left(\frac{2mL}{D} \right)}{8 \cdot L \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $\frac{2mL}{D} > 4$	$k_v = \frac{d^2 \ln \left[\frac{2mL}{D} + \sqrt{1 + \left(\frac{2mL}{D} \right)^2} \right]}{8 \cdot L \cdot T}$ $k_v = \frac{d^2 \ln \left(\frac{2mL}{D} \right)}{8 \cdot L \cdot T}$ for $\frac{2mL}{D} > 4$	
G	$k_v = \frac{q \ln \left[\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D} \right)^2} \right]}{2 \cdot \pi \cdot L \cdot H_1}$	$k_v = \frac{d^2 \ln \left[\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D} \right)^2} \right]}{8 \cdot L \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ $k_v = \frac{d^2 \ln \left(\frac{2mL}{D} \right)}{8 \cdot L \cdot (t_2 - t_1)} \ln \frac{H_1}{H_2}$ for $\frac{mL}{D} > 4$	$k_v = \frac{d^2 \ln \left[\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D} \right)^2} \right]}{8 \cdot L \cdot T}$ $k_v = \frac{d^2 \ln \left(\frac{2mL}{D} \right)}{8 \cdot L \cdot T}$ for $\frac{mL}{D} > 4$	Dimensionless head ratio log T

FIGURE 2
FORMULAS FOR DETERMINATION OF HYDRAULIC CONDUCTIVITY

ATLANTIC PROCEDURE NO. 1071
(FROM HVORSLEV, 1951)

ATLANTIC PROCEDURE NO. 1256-A (1055-P)

GAS CHROMATOGRAPHY ANALYSIS USING EXTERNAL STANDARD CALIBRATION

ATLANTIC ENVIRONMENTAL SERVICES, INC.
COLCHESTER, CONNECTICUT

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SECTION 1.0: PURPOSE

To establish a standard procedure for conducting gas chromatograph (GC) analysis using external standard calibration.

SECTION 2.0: SCOPE

This procedure details the steps necessary to identify and quantify organic compounds using gas chromatography and external standard calibration.

SECTION 3.0: RESPONSIBILITY

First - Project Manager

Second - Field Team Leader

Third - Photovac Operator

SECTION 4.0: SUPPORTING PROCEDURES

None

SECTION 5.0: PROCEDURE

5.1 Introduction

A gas chromatography system consists of the following components: an injection port, column, oven, detector, data recording system, and a carrier gas delivery system. The oven may be isothermal or temperature programmable. The choice of the column, detector, oven temperature(s) and carrier gas flow rate are

dependent on the compounds of interest.

5.2 Carryover Contamination

Contamination by carryover can occur whenever high-concentration and low-concentration samples are sequentially analyzed. To reduce carryover, the sample syringe or purging device must be rinsed out between samples with water, air or solvent. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of a solvent, air or water blank to check for cross-contamination.

5.3 Analyte Identification

Unknown compounds detected in samples will be identified by matching their retention times with those of known compounds found in the standards.

5.4 Peak Response

Peak area will normally be used to quantify response; however, peak height may be used.

5.5 External Standard Calibration Procedure

For each analyte of interest, prepare calibration standards at a minimum of three concentrations by adding volumes of one or more stock standards to a volumetric flask and diluting to volume with an appropriate solvent. One of the external standards should be at a concentration near, but above, the method detection limit. The other concentrations should correspond to the expected range of concentrations found in real samples or should define the linear or working range of the detector.

Inject each calibration standard using the technique that will be used to introduce the actual samples into the gas chromatograph (e.g., 2-5 μl injections, purge-and-trap, head space, etc.)

A single standard, other than the highest or lowest concentration analyzed, will be used to quantify all samples and to determine the linearity of the other standards. This standard shall be refereed to as the mid-range standard. The linearity of the upper and lower standards can be calculated using the following formula.

$$\frac{Az}{As} \times \frac{Cs}{Cz} \times \frac{Vs}{Vz} \times 100 = (100 \pm 20\%)$$

where:

Az = Response of upper or lower standard
As = Response of mid range standard
Cz = Concentration of upper or lower standard
Cs = Concentration of mid range standard
Vz = Volume of upper or lower standard injected
Vs = Volume of mid range standard injected

If the response for an analyte is within 20% of the ideal value (100%) over the working range, linearity through the origin can be assumed. A result will be labeled as an estimated value if there is not an upper and lower standard linear to within 20% of the ideal value (100%) or if the response for the compound is above the linear range of the detector.

The mid range standard should be analyzed before the first analysis of each day and after the last, or every twenty samples. A standard must be run every day the instrument is in use.

The response of each succeeding analysis of the mid range standard shall be compared to the response of the mid range standard obtained during the most recent analysis of the calibration standards. This is done to monitor change in detector response over time. A new calibration curve should be prepared for an analyte if the response has changed by more than 15%. The following formula can be used to determine the percent change for a mid range standard.

$$\frac{\textit{area of succeeding analysis}}{\textit{area of initial analysis}} \times 100 = (100 \pm 15\%)$$

The concentration of analytes in samples can be determined using the following formula.

$$\frac{Ax}{As} \times \frac{Cs}{1} \times \frac{Vs}{Vx} \times \frac{DF}{\%S} \times \frac{Wt.x}{Vol.x} = Cx$$

where:

Ax = Response of analyte in sample
As = Response of analyte in Standard
Cx = Concentration of analyte in sample
Cs = Concentration of analyte in standard
Vx = Volume of sample injected
Vs = Volume of standard injected
DF = Dilution factor of sample
%S = Percent solids of sample
Wt.x = Wet weight of sample used in grams
Vol.x = Volume of final extraction solvent used in ml

Alternately, the data recording system (integrator) can be used to perform equivalent calculations to determine percent linearity, percent change and sample analyte concentration.

SECTION 6.0 REFERENCES

U.S. EPA, 1986. Test Methods for Evaluating Solid Waste, SW-846 Office of Solid Waste and Emergency Response, Washington, D.C. 20460, Method 8000.

ATLANTIC PROCEDURE NO. 1256-B (1056-P)

MICROSCALE EXTRACTION

ATLANTIC ENVIRONMENTAL SERVICES, INC.
COLCHESTER, CONNECTICUT

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SECTION 1.0: PURPOSE

To establish a standard procedure for conducting microscale extraction of soils.

SECTION 2.0: SCOPE

This procedure details the equipment and procedures necessary to perform microscale extraction.

SECTION 3.0: RESPONSIBILITY

First - Project Manager

Second - Field Team Leader

Third - Field Technician

SECTION 4.0: SUPPORTING PROCEDURES

None

SECTION 5.0: EQUIPMENT

- a Burrell wrist-action shaker or equivalent
- analytical balance which reads to at least 0.1 grams
- extraction vessels - 20 to 50 ml glass or plastic containers
- steel ball bearings (optional)

SECTION 6.0: PROCEDURE

- Place up to 10 g of sample in an extraction vessel.
- Add 5 steel balls (optional).
- Add extraction solvent.
- Place extraction vessel on a wrist-action shaker for at least 40 minutes.

SECTION 7.0: REFERENCES

U.S. EPA, 1988. Field Screening Methods Catalog User's Guide, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, U.S. Environmental Protection Agency, Washington, D.C. 20460, Field Method 18.

ATLANTIC PROCEDURE NO. 1256-C (1057-P)

PCB AND PESTICIDE ANALYSIS BY GAS CHROMATOGRAPHY

ATLANTIC ENVIRONMENTAL SERVICES, INC.
COLCHESTER, CONNECTICUT

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SECTION 1.0: PURPOSE

To establish a standard procedure for conducting PCB and pesticide analysis using a gas chromatograph.

SECTION 2.0: SCOPE

This procedure details the equipment and procedures necessary to perform PCB pesticide analysis using gas chromatography.

SECTION 3.0: RESPONSIBILITY

First - Project Manager
Second - Field Team Leader
Third - Field Technician

SECTION 4.0: SUPPORTING PROCEDURES

Gas chromatography analysis using External Standard Calibration
Atlantic Procedure 1256-A

Microsolvent extraction, Atlantic Procedure 1256-B

SECTION 5.0: EQUIPMENT AND OPERATING CONDITIONS

- a gas chromatograph with a electron capture detector, integrator and an oven capable of maintaining at least 250° C
- analytical column, a Supelcoport 100/120 mesh coated with 1.5% SP-2250/1.95% SP-2401 packed in a 1.8 m X 4 mm ID glass column or equivalent
- carrier gas - nitrogen (UHP)

- carrier gas flow rate, 50 - 75 ml/min.
- isothermal oven temperature, 160° C to 240° C
- extraction solvent a 1:4:5 ration of water/methanol/hexane
- recommended injection size 2 μl of hexane layer

SECTION 6.0: EXTRACTION

Microscale extraction, Atlantic Procedure 1256-B

SECTION 7.0: CLEANUP

The hexane extract can be cleaned up if needed by transferring the hexane extract to a vial containing sulfuric acid and shaking. Inject hexane layer after it has separated. This may not be used for acid sensitive pesticides.

SECTION 8.0: CALIBRATION

External standard calibration is used according to procedures outlined in Atlantic Standard Operating Procedure Number 1256-A.

SECTION 9.0: REFERENCES

U.S. EPA, 1986. Test Methods for Evaluating Solid Waste; SW-846, Office of Solid Waste and Emergency Response, Washington, D.C. 20460, Method 8080.

U.S. EPA, 1988. Field Screening Methods Catalog User's Guide, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, U.S. Environmental Protection Agency, Washington, D.C. 20460, Field Method 18.

ATLANTIC PROCEDURE NO. 1256-D

STANDARD OPERATING PROCEDURES FOR THE SAMPLING OF VOLATILE ORGANIC COMPOUNDS IN AMBIENT AIR USING TENAX® ADSORPTION

ATLANTIC ENVIRONMENTAL SERVICES, INC.
COLCHESTER, CONNECTICUT

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SECTION 1.0: PURPOSE

To establish a standard procedure for sampling ambient air for volatile organic compounds in accordance with Method T01 from the Compendium for the Determination of Toxic Organics in Ambient Air, EPA-600/4-84-041.

SECTION 2.0: SCOPE

The document describes the protocol for collection of certain volatile organic compounds which can be captured on Tenax® GC (poly(2,6-Diphenyl phenylene oxide)) and determined by thermal desorption GC/MS techniques.

Compounds which can be determined by this method are nonpolar organics having boiling points in the range of approximately 80° C - 200° C. However, not all compounds falling into this category can be determined. Table 1 gives a listing of compounds for which the method has been used. Other compounds may yield satisfactory results but validation by the individual user on laboratory is required.

SECTION 3.0: RESPONSIBILITY

First - Project Manager

Second - Field Team Leader

Third - Field Technician

SECTION 4.0: SUPPORTING PROCEDURES

Atlantic Procedure 1041, Sample Chain-of-Custody

Atlantic Procedure 1042, Shipping Procedures for Environmental Field Samples

SECTION 5.0: SUMMARY OF PROTOCOL

Ambient air is drawn through a cartridge containing ~1-2 grams of Tenax® and certain volatile organic compounds are trapped on the resin while highly volatile organic compounds and most inorganic atmospheric constituents pass through the cartridge. The cartridge is then transferred to the laboratory and analyzed.

Contamination of the Tenax® cartridge with the compound(s) of interest is a commonly encountered problem in the method. The user must be extremely careful in the preparation, storage, and handling of the cartridges throughout the entire sampling and analysis process to minimize this problem.

SECTION 6.0: APPARATUS AND MATERIALS

- Sampling System - Capable of accurately and precisely drawing an air flow of 10-500 ml/minute through the Tenax® cartridge. All sampling lines will either be made of Teflon or stainless steel.
- Tenax® cartridges, prepared and supplied by the analytical laboratory
- Polyester gloves - for handling glass Tenax® cartridges
- Glass Fiber Filter - 1-inch diameter, to fit in filter holder (optional).
- Perfluorotributylamine (FC-43).
- Granular activated charcoal - for preventing contamination of Tenax® cartridges during storage.

SECTION 7.0: SAMPLING

7.1 Flow Rate and Total Volume Selection

7.1.1

Each compound has a characteristic retention volume (liters of air per gram of adsorbent) which must not be exceeded. Since the retention volume is a function of temperature, and possibly other sampling variables, one must include an adequate margin of safety to ensure good collection efficiency. Approximate breakthrough volumes at 38° C (100° F) in liters/gram of Tenax® are provided in Table 1. These retention volume data are supplied only as rough guidance and are subject to considerable variability, depending on cartridge design as well as sampling parameters and atmospheric conditions.

7.1.2

To calculate the maximum total volume of air which can be sampled, use the following equation:

$$V_{MAX} = \frac{WV_b}{1.5}$$

where:

V_{MAX} is the calculated maximum total volume in liters.

V_b is the breakthrough volume for the least retained compound of interest (Table 1) in liters per gram of Tenax®.

W is the weight of Tenax® in the cartridge, in grams.

1.5 is a dimensionless safety factor to allow for variability in atmospheric conditions. This factor is appropriate for temperatures in the range of 25-30° C. If

higher temperatures are encountered, the factor should be increased (i.e., maximum total volume decreased).

7.1.3

To calculate maximum flow rate, use the following equation:

$$Q_{MAX} = \frac{V_{MAX}}{t} \times 1000$$

Q_{MAX} is the calculated maximum flow rate in milliliters per minute.

t is the desired sampling time in minutes. Times greater than 24 hours (1440 minutes) generally are unsuitable because the flow rate required is too low to be accurately maintained.

7.1.4

The maximum flow rate Q_{MAX} should yield a linear flow velocity of 50-500 cm/minute. Calculate the linear velocity corresponding to the maximum flow rate using the following equation:

$$B = \frac{Q_{MAX}}{\pi r^2}$$

where

B is the calculated linear flow velocity in centimeters per minute.
r is the internal radius of the cartridge in centimeters.

If B is greater than 500 centimeters per minute, either the total sample volume (V_{MAX}) should be reduced or the sample flow rate (Q_{MAX}) should be reduced by increasing the collection time. If B is less than 50 centimeters per minute, the sampling rate (Q_{MAX}) should be increased by reducing the sampling time. The total sample value (V_{MAX}) cannot be increased due to component breakthrough.

7.1.5

The flow rate calculated as described above defines the maximum flow rate allowed. In general, one should collect additional samples in parallel for the same time period but at lower flow rates. This practice yields a measure of quality control and is further discussed in the literature (5). In general, flow rates 2 to 4 fold lower than the maximum flow rate should be employed for the parallel samples. In all cases a constant flow rate should be achieved for each cartridge since accurate integration of the analyte concentration requires that the flow be constant over the sampling period.

7.2 Sample Collection

7.2.1

Collection of an accurately known volume of air is critical to the accuracy of the results. For this reason the use of mass flow controllers or a constant volume stroke recording pump rather than conventional needle valves, rotameters, or orifices is highly recommended, especially at low flow velocities (e.g., less than 100 milliliters/minute).

7.2.2

Prior to sample collection, insure that the sampling flow rate has been calibrated over a range including the rate to be used for sampling, with a "dummy" Tenax® cartridge in place. Generally calibration is accomplished using a soap bubble flow meter or calibrated wet test meter. The flow calibration device is connected to the flow exit, assuming the entire flow system is sealed. ASTM Method D3686

describes an appropriate calibration scheme, not requiring a sealed flow system downstream of the pump.

7.2.3

The flow rate should be checked before and after each sample collection. If the sampling interval exceeds four hours, the flow rate should be checked at an intermediate point during sampling as well. In general, a flow meter or stroke counter should be included to allow observation of the sampling flow rate without disrupting the sampling process.

7.2.4

To collect an air sample, the cartridges are removed from the sealed container just prior to initiation of the collection process. If glass cartridges are employed, they must be handled only with clean polyester gloves and should not contact any other surfaces. Cartridges should be shipped in a sealed containers with activated charcoal. They should be shipped and stored separately from any possible sources of volatile organics.

7.2.5

An optional particulate filter and holder are placed on the inlet to the cartridges and the exit end of the cartridge is connected to the sampling pump. In many sampling situations, the use of a filter is not necessary if only the total concentration of a component is desired. Glass cartridges may be connected using teflon ferrules and Swagelok (stainless steel or teflon) fittings. Start the pump and record the following parameters on an appropriate data sheet: date, sampling

location, time, ambient temperature, barometric pressure, relative humidity, flow rate, cartridge number and equipment meter serial numbers.

7.2.6

Allow the sampler to operate for the desired time, periodically recording the variables listed above. Check flow rate at the midpoint of the sampling interval if longer than four hours. At the end of the sampling period, record the parameters listed in 7.2.5 and check the flow rate and record the value. If the flows at the beginning and end of the sampling period differ by more than 10%, the cartridge should be marked as suspect.

7.2.7

Remove the cartridges (one at a time) and place in the original container (use clean polyester gloves for glass cartridges). Seal the cartridges in culture tubes in a friction-top can containing a layer of activated charcoal and package for immediate shipment of the laboratory for analysis. Store cartridges at reduced temperature (e.g., - 20° C) before analysis if possible to maximize storage stability. No sources of volatile organics should be stored with the cartridge. Cartridges should be analyzed within two weeks after sampling.

7.2.8

Calculate and record the average sample rate for each cartridge according to the following equation:

$$Q_A = \frac{Q_1 + Q_2 + \ldots Q_N}{N}$$

where

Q_A = Average flow rate in ml/minute

$Q_1, Q_2, \ldots\ldots Q_N$ = flow rates determined at beginning, end, and immediate points during sampling

N = number of points averaged

7.2.9

Calculate and record the total volumetric flow for each cartridge using the following equation:

$$V_M = \frac{T \times QA}{1000}$$

where

Vm = Total volume sampled in liters at measured temperature and pressure.
T_2 = Stop time
T_1 = Start time
T = Sampling time = $T_2 - T_1$, minutes

7.2.10

The total volume (V_S) at standard conditions, 25° C and 760 mmHg, is calculated from the following equation:

$$V_S = V_M \times \frac{P_A}{760} \times \frac{298}{273 + t_A}$$

where

P_A = Average barometric pressure, mmHg
t_A = Average ambient temperature, °C

SECTION 8.0 QA/QC SAMPLES

8.1

During each sampling event at least one clean cartridge will accompany the samples to the field and back to the laboratory, without being used for sampling, to serve as a field blank. The average amount of material found on the field blank cartridge may be subtracted from the amount found on the actual samples. However, if the blank level is greater than 25% of the sample amount, data for that component must be identified as suspect.

8.2

During each sampling event, at least one set of parallel samples (two or more samples collected simultaneously) will be collected, preferably at different flow rates as described in Section 7.1. If agreement between parallel samples is not generally within ±25%, the user should collect parallel samples on a much more frequent basis (perhaps for all sampling points). If a trend of lower apparent concentrations with increasing flow rate is observed for a set of parallel samples, one should consider using a reduced flow rate and longer sampling interval if possible. If this practice does not improve, the reproducibility further evaluation of the method performance for the compound of interest may be required.

8.3

During each sampling event, a minimum of 10% of all samples should be collected with a backup cartridge (two cartridges in series). Backup cartridges should contain less than 20% of the amount of components of interest found in the front

cartridges, or be equivalent to the blank cartridge level, whichever is greater. The frequency of use of backup cartridges should be increased if increased flow rate is shown of yield reduced component levels for parallel sampling. This practice will help to identify problems arising from breakthrough of the component of interest during sampling.

SECTION 9.0 TEST METHOD

The concentration of volatile organic compounds captured on the Tenax cartridge will be determined by thermal desorption GC/MS techniques as specified in Method T01, *Method for the Determination of Volatile Organic Compounds in Ambient Air Using Tenax Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS) (U.S. EPA 1984).*

When an analytical laboratory is selected to perform these analyses, its SOP for Method T01 will be submitted to the U.S. EPA and CTDEP for review and approval.

SECTION 10.0 REFERENCES

1. U.S. EPA Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, EPA-600/4-84-041, 1984.

TABLE 1 AMBIENT AIR SAMPLING TARGET COMPOUNDS AND RETENTION VOLUME	
Compound	**Estimated Retention Volume at 100°F (38°C) - Liters/Gram**
EPA Method T01 — Volatile Organics	
Benzene	19
Toluene	97
Ethylbenzene	200
Xylene(s)	200
Cumene	440
n-Heptane	20
l-Heptane	40
Chloroform	8
Carbon Tetrachloride	8
1,2-Dichloroethane	10
1,1,1-Trichloroethane	6
Tetrachloroethylene	80
Trichloroethylene	20
1,2-Dichloropropane	30
1,3-Dichloropropane	90
Chlorobenzene	150
Bromoform	100
Ethylene Dibromide	60
Bromobenzene	300

TO1 SAMPLER FIELD DATA SUMMARY

Site Location:	Sample S/N:	Ambient Temperature:	Before	After
Date:	Sampler Set Point:	Barometric Pressure:		
Performed By:	Sample I.D.:	Relative Humidity:		

PIT I.D.	Cartridge I.D.	Sampling Period			Flow Rate Indicator (counts)			Sample Volume (L)	
		Start	End	Minutes	Start	End	Total	Actual	STD

COMMENTS:

Griffin Technica Procedure 002

Operation of the Scitec MAP Analyzer Model 310 for Lead in Soil Analysis

Approved by Franklin Mills 2/2/93

Franklin Mills, President Date

Note: You are not allowed to use the MAP Model 310 unless you possess a certificate from the Scitec Corporation as proof that you have received an 8-hour course in radiation safety. See the Radiation Protection Program, pertinent sections of which are included in this document under "References".

Griffin Technica, 6 Way Road, Middlefield, Connecticut

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Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

To establish a standard procedure for the operation of the MAP Model 310 Spectrum Analyzer for analysis of soil *in situ* for the presence of lead.

SECTION 1.0: PURPOSE

SECTION 2.0: SCOPE

The procedure details the steps necessary for the operation of the MAP Model 310 for performing analysis of soil for lead. Not included in this procedure is the Radiation Safety Program, which is necessarily a part of any operation of this device.

SECTION 3.0: RESPONSIBILITY

First	Company President
Second	MAP Operator

SECTION 4.0: SUPPORTING PROCEDURES

Griffin Technica Procedure 001 *Operation of the Scitec MAP Analyzer Model 310 for Lead in Paint Analysis.* Also see Griffin Technica *Radiation Safety Program*.

SECTION 5.0: PROCEDURE

5.1 Introduction

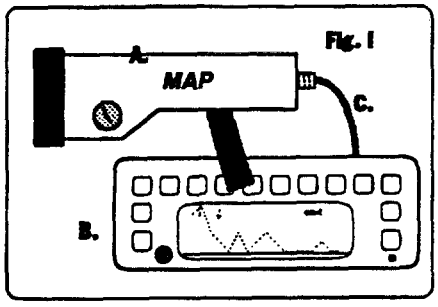
The MAP (Metal Analysis Probe) Model 310 can be used in combination with bulk sample collection and laboratory analysis for the lead in soil. This procedure describes the necessary equipment needed for operation, the method of validating the calibration of the unit, and the proper positioning of the assayer and test times.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

5.2 Equipment Required

Equipment needed for operation of MAP Model 310 includes:

- Scanner (A)
- Control Console (B)
- Cable (C)
- Assayer key (not shown)
- Lead Standard (not shown)



Optional equipment includes:

- Battery charger/download interface unit
- Null modem cable (to connect computer)
- Portable computer (to store downloaded results)

5.3 Instrument Setup

1. Check the connectors to assure that they are clean and free from dirt or loose particles. Connect the scanner to the console with the cable, properly engaging the Breech Lok connectors on both ends of the cable.

   Connectors

   The console, assayer, and the cable each have a "Breech-Lok" type connector to provide a quick connect or disconnect operation.

   Breech-Lok connectors cannot be coupled until key/keyway alignment has been achieved. Keys in the connector mechanism drop into keyways with a

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

positive "feel" before coupling can begin. A 90 degree coupling ring rotation brings the plug to the fully mated position. Three full mate indicators are provided:

- A red band at the rear of the plug disappears.
- A détente mechanism provides an audible click and a distinct tactile indication of locking.
- An indicator line on the receptacle aligns with the main key way indicator on the coupling ring, for positive visual inspection.

2. Turn the power switch "ON." The console will briefly flash a "SELF TEST IN PROGRESS" message. The display will then show "Connect delay" and the delay time remaining. This 15 second delay allows the electronic circuitry to stabilize before measurements are taken.
3. If the results from previous testing have been downloaded to the computer, press the "<ETC>" key. At the next screen press the "MEMCLR" key to clear the memory. Press the "YES" key to confirm the operation. The right hand bottom corner of the screen should read, "AVAIL: 325," to indicate that the memory is ready to receive data from 325 test operations.
4. At the main screen, press the "DATE" key to enter the current date. Enter the date as 6 digits (for example "022393" for February 23, 1993). Press "ENTER" when date is correct.
5. At the main screen, press "ID" to enter the necessary identification number for the sample. Use up to 17 digits including dots (".") as separators. Since you will be running

a calibration validation test, use the prefix "0.0." before the sequential ID number to identify it as a validation.

6. At the main screen, press the "<ETC>" key, and press the "INIT" key when the new screen appears. At the next screen, which will display the request to "SELECT PRIMARY ELEMENT TO ASSAY," press the number assigned to "K-LBP," then "ENTER," then "YES" to indicate you want to select other elements, then the number assigned to "L-LBP," then "ENTER," and then "YES". Pressing this last key will automatically add the "Lead in Soil" calibration.

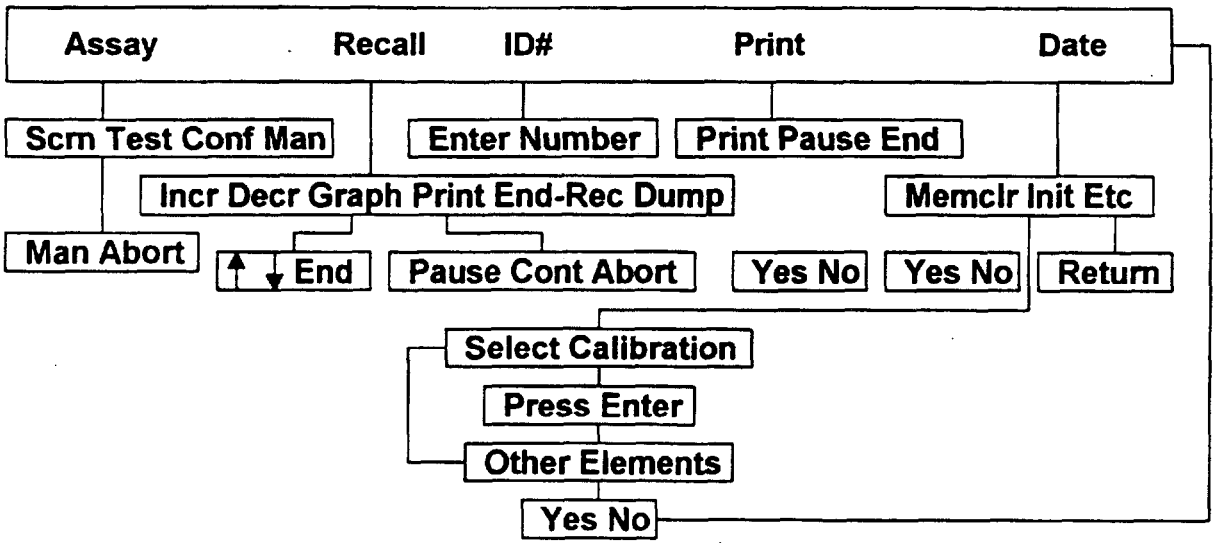
7. Using the lead standard painted block included, perform five (5) TEST's by entering an ID number once, then pressing the "ASSAY" key and the "TEST" key for each test. Holding the face of the assayer against the block, place the key in the lock at the front end of the assayer and turn key clockwise until it can be turned no more, then press "TEST" to begin the operation. *(For more complete instructions on testing, see 2. under "Sampling" below and check the Radiation Protection Program for proper use of the Model 310, pertinent sections of which are included in this document under "References.")* Write down the results on the "Validation Test" form, and check to see that the average of the five tests falls within the range of + or - 0.3 mg/cm^2 of the values recorded from the factory validation test. If the average does not, postpone testing until the manufacturer can calibrate the instrument properly.

8. Now perform at least three (3) TEST's of either the "GENERIC SOIL SAMPLE" or the "SITE SPECIFIC SOIL SAMPLE," whichever is indicated on the "JOB DETAIL" sheet. Compare the average from these tests with the laboratory results for the soil sample used.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

Record the difference as the "ADJUSTMENT FACTOR" on the "Validation Test" form to be added or subtracted from all test results for the day.

Fig. II MAP Model 310 Menu Tree



5.4 Sampling

1. With the cable connected to the assayer and the console, go to the site of the first point on the grid of the area to be tested and place the face of the assayer flat against the soil. If there are any pebbles or debris, remove these from the site before beginning testing.
2. Press the "ASSAY" key at the main screen. Open the shutter by engaging the key in the lock at the front of the assayer and then turning it clockwise until it stops. Now press the "TEST" key and hold the assayer motionless until the screen displays the following message: "Turn key off now." Once you have done this, record the results on the data sheet and continue to the next point on the grid.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

3. Make sure there is no accumulation of dust on the front of the assayer. With the key removed from the keylock on the assayer, examine the face after each assay while making sure not to point it directly at your body or face. Use a soft bristle brush or a compressed air spray can to remove any dust.
4. When testing is completed for the day or when the console display indicates that there is no available memory left, download the results to the portable computer using the null modem cable and the MAP Utilities program.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

SECTION 6.0: TRANSPORT AND STORAGE OF EQUIPMENT

1. When transporting the MAP Model 310, you must place it in the supplied padded case with the appropriate radiation warning stickers in place. The unit should be broken down into its components. Be sure that the key that opens the shutter of the device is not engaged in the keylock on the assay.
2. When the device is transported by automobile, it must be closed in the trunk of the vehicle or secured within the passenger area of the vehicle at the point farthest from the occupants. If the operator leaves the vehicle, it must be kept locked while the operator is away.
3. When it is necessary for the device to be kept over night away from the regular storage facility, it must be kept in a locked area accessible only to the operator. If the operator is lodging over night, the device must be kept in his locked vehicle and not in the place of lodging. If the over night stay is not scheduled in advance with the Radiation Safety Officer (RSO) of Griffin Technica, then the operator must notify the RSO for approval.
4. Whenever possible, the device should be returned to the permanent storage facility and signed in by the operator.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

SECTION 7.0: REFERENCES

1. "Spectrum Analyzer, Operations Manual," Scitec Corporation, ND.
2. "Spectrum Analyzer, Radiation Safety and MAP Spectrum Analyzer Operator Training Seminar", Scitec Corporation, ND.
3. "Griffin Technica, Inc., Radiation Protection Program," Griffin Technica, Inc., ND.

Below are pertinent sections from this document:

Radiation Protection Program
XRF Spectrum Analyzer

Griffin Technica, Inc.

Sections Included:

Personnel Training Program	2
Personnel Monitoring Program	5
Safe Use of the XRF	6
Emergency Procedures	7

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

Personnel Training Program 2

Personnel Training Program 2

- Course Outline 2.1
- Training Provider 2.2
- Recordkeeping 2.3

Personnel will be instructed by means of a lecture:

1. Before assuming duties with, or in the vicinity of, radioactive materials.
2. During annual refresher training.
3. Whenever there is a significant change of duties, regulations, or the terms of the license.

2.1 Course Outline

Instruction for individuals in attendance will include the following subjects:

1. Applicable regulations and license conditions.
2. Areas where radioactive material is used or stored.
3. Potential hazards associated with radioactive material in each area where the employee will work.
4. Appropriate radiation safety procedures.
5. Licensee's in-house rules.
6. Each individual's obligation to report unsafe conditions to the Radiation Safety Officer.
7. Appropriate responses to emergencies or unsafe conditions.
8. Worker's right to be informed of occupational radiation exposure and bioassay results.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

9. Locations where the licensee has posted or made available notices, copies of pertinent regulations, and copies of pertinent licenses and license conditions.

2.2 Training Provider

Radiation safety and use of the Scitec MAP Analyzer will be taught by a representative of the Scitec Corporation. No one will be allowed to use the Scitec MAP Analyzer until completion of this 8-hour course and receipt of a certificate of attendance.

All matters pertaining to in-house procedures and storage will be taught in a supplementary course by the RSO.

2.3 Recordkeeping

Records of initial and refresher training will be maintained for a period of five years and will include:

1. The name of the individual who conducted the training.
2. The name(s) of the individual(s) who received the training.
3. The dates and duration of the training session.
4. A list of the topics covered.

3.3 Notification Procedures

Before the XRF is carried into any other state, the radiation control authority for that state must be contacted to determine any additional requirements beyond written notification. This is the duty of the RSO. The portable XRF is not to be transported out of state without the authorization of the RSO.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

Personnel Monitoring 5

- Devices 5.1
- Procedures 5.2

5.1 Devices

Monitoring of personnel for exposure to X-Ray, Beta, and Gamma radiation will be performed with the Landauer Thermoluminescent Dosimetry badge, Type K1. The unit consists of a tray module, consisting of three TLD elements in a closed cassette, and a holder. A second tray module is shipped with each round, to be used as a control sample to detect background radiation. This control tray module is kept in the office of the RSO away from the XRF.

5.2 Procedures

1. At the beginning of every quarter of the year, each employee will be issued a new tray module. Replacement of the tray module in the holder will be performed by the RSO.
2. When the employee receives a new tray module, it is his or her duty to make sure that the name shown on the module is correct.
3. The badge, consisting of module and holder, is to be worn by every employee who uses the portable XRF. It is to be put on before signing out the XRF in the log and kept on ones body until the XRF is signed back in.
4. The badge should never be stored in a hot or sunny place.
5. The results of personnel monitoring will be reported to concerned personnel by the RSO within 24 hours of their receipt from Landauer.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

Safe Use of the XRF 6

1. During the performance of your duties, keep the curious away but do not draw unnecessary attention so that people are frightened.
2. Wear film badges whenever working with or around the portable XRF. Do not store them in hot places such as glove compartments.
3. Work quickly and keep the exposed source painted away from you. Distance and brevity are the two best operator protections.
4. Keep the portable XRF "OFF" whenever it is not in use.
5. Always transport the portable XRF in its carrying case. When transporting it by car or truck, keep the closed case in the trunk or back of the truck, as far as possible from the operator or driver. Make sure the case is secured in place so that it cannot be jostled by the movement of the vehicle.
6. Always position the front end of the XRF securely against the surface to be assayed before opening the shutter. Close the shutter before removing the XRF from the surface.
7. Carry the XRF by its pistol grip, with the shutter closed, so that the front of the device points down. When moving to another building or a remote area of the building you're in, carry the XRF in its carrying case.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

Emergency Procedures 7

- Notification of Accident 7.1
- Emergency Procedures 7.2

7.1 Notification of Accident

The first action to be taken in the event of an accident with the portable XRF if to keep other people away from the site. Then notify the following:

- State radiation regulatory agency
- RSO
- Scitec Corporation (the manufacturer)
- State Patrol
- Fire Department

7.2 Emergency Procedures

IF: The XRF is superficially damaged, dented, flooded, or otherwise injured from a drop, minor runover, etc. The device housing is in one piece with a minor break or two in the aluminum housing. The source is obviously in place, or, at least, the source location is not torn apart.

THEN:

1. Turn the XRF over to view the source area if necessary. Do not walk through the site where the device was pushed or pulled. Visually inspect the source area for damage.
2. If the source area is intact, pick up the device, place it in a storage container and return it to the permanent storage area.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

3. Call the Scitec RSO (Bill Boyce at 1(800)466-5323) for assistance in shipping the device back to the UNC factory for repair or disposal.

DO NOT SHIP THE DEVICE WITHOUT SCITEC APPROVAL OR KNOWLEDGE.

IF: The device is broken apart, severely burned, severely crushed, the parts strewn around, or the source holder is visibly damaged.

THEN:

1. Freeze the site. Rope off the damage site for 10 feet around. If a vehicle is involved, stop the vehicle and have the driver walk away. Do not walk through the damage site. If radioactive material is loose, it can be picked up and traced elsewhere.
2. Call the RSO, and/or the nearest public health department office for help. The object is to get an expert radiation technician to the site with an operating survey meter who can determine if the radioactive material is lost or is intact.
3. The radiation expert will determine whether the site is safe, will remove the contamination if there is any, and will prepare the damaged equipment for shipment to the factory for repair or disposal.
4. Call the Scitec factory and RSO, and brief them on the situation.

7.3 Loss or Theft

Notify the state Public Health Department, the police, and the RSO immediately in the case of a stolen device.

Note: You must have a certificate from the Scitec Corporation to use MAP Model 310

(425-μm) sieve is required in total amount of 220 g, allocated as follows:

Test	Grams
Liquid limit	100
Plastic limit	15
Centrifuge moisture equivalent	10
Volumetric shrinkage	30
Check tests	65

6. Preparation of Test Sample

6.1 Select that portion of the air-dried sample selected for purpose of tests and record the mass as the mass of the total test sample uncorrected for hygroscopic moisture. Separate the test sample by sieving with a No. 10 (2.00-mm) sieve. Grind that fraction retained on the No. 10 sieve in a mortar with a rubber-covered pestle until the aggregations of soil particles are broken up into the separate grains. Then separate the ground soil into two fractions by sieving with a No. 10 sieve.

6.2 Wash that fraction retained after the second sieving free of all fine material, dry, and weigh. Record this mass as the mass of coarse material. Sieve the coarse material, after being washed and dried, on the No. 4 (4.75-mm) sieve and record the mass retained on the No. 4 sieve.

7. Test Sample for Particle-Size Analysis

7.1 Thoroughly mix together the fractions passing the No. 10 (2.00-mm) sieve in both sieving operations, and by the method of quartering or the use of a sampler, select a portion weighing approximately 115 g for sandy soils and approximately 65 g for silt and clay soil for particle-size analysis.

8. Test Sample for Soil Constants

8.1 Separate the remaining portion of the material passing the No. 10 (2.00-mm) sieve into two parts by means of a No. 40 (425-μm) sieve. Discard the fraction retained on the No. 40 sieve. Use the fraction passing the No. 40 sieve for the determination of the soil constants.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

Designation: D 422 – 63 (Reapproved 1972)[1]

Standard Method for PARTICLE-SIZE ANALYSIS OF SOILS[1]

This standard is issued under the fixed designation D 422; 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.

[A] NOTE—Section 2 was added editorially and subsequent sections renumbered in July 1984.

1. Scope

1.1 This method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Notes 1 and 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-μm), or No. 200 (75-μm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-μm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 μm.

2. Applicable Documents

2.1 *ASTM Standards:*

D421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

E 100 Specification for ASTM Hydrometers[4]

3. Apparatus

3.1 *Balances*—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 *Stirring Apparatus*—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup[5] (Note 3) conforming to the general details shown in Fig. 3 (Notes 4 and 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft^3/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

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

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.01.

[5] Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. Order Adjunct No. 12-404220-00.

results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 *Hydrometer*—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 *Sedimentation Cylinder*—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 *Thermometer*—A thermometer accurate to 1°F (0.5°C).

3.6 *Sieves*—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

3-in. (75-mm)	No. 10 (2.00-mm)
2-in. (50-mm)	No. 20 (850-µm)
1½-in. (37.5-mm)	No. 40 (425-µm)
1-in. (25.0-mm)	No. 60 (250-µm)
¾-in. (19.0-mm)	No. 140 (106-µm)
⅜-in. (9.5-mm)	No. 200 (75-µm)
No. 4 (4.75-mm)	

NOTE 6—A set of sieves giving uniform spacing of points for the graph, as required in Section 17, may be used if desired. This set consists of the following sieves:

3-in. (75-mm)	No. 16 (1.18-mm)
1½-in. (37.5-mm)	No. 30 (600-µm)
¾-in. (19.0-mm)	No. 50 (300-µm)
⅜-in. (9.5-mm)	No. 100 (150-µm)
No. 4 (4.75-mm)	No. 200 (75-µm)
No. 8 (2.36-mm)	

3.7 *Water Bath or Constant-Temperature Room*—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

3.8 *Beaker*—A beaker of 250-mL capacity.

3.9 *Timing Device*—A watch or clock with a second hand.

4. Dispersing Agent

4.1 A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

NOTE 7—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or, adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

4.2 All water used shall be either distilled or demineralized water. The water for a hydrometer test shall be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
⅜ (9.5)	500
¾ (19.0)	1000

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
1 (25.4)	2000
1½ (38.1)	3000
2 (50.8)	4000
3 (76.2)	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in Section 5 of Practice D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm), 2-in. (50-mm), 1½-in. (37.5-mm), 1-in. (25.0-mm), ¾-in. (19.0-mm), ⅜-in. (9.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.

HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1° temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cyclinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hy-

drometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at 230 ± 9°F (110 ± 5°C), and weigh again. Record the masses.

9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/L). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. If stirring apparatus A is used, transfer the soil - water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

NOTE 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil - water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, if necessary, so that the total volume in the cup is 250 mL, but no more.

NOTE 10—The initial air pressure of 1 psi is required to prevent the soil - water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil - water slurry to the sedimentation cylinder.

10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil - water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75-μm) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at 230 ± 9°F (110 ± 5°C) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

CALCULATIONS AND REPORT

12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the ⅜-in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the ⅜-in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

13. Hygroscopic Moisture Correction Factor

13.1 The hydroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight W' in the equation for percentage remaining in suspension.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\,000/W') \times G/(G - G_1)](R - G_1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W') \times 100$$

where:

a = correction faction to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

P = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

R = hydrometer reading with composite correction applied (Section 7),

W' = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,

G = specific gravity of the soil particles, and

G_1 = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for R is based on a value of one for G_1.

15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. Accord-

ing to Stokes' law:

$$D = \sqrt{[30n/980(G - G_1)] \times L/T}$$

where:

D = diameter of particle, mm,

n = coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),

L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (Table 2)),

T = interval of time from beginning of sedimentation to the taking of the reading, min,

G = specific gravity of soil particles, and

G_1 = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE 14—Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows:

$$D = A\sqrt{L/T}$$

where:

A = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of A for a range of temperatures and specific gravities are given in Table 3. The value of A does not change for a series of readings constituting a test, while values of L and T do vary.

15.3 Values of D may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of L is divided by T using the A- and B-scales, the square root being indicated on the D-scale. Without ascertaining the value of the square root it may be multiplied by A, using either the C- or CI-scale.

16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

17. Graph

17.1 When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

(1) Gravel, passing 3-in. and retained on No. 4 sieve ..... %

(2) Sand, passing No. 4 sieve and retained on No. 200 sieve ..... %

(a) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve ..... %

(b) Medium sand, passing No. 10 sieve and retained on No. 40 sieve ..... %

(c) Fine sand, passing No. 40 sieve and retained on No. 200 sieve ..... %

(3) Silt size, 0.074 to 0.005 mm ..... %

(4) Clay size, smaller than 0.005 mm ..... %

Colloids, smaller than 0.001 mm ..... %

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains material retained on the No. 4 sieve sufficient to require a sieve analysis on that portion, the results may be reported as follows (Note 17):

SIEVE ANALYSIS

Sieve Size	Percentage Passing
3-in.	.....
2-in.	.....
1½-in.	.....
1-in.	.....
⅜-in.	.....
⅛-in.	.....
No. 4 (4.75-mm)	.....
No. 10 (2.00-mm)	.....
No. 40 (425-μm)	.....
No. 200 (75-μm)	.....

HYDROMETER ANALYSIS

0.074 mm	.....
0.005 mm	.....
0.001 mm	.....

NOTE 17—No. 8 (2.36-mm) and No. 50 (300-μm) sieves may be substituted for No. 10 and No. 40 sieves.

TABLE 1 Values of Correction Factor, a, for Different Specific Gravities of Soil Particles[A]

Specific Gravity	Correction Factor[A]
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

[A] For use in equation for percentage of soil remaining in suspension when using Hydrometer 152H.

TABLE 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes[A]

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.8	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5

TABLE 2 Continued

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

[A] Values of effective depth are calculated from the equation:

$$L = L_1 + \tfrac{1}{2}\,[L_2 - (V_b/A)]$$

where:

L = effective depth, cm,
L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm,
L_2 = overall length of the hydrometer bulb, cm,
V_b = volume of hydrometer bulb, cm^3, and
A = cross-sectional area of sedimentation cylinder, cm^2

Values used in calculating the values in Table 2 are as follows:

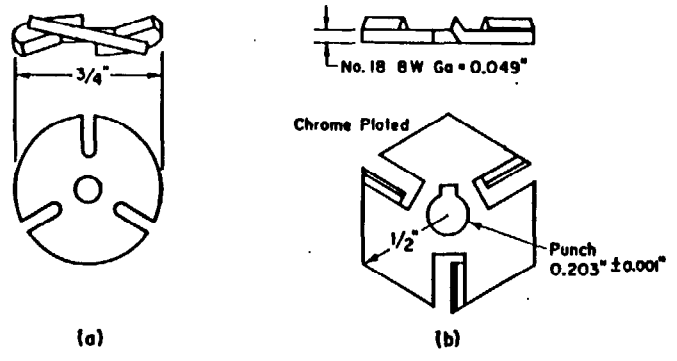
For both hydrometers, 151H and 152H:
L_2 = 14.0 cm
V_b = 67.0 cm^3
A = 27.8 cm^2

For hydrometer 151H:
L_1 = 10.5 cm for a reading of 1.000
= 2.3 cm for a reading of 1.031

For hydrometer 152H:
L_1 = 10.5 cm for a reading of 0 g/litre
= 2.3 cm for a reading of 50 g/litre

TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

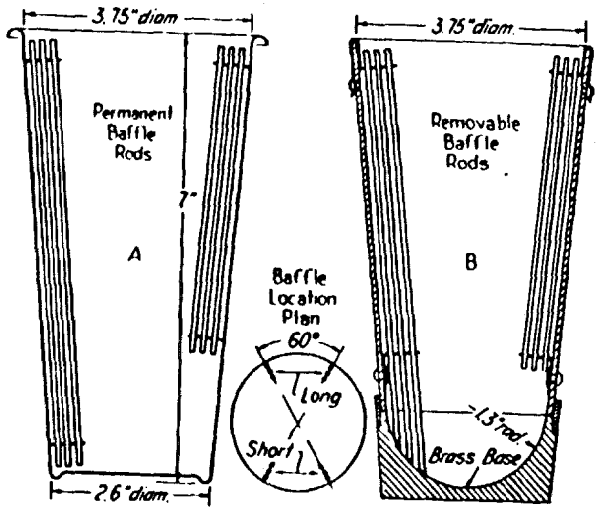
Temperature, °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149



Metric Equivalents

in.	0.001	0.049	0.203	½	¾
mm	0.03	1.24	5.16	12.7	19.0

FIG. 1 Detail of Stirring Paddles



Metric Equivalents

in	1.3	2.6	3.75
mm	33	66	95.2

FIG. 2 Dispersion Cups of Apparatus

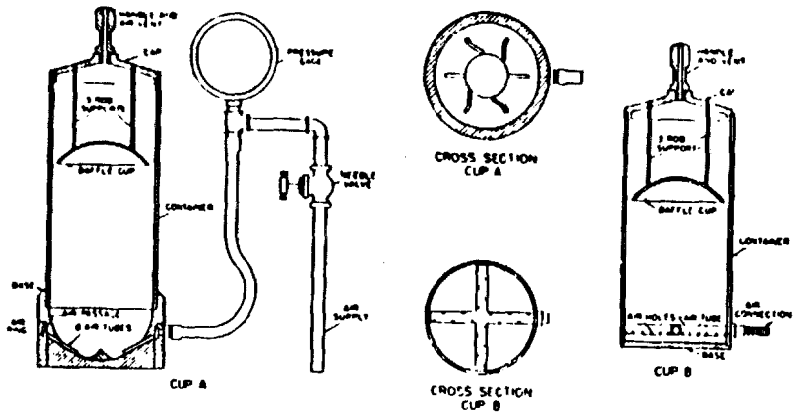
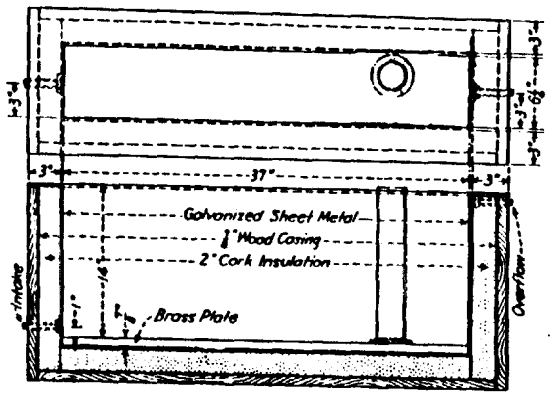


FIG. 3 Air-Jet Dispersion Cups of Apparatus B



Metric Equivalents

in.	⅞	1	3	6¼	14	37
mm	22.2	25.4	76.2	158.2	356	940

FIG. 4 Insulated Water Bath

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American Association State Highway and Transportation Officials Standard
AASHTO No. T 100

Standard Test Method for SPECIFIC GRAVITY OF SOILS[1]

This standard is issued under the fixed designation D 854, 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 test method covers determination of the specific gravity of soils by means of a pycnometer. When the soil is composed of particles larger than the No. 4 (4.75-mm) sieve, the method outlined in Test Method C 127 shall be followed. When the soil is composed of particles both larger and smaller than the No. 4 sieve, the sample shall be separated on the No. 4 sieve and the appropriate test method used on each portion. The specific gravity value for the soil shall be the weighted average of the two values (Note 1). When the specific gravity value is to be used in calculations in connection with the hydrometer portion of Method D 422, it is intended that the specific gravity test be made on that portion of the soil which passes the No. 10 (2.00-mm) sieve.

NOTE 1—The weighted average specific gravity should be calculated using the following equation:

$$G_{a\text{-}g} = \frac{1}{\dfrac{R_1}{100G_1} + \dfrac{P_1}{100G_2}}$$

where:

$G_{a\text{-}g}$ = weighted average specific gravity of soils composed of particles larger and smaller than the No. 4 (4.75-mm) sieve,

R_1 = percent of soil particles retained on the No. 4 sieve,

P_1 = percent of soil particles passing the No. 4 sieve,

G_1 = apparent specific gravity of soil particles retained on the No. 4 sieve as determined by Test Method C 127, and

G_2 = specific gravity of soil particles passing the No. 4 sieve as determined by this test method.

1.2 The values stated in acceptable metric units are to be regarded as the standard.

1.3 *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.*

2. Applicable Documents

2.1 *ASTM Standards*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]

C 670 Practice for Preparing Precision Statements for Test Methods for Construction Materials[2]

D 422 Method for Particle-Size Analysis of Soils[3]

E 12 Definitions of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases[4]

3. Definition

3.1 *specific gravity*—the ratio of the mass of a unit volume of a material at a stated temperature to the mass in air of the same volume of gas-free distilled water at a stated temperature (per Definitions E 12).

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved Nov. 28, 1983. Published January 1984. Originally issued as D 854 - 45. Last previous edition D 854 - 58 (1979).

[2] *Annual Book of ASTM Standards*, Vol 04.02.

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

[4] *Annual Book of ASTM Standards*, Vol 15.05.

4. Significance and Use

4.1 The specific gravity of a soil is used in almost every equation expressing the phase relationship of air, water, and solids in a given volume of material.

4.2 The term "solid particles," as used in geotechnical engineering, is typically assumed to mean naturally occurring mineral particles that are not very soluble in water. Therefore, the specific gravity of materials containing extraneous matter (such as cement, lime, etc.), water-soluble matter (such as sodium chloride), and soils containing matter with a specific gravity of less than one, typically require special treatment or a qualified definition of specific gravity.

5. Apparatus

5.1 *Pycnometer*—Either a volumetric flask having a capacity of at least 100 mL or a stoppered bottle having a capacity of at least 50 mL (Note 2). The stopper shall be of the same material as the bottle, and of such size and shape that it can be easily inserted to a fixed depth in the neck of the bottle, and shall have a small hole through its center to permit the emission of air and surplus water.

NOTE 2—The use of either the volumetric flask or the stoppered bottle is a matter of individual preference, but in general, the flask should be used when a larger sample than can be used in the stoppered bottle is needed due to maximum grain size of the sample.

5.2 *Balance*—Either a balance sensitive to 0.01 g for use with the volumetric flask, or a balance sensitive to 0.001 g for use with the stoppered bottle.

6. Calibration of Pycnometer

6.1 The pycnometer shall be cleaned, dried, weighed, and the weight recorded. The pycnometer shall be filled with distilled water (Note 3) essentially at room temperature. The weight of the pycnometer and water, W'_a, shall be determined and recorded. A thermometer shall be inserted in the water and its temperature T_i determined to the nearest whole degree.

NOTE 3—Kerosine is a better wetting agent than water for most soils and may be used in place of distilled water for oven-dried samples.

6.2 From the weight W'_a determined at the observed temperature T_i a table of values of weights W'_a shall be prepared for a series of temperatures that are likely to prevail when weights W'_b are determined later (Note 4). These values of W'_a shall be calculated as follows:

$$W'_a \text{ (at } T_x) = (\text{density of water at } T_x/\text{density of water at } T_i) \times (W'_a(\text{at } T_i) - W'_f) + W'_f$$

where:

W'_a = weight of pycnometer and water, g,

W'_f = weight of pycnometer, g,

T_i = observed temperature of water, °C, and

T_x = any other desired temperature, °C.

NOTE 4—This method provides a procedure that is most convenient for laboratories making many determinations with the same pycnometer. It is equally applicable to a single determination. Bringing the pycnometer and contents to some designated temperature when weights W'_a and W'_b are taken, requires considerable time. It is much more convenient to prepare a table of weights W'_a for various temperatures likely to prevail when weights W'_b are taken. It is important that weights W'_a and W'_b be based on water at the same temperature. Values for the relative density of water at temperatures from 18 to 30°C are given in Table 1.

7. Sampling

7.1 The soil to be used in specific gravity test may contain its natural moisture or be oven-dried. The weight of the test sample on an oven-dry basis shall be at least 25 g when the volumetric flask is to be used, and at least 10 g when the stoppered bottle is to be used.

7.2 *Samples Containing Natural Moisture*—When the sample contains its natural moisture, the weight of the soil, W'_s, on an oven-dry basis shall be determined at the end of the test by evaporating the water in an oven maintained at 230 ±9°F (110 ±5°C) (Note 5). Samples of clay soils containing their natural moisture content shall be dispersed in distilled water before placing in the flask, using the dispersing equipment specified in Method D 422 (Note 6).

7.3 *Oven-Dried Samples*—When an oven-dried sample is to be used, the sample shall be dried for at least 12 h, or to constant weight, in an oven maintained at 230 ±9°F (110 ±5°C) (Note 5), cooled in a desiccator, and weighed upon removal from the desiccator. The sample shall then be soaked in distilled water for at least 12 h.

NOTE 5—Drying of certain soils at 110°C may bring about loss of moisture of composition or hydration, and in such cases drying shall be done, if desired, in reduced air pressure and at a lower temperature.

NOTE 6—The minimum volume of slurry that can be prepared by the dispersing equipment specified in Method D 422 is such that a 500-mL flask is needed as the pycnometer.

8. Procedure

8.1 Place the sample in the pycnometer, taking care not to lose any of the soil in case the weight of the sample has been determined. Add distilled water to fill the volumetric flask about three-fourths full or the stoppered bottle about half full.

8.2 Remove entrapped air by either of the following methods: (*1*) subject the contents to a partial vacuum (air pressure not exceeding 100 mm Hg) or (2) boil gently for at least 10 min while occasionally rolling the pycnometer to assist in the removal of the air. Subject the contents to reduced air pressure either by connecting the pycnometer directly to an aspirator or vacuum pump, or by use of a bell jar. Some soils boil violently when subjected to reduced air pressure. It will be necessary in those cases to reduce the air pressure at a slower rate or to use a larger flask. Cool samples that are heated to room temperature.

8.3 Fill the pycnometer with distilled water, clean the outside and dry with a clean, dry cloth. Determine the weight of the pycnometer and contents, W_b, and the temperature in degrees Celsius, T_b, of the contents as described in Section 6.

9. Calculation and Report

9.1 Calculate the specific gravity of the soil, based on water at a temperature T_b, as follows:

$$\text{Specific gravity, } T_b/T_b = W_s/[W_s + (W_p - W_b)]$$

where:

W_s = weight of sample of oven-dry soil, g,
W_p = weight of pycnometer filled with water at temperature T_b (Note 7), g,
W_b = weight of pycnometer filled with water and soil at temperature T_b, g, and
T_b = temperature of the contents of the pycnometer when weight W_b was determined, °C.

NOTE 7—This value shall be taken from the table of values of W_p, prepared in accordance with 6.2, for the temperature prevailing when weight W_b was taken.

9.2 Unless otherwise required, specific gravity values reported shall be based on water at 20°C. The value based on water at 20°C shall be calculated from the value based on water at the observed temperature T_b, as follows:

$$\text{Specific gravity, } T_b/20\,C = A \times \text{specific gravity, } T_b/T_b$$

where:

A = a number found by dividing the relative density of water at temperature T_b by the relative density of water at 20°C. Values for a range of temperatures are given in Table 1.

9.3 When it is desired to report the specific gravity value based on water at 4°C, such a specific gravity value may be calculated by multiplying the specific gravity value at temperature T_b by the relative density of water at temperature T_b.

9.4 When any portion of the original sample of soil is eliminated in the preparation of the test sample, the portion on which the test has been made shall be reported.

10. Precision and Bias

10.1 Criteria for judging the acceptability of specific gravity test results obtained by this test method on material passing the No. 4 (4.75-mm) sieve are given as follows (Note 8):

Material and Type Index	Standard Deviation[A]	Acceptable Range of Two Results (percent of mean)[A]
Single-operator precision		
Cohesive soils	0.021	0.06
Noncohesive soils	[B]	[B]
Multilaboratory precision		
Cohesive soils	0.056	0.16
Noncohesive soils	[B]	[B]

[A] These numbers represent, respectively, the (1S) and (D2S) limits as described in Practice C 670.

[B] Criteria for assigning standard deviation values for noncohesive soils are not available at the present time.

NOTE 8—The figures given in Column 2 are the standard deviations that have been found to be appropriate for the materials described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

TABLE 1 Relative Density of Water and Conversion Factor K For Various Temperatures

Temperature, °C	Relative Density of Water	Correction Factor K
18	0.9986244	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977
30	0.9956780	0.9974

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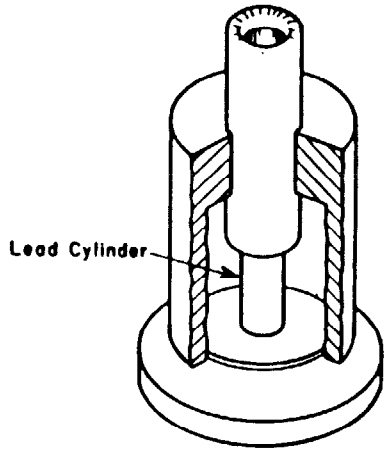

FIG. 4 Lead Deformation Apparatus Assembly

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Designation: D 2216 – 80

An American National Standard

Standard Method for LABORATORY DETERMINATION OF WATER (MOISTURE) CONTENT OF SOIL, ROCK, AND SOIL-AGGREGATE MIXTURES[1]

This standard is issued under the fixed designation D 2216; 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 method covers the laboratory determination of the water (moisture) content of soil, rock, and soil-aggregate mixtures by weight. For simplicity, the word "material" hereinafter refers to either soil, rock, or soil-aggregate mixtures, whichever is most applicable.

1.2 The water content of a material is defined as the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material particles.

1.3 This method does not give true representative results for: materials containing significant amounts of halloysite, montmorillonite, or gypsum minerals; highly organic soils; or, materials in which the pore water contains dissolved solids (such as salt in the case of marine deposits). For a material of the previously mentioned types, a modified method of testing or data calculation may be established to give results consistent with the purpose of the test.

2. Summary of Method

2.1 The practical application in determining the water content of a material is to determine the mass of water removed by drying the moist material (test specimen) to a constant mass in a drying oven controlled at 110 ± 5°C and to use this value as the mass of water in the test specimen. The mass of material remaining after oven-drying is used as the mass of the solid particles.

3. Significance and Use

3.1 For many soil types, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and an index property.

3.2 The water content of a soil is used in almost every equation expressing the phase relationships of air, water, and solids in a given volume of material.

3.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limit, is used to express its relative consistency or liquidity index.

3.4 The term "water" as used in geotechnical engineering, is typically assumed to be "pore" or "free" water and not that which is hydrated to the mineral surfaces. Therefore, the water content of materials containing significant amounts of hydrated water at in-situ temperatures or less than 110°C can be misleading.

3.5 The term "solid particles" as used in geotechnical engineering, is typically assumed to mean naturally occurring mineral particles that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, etc), water-soluble matter (such as salt) and highly organic

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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matter typically require special treatment or a qualified definition of water content.

4. Apparatus

4.1 *Drying Oven*, thermostatically-controlled, preferably of the forced draft type, and maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

4.2 *Balances*, having a precision (repeatability) of ±0.01 g for specimens having a mass of 200 g or less, ±0.1 g for specimens having a mass of between 200 and 1000 g, or ± 1 g for specimens having a mass greater than 1000 g.

4.3 *Specimen Containers*. Suitable containers made of material resistant to corrosion and a change in mass upon repeated heating, cooling, and cleaning. Containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g, while for specimens having a mass greater than about 200 g, containers without lids may be used (Note 1). One container is needed for each water content determination.

NOTE 1—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing.

4.4 *Desiccator*—A desiccator of suitable size (a convenient size is 200 to 250-mm diameter) containing a hydrous silica gel. This equipment is only recommended for use when containers having close-fitting lids are not used. See 7.4.1.

5. Samples

5.1 Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct contact with sunlight.

5.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corrodible containers (such as steel thin-walled tubes, paint cans, etc.) or sample bags are used.

6. Test Specimen

6.1 For water contents being determined in conjunction with another ASTM method, the method of specimen selection specified in that method controls.

6.2 The manner in which the test specimen is selected and its required mass is basically dependent on the purpose (application) of the test, type of material being tested, and the type of sample (specimen from another test, bag, tube, split-barrel, etc.). In all cases, however, a representative portion of the total sample shall be selected. If a layered soil or more than one soil type is encountered, select an average portion or individual portions or both, and note which portion(s) was tested in the report of the results.

6.2.1 For bulk samples, select the test specimen from the material after it has been thoroughly mixed. The mass of moist material selected shall be in accordance with the following table:

Sieve Retaining More Than About 10 % of Sample	Recommended Minimum Mass of Moist Specimen, g
2.0 mm (No. 10) sieve	100 to 200
4.75 mm (No. 4) sieve	300 to 500
19 mm	500 to 1000
38 mm	1500 to 3000
76 mm	5000 to 10 000

6.2.2 For small (jar) samples, select a representative portion in accordance with the following procedure:

6.2.2.1 For cohesionless soils, thoroughly mix the material, then select a test specimen having a mass of moist material in accordance with the table in 6.2.1. See Note 2.

6.2.2.2 For cohesive soils, remove about 3 mm of material from the exposed periphery of the sample and slice it in half (to check if the material is layered) prior to selecting the test specimen. If the soil is layered see 6.2. The mass of moist material selected should not be less than 25 g or should be in accordance with the table in 6.2.1 if coarse-grained particles are noted. (Note 2).

6.3 Using a test specimen smaller than the minimum mass indicated previously requires discretion, though it may be adequate for the purpose of the test. A specimen having a mass less than the previously indicated value shall be noted in the report of the results.

NOTE 2—In many cases, when working with a small sample containing a relatively large coarse-grained particle, it is appropriate not to include this particle in the test specimen. If this occurs, it should be noted in the report of the results.

7. Procedure

7.1 Select representative test specimens in accordance with Section 6.

7.2 Place the moist specimen in a clean, dry container of known mass (Note 3), set the lid securely in position, and determine the mass of the container and moist material using an appropriate balance (4.2). Record these values.

7.3 Remove the lid and place the container with moist material in a drying oven maintained at 110 ± 5°C and dry to a constant mass (Notes 4, 5, and 6).

NOTE 3—To assist in the oven-drying of large test specimens, they should be placed in containers having a large surface area (such as pans) and the material broken up into smaller aggregations.

NOTE 4—The time required to obtain constant mass will vary depending on the type of material, size of specimen, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment, and experience with the materials being tested and the apparatus being used. In most cases, drying a test specimen over night (about 16 h) is sufficient. In cases where there is doubt concerning the adequacy of drying, drying should be continued until the mass after two successive periods (greater than ½ h) of drying indicate an insignificant change (less than about 0.1 %). Specimens of sand may often be dried to constant mass in a period of about 4 h, when a forced-draft oven is used.

NOTE 5—Oven-drying at 110 ± 5°C does not always result in water content values related to the intended use or the basic definition especially for materials containing gypsum or other minerals having significant amounts of hydrated water or for soil containing a significant amount of organic material. In many cases, and depending on the intended use for these types of materials, it might be more applicable to maintain the drying oven at 60 ± 5°C or use a vacuum desiccator at a vacuum of approximately 133 Pa (10 mm Hg) and at a temperature ranging between 23 and 60°C for drying. If either of these drying methods are used, it should be noted in the report of the results.

NOTE 6—Since some dry materials may absorb moisture from moist specimens, dried specimens should be removed before placing moist specimens in the oven. However, this requirement is not applicable if the previously dried specimens will remain in the drying oven for an additional time period of about 16 h.

7.4 After the material has dried to constant mass remove the container from the oven and replace the lid. Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands and the operation of the balance will not be affected by convection currents. Determine the mass of the container and oven-dried material using the same balance as used in 7.2. Record this value.

7.4.1 If the container does not have a lid, weigh the container and material right after their temperatures are such that the operation of the balance will not be affected by convection currents or after cooling in a desiccator.

NOTE 7—Cooling in a desiccator is recommended since it prevents absorption of moisture from the atmosphere during cooling.

8. Calculation

8.1 Calculate the water content of the material as follows:

$$w = [(W_1 - W_2)/(W_2 - W_c)] \times 100 = \frac{W_w}{W_s} \times 100$$

where:

w = water content, %,
W_1 = mass of container and moist specimen, g,
W_2 = mass of container and oven-dried specimen, g,
W_c = mass of container, g,
W_w = mass of water, g, and
W_s = mass of solid particles, g.

9. Report

9.1 The report (data sheet) shall include the following:

9.1.1 Identification of the sample (material) being tested, by boring number, sample number, test number, etc.

9.1.2 Water content of the specimen to the nearest 0.1 % or 1 %, depending on the purpose of the test.

9.1.3 Indication of test specimen having a mass less than the minimum indicated in Section 6.

9.1.4 Indication of test specimen containing more than one soil type (layered, etc).

9.1.5 Indication of the method of drying if different from oven-drying at 110 ± 5°C.

9.1.6 Indication of any material (size and amount) excluded from the test specimen.

10. Precision and Accuracy

10.1 Requirements for the precision and accuracy of this test method have not yet been developed.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

Designation: D 2217 – 85

Standard Practice for WET PREPARATION OF SOIL SAMPLES FOR PARTICLE-SIZE ANALYSIS AND DETERMINATION OF SOIL CONSTANTS[1]

This standard is issued under the fixed designation D 2217; 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.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This practice covers the wet preparation of soil samples as received from the field for particle-size analysis and determination of soil constants.

1.2 Procedure A provides for drying the field sample at a temperature not exceeding 140°F (60°C), making a wet separation on the No. 10 (2.00-mm) sieve, or No. 40 (425-μm) sieve, or both, as needed, and finally drying at a temperature not exceeding 140°F. Procedure B provides that the sample shall be kept at a moisture content equal to or greater than the natural water content. The procedure to be used should be indicated in the specification for the material being tested. If no procedure is specified, the provisions of Procedure B shall govern.

1.3 *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.*

2. Applicable Documents

2.1 *ASTM Standards:*

D421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

D422 Method for Particle-Size Analysis of Soils[2]

E 11 Specification for Wire Cloth Sieves for Testing Purposes[3]

3. Significance and Use

3.1 Procedure A is used to prepare soil samples for plasticity tests and particle-size analysis when the coarse-grained particles of a sample are soft and pulverize readily, as in Practice D 421, or when the fine particles are very cohesive and tend to resist removal from the coarse particles.

3.2 Some soils never dry out in nature and may change their characteristics greatly when dried. If the true natural gradation and plasticity characteristics of such soils are desired, these soils should be shipped to the laboratory in sealed containers and processed in accordance with Procedure B of this practice.

3.3 Liquid limit and plasticity index values derived from samples containing their natural moisture are usually, but not always, equal to or higher than values derived from similar samples of the dried soil. In the case of fine-grained organic soil, there is a radical drop in plasticity due to oven drying.

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

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

[3] *Annual Book of ASTM Standards*, Vol 14.02.

Standard Test Methods for MOISTURE, ASH, AND ORGANIC MATTER OF PEAT MATERIALS[1]

This standard is issued under the fixed designation D 2974; 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 These test methods[2] cover measurement of the weight percentage of moisture, ash, and organic matter in peat materials, including moss, humus, and reed-sedge types.

1.2 *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.*

2. Summary of Methods

2.1 *Method I*—Moisture is determined by drying a peat sample at 105°C. The loss in weight represents the total moisture content expressed as percentage by weight of the as-received sample.

2.2 *Method II*—This is an alternative moisture method which removes the total moisture in two steps: (*1*) evaporation of moisture by air at room temperature (air-drying) and (*2*) the subsequent loss in weight of the air-dried sample at 105°C. This method provides a more stable sample, the air-dried sample, when tests for nitrogen, pH, cation exchange, sand content, etc., are to be made.

2.3 Ash content of a peat sample is determined by igniting the oven-dried sample from the total moisture determination in a muffle furnace at 550°C. The substance remaining after ignition is the ash, and this includes mineral impurities such as sand. The ash content is expressed as a weight percentage of the oven-dried sample.

2.4 Organic matter is determined by difference.

3. Apparatus

3.1 *Oven*, regulated to a constant temperature of 105 ± 5°C.

3.2 *Muffle Furnace*, regulated to a constant temperature of 550°C.

3.3 *Evaporating Dishes*, high silica or porcelain, not less than 75-mL capacity.

3.4 *Blender*, high-speed.

3.5 *Aluminum Foil*, heavy-duty.

3.6 *Porcelain pan, spoons, etc.*

4. Preparation of Sample

4.1 Place a representative field sample on a square rubber sheet, paper, or oil cloth. Reduce the sample to the quantity required by quartering and place in a moistureproof container. *Work rapidly to prevent moisture losses.*

MOISTURE

5. Procedure—Method I

5.1 Mix the sample thoroughly and place a test specimen of at least 50 g in an ignited and weighed (with fitted heavy-duty aluminum foil cover) high silica or porcelain evaporating dish of not less than 100 mL capacity. Crush soft lumps with a spoon or spatula. Cover immediately with the aluminum foil and weigh to the nearest 0.01 g. Dry uncovered for 16 h at 105°C. Remove from the oven, cover tightly, cool, and weigh.

[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.18 on Peats and Related Materials.

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[2] These test methods are currently undergoing an extensive review by Committee D-18.

6. Calculation

6.1 Calculate the moisture content as follows:

$$\text{Moisture, \%} = [(A - B) \times 100]/A$$

where:

A = grams of as-received test specimen, and
B = grams of oven-dried test specimen.

NOTE—In geotechnical engineering the moisture content is commonly expressed as a proportion of the oven-dried mass. Care must be taken to indicate which system is being used.

7. Procedure—Method II

7.1 Use Method II when pH, nitrogen, sand content, cation exchange capacity, etc., are to be tested. Mix thoroughly and weigh a 100 to 300-g representative sample and spread evenly on a large flat pan. Crush soft lumps with a spoon or spatula and let the sample come to moisture equilibrium with room air, not less than 24 h. Stir occasionally to maintain maximum air exposure of the entire sample. When the weight is constant, calculate the loss in weight as percent moisture removed by air drying. Grind a representative portion of the air-dried sample 1 to 2 min in a high-speed blender. Use the ground portion for moisture, ash, nitrogen, etc., determinations.

7.2 Thoroughly mix the air-dried, ground sample and weigh to the nearest 0.01g the equivalent of 50 g of test specimen on the as-received basis. Determine the grams of air-dried sample equivalent to 50 g of as-received sample as follows:

$$\text{Equivalent sample weight, g} = 50.0 - [(50 \times \text{percent moisture removed in air drying})/100]$$

Place the weighed sample in an ignited and weighed (with fitted heavy-duty aluminum foil cover) high silica or porcelain evaporating dish and proceed as in Method I.

8. Calculation

8.1 Calculate the moisture content as follows:

$$\text{Moisture, \%} = (50 - B) \times 2$$

where:

B = grams of oven-dried sample.

ASH

9. Procedure

9.1 Place an uncovered (retain cover for weighing) high silica or porcelain dish containing the dried test specimen from the moisture determinations in a muffle furnace. Gradually bring to 550°C and hold until completely ashed. Cover with the retained aluminum foil cover, cool, and weigh.

10. Calculation

10.1 Calculate the ash content as follows:

$$\text{Ash, \%} = (C \times 100)/B$$

where:

C = grams of ash, and
B = grams of oven-dried test specimen.

ORGANIC MATTER

11. Procedure

11.1 Determine the amount of organic matter by difference, as follows:

$$\text{Organic matter, \%} = 100.0 - D$$

where:

D = weight percentage of ash.

REPORT

12. Report

12.1 Report all results to the nearest 0.1 %.

12.2 Indicate whether moisture contents are by proportion of as-received mass or oven-dried mass.

13. Precision and Bias

13.1 The precision and bias of these test methods have not been determined. Data are being sought for use in developing a precision and bias statement.

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METHOD 9081A

CATION-EXCHANGE CAPACITY OF SOILS (SODIUM ACETATE)

1.0 SCOPE AND APPLICATION

1.1 Method 9081 is applicable to most soils, including calcareous and noncalcareous soils. The method of cation-exchange capacity by summation (Chapman, 1965, p. 900; see Step 10.1) should be employed for distinctly acid soils.

2.0 SUMMARY OF METHOD

2.1 The soil sample is mixed with an excess of sodium acetate solution, resulting in an exchange of the added sodium cations for the matrix cations. Subsequently, the sample is washed with isopropyl alcohol. An ammonium acetate solution is then added, which replaces the adsorbed sodium with ammonium. The concentration of displaced sodium is then determined by atomic absorption, emission spectroscopy, or an equivalent means.

3.0 INTERFERENCES

3.1 Interferences can occur during analysis of the extract for sodium content. Thoroughly investigate the chosen analytical method for potential interferences.

4.0 APPARATUS AND MATERIALS

4.1 Centrifuge tube and stopper: 50-mL, round-bottom, narrow neck.

4.2 Mechanical shaker.

4.3 Class A volumetric flask: 100-mL.

4.4 Top-loading balance: capable of weighing to 1 g.

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 Reagent water. All references to water in this method refer to reagent water, as defined in Chapter One.

5.3 Sodium acetate (NaOAc), 1.0 N: Dissolve 136 g of $NaC_2H_2O_2 \cdot 3H_2O$ in water and dilute it to 1,000 mL. The pH of this solution should be 8.2. If needed, add a few drops of acetic acid or NaOH solution to bring the reaction of the solution to pH 8.2.

5.4 Ammonium acetate (NH_4OAc), 1 N: Dilute 114 mL of glacial acetic acid (99.5%) with water to a volume of approximately 1 liter. Then add 138 mL of concentrated ammonium hydroxide (NH_4OH) and add water to obtain a volume of about 1,980 mL. Check the pH of the resulting solution, add more NH_4OH, as needed, to obtain a pH of 7, and dilute the solution to a volume of 2 liters with water.

5.5 Isopropyl alcohol: 99%.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must be collected using a sampling plan that addresses the considerations discussed in Chapter Nine of this manual.

7.0 PROCEDURE

7.1 Weigh 4 g of medium- or fine-textured soil or 6 g of coarse-textured soil and transfer the sample to a 50-mL, round-bottom, narrow-neck centrifuge tube. (A fine soil has >50% of the particles $\leq$ 0.074 mm, medium soil has >50% $\geq$ 0.425 mm, while a coarse soil has more than 50% of its particles $\geq$ 2 mm.

7.2 Add 33 mL of 1.0 N NaOAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear.

7.3 Decant the liquid, and repeat Step 7.2 three more times.

7.4 Add 33 mL of 99% isopropyl alcohol, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear.

7.5 Repeat the procedure described in Step 7.4 two more times.

7.6 Add 33 mL of NH_4OAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear. Decant the washing into a 100-mL Class A volumetric flask.

7.7 Repeat the procedure described in Step 7.6 two more times.

7.8 Dilute the combined washing to the 100-mL mark with ammonium acetate solution and determine the sodium concentration by atomic absorption, emission spectroscopy, or an equivalent method.

8.0 QUALITY CONTROL

8.1 Refer to Chapter One for specific quality control procedures.

8.2 Material of known cation-exchange capacity must be routinely analyzed as a laboratory control sample to verify precision and bias of the analytical process.

9.0 METHOD PERFORMANCE

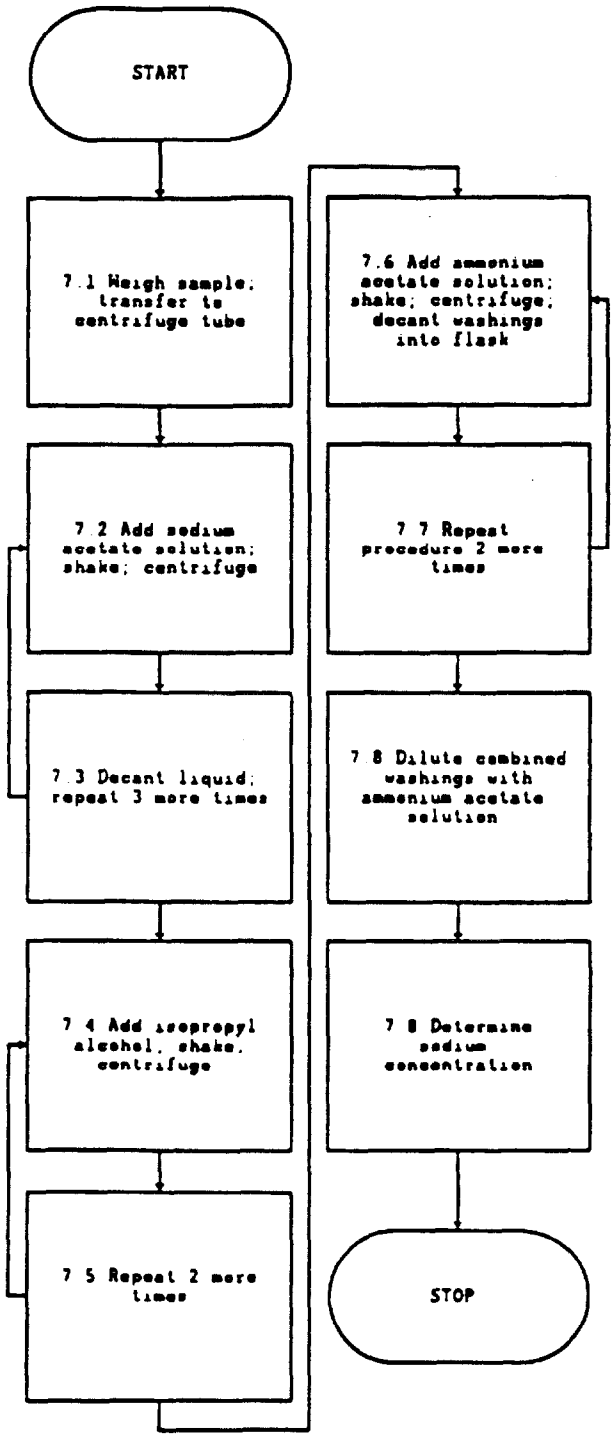
9.1 No data provided.

10.0 REFERENCES

10.1 This method is based on Chapman, H.D., "Cation-exchange Capacity," pp. 891-900, in C.A. Black (ed.), Method of Soil Analysis, Part 2: Chemical and Microbiological Properties, Am. Soc. Agron., Madison, Wisconsin (1965).

METHOD 9081A

CATION-EXCHANGE CAPACITY OF SOIL (SODIUM ACETATE)



METHOD FOR THE DETERMINATION OF VOLATILE ORGANIC COMPOUNDS IN AMBIENT AIR USING TENAX® ADSORPTION AND GAS CHROMATOGRAPHY/MASS SPECTROMETRY (GC/MS)

1. Scope

1.1 The document describes a generalized protocol for collection and determination of certain volatile organic compounds which can be captured on Tenax® GC (poly(2,6-Diphenyl phenylene oxide)) and determined by thermal desorption GC/MS techniques. Specific approaches using these techniques are described in the literature (1-3).

1.2 This protocol is designed to allow some flexibility in order to accommodate procedures currently in use. However, such flexibility also results in placement of considerable responsibility with the user to document that such procedures give acceptable results (i.e. documentation of method performance within each laboratory situation is required). Types of documentation required are described elsewhere in this method.

1.3 Compounds which can be determined by this method are nonpolar organics having boiling points in the range of approximately 80° - 200°C. However, not all compounds falling into this category can be determined. Table 1 gives a listing of compounds for which the method has been used. Other compounds may yield satisfactory results but validation by the individual user is required.

2. Applicable Documents

2.1 ASTM Standards:

D1356 Definitions of Terms Related to Atmospheric Sampling and Analysis.

E355 Recommended Practice for Gas Chromatography Terms and Relationships.

2.3 Other documents:

Existing procedures (1-3).
U.S. EPA Technical Assistance Document (4).

3. Summary of Protocol

3.1 Ambient air is drawn through a cartridge containing ~1-2 grams of Tenax and certain volatile organic compounds are trapped on the resin while highly volatile organic compounds and most inorganic atmospheric constituents pass through the cartridge. The cartridge is then transferred to the laboratory and analyzed.

3.2 For analysis the cartridge is placed in a heated chamber and purged with an inert gas. The inert gas transfers the volatile organic compounds from the cartridge onto a cold trap and subsequently onto the front of the GC column which is held at low temperature (e.g. - 70°C). The GC column temperature is then increased (temperature programmed) and the components eluting from the column are identified and quantified by mass spectrometry. Component identification is normally accomplished, using a library search routine, on the basis of the GC retention time and mass spectral characteristics. Less sophistacated detectors (e.g. electron capture or flame ionization) may be used for certain applications but their suitability for a given application must be verified by the user.

3.3 Due to the complexity of ambient air samples only high resolution (i.e. capillary) GC techniques are considered to be acceptable in this protocol.

4. Significance

4.1 Volatile organic compounds are emitted into the atmosphere from a variety of sources including industrial and commercial facilities, hazardous waste storage facilities, etc. Many of these compounds are toxic; hence knowledge of the levels of

such materials in the ambient atmosphere is required in order to determine human health impacts.

4.2 Conventional air monitoring methods (e.g. for workspace monitoring) have relied on carbon adsorption approaches with subsequent solvent desorption. Such techniques allow subsequent injection of only a small portion, typically 1-5% of the sample onto the GC system. However, typical ambient air concentrations of these compounds require a more sensitive approach. The thermal desorption process, wherein the entire sample is introduced into the analytical (GC/MS) system fulfills this need for enhanced sensitivity.

5. Definitions

Definitions used in this document and any user prepared SOPs should be consistent with ASTM D1356(6). All abbreviations and symbols are defined with this document at the point of use.

6. INTERFERENCES

6.1 Only compounds having a similar mass spectrum and GC retention time compared to the compound of interest will interfere in the method. The most commonly encountered interferences are structural isomers.

6.2 Contamination of the Tenax cartridge with the compound(s) of interest is a commonly encountered problem in the method. The user must be extremely careful in the preparation, storage, and handling of the cartridges throughout the entire sampling and analysis process to minimize this problem.

7. Apparatus

7.1 Gas Chromatograph/Mass Spectrometry system - should be capable of subambient temperature programming. Unit mass resolution or better up to 800 amu. Capable of scanning 30-440 amu region every 0.5-1 second. Equipped with data system for instrument control as well as data acquisition, processing and storage.

7.2 Thermal Desorption Unit - Designed to accommodate Tenax cartridges in use. See Figure 2a or b.

7.3 Sampling System - Capable of accurately and precisely drawing an air flow of 10-500 ml/minute through the Tenax cartridge. (See Figure 3a or b.)

7.4 Vacuum oven - connected to water aspirator vacuum supply.

7.5 Stopwatch

7.6 Pyrex disks - for drying Tenax.

7.7 Glass jar - Capped with Teflon-lined screw cap. For storage of purified Tenax.

7.8 Powder funnel - for delivery of Tenax into cartridges.

7.9 Culture tubes - to hold individual glass Tenax cartridges.

7.10 Friction top can (paint can) - to hold clean Tenax cartridges.

7.11 Filter holder - stainless steel or aluminum (to accommodate 1 inch diameter filter). Other sizes may be used if desired. (optional)

7.12 Thermometer - to record ambient temperature.

7.13 Barometer (optional).

7.14 Dilution bottle - Two-liter with septum cap for standards preparation.

7.15 Teflon stirbar - 1 inch long.

7.16 Gas-tight glass syringes with stainless steel needles - 10-500 µl for standard injection onto GC/MS system..

7.17 Liquid microliter syringes - 5.50 µL for injecting neat liquid standards into dilution bottle.

7.18 Oven - 60 ± 5°C for equilibrating dilution flasks.

7.19 Magnetic stirrer.

7.20 Heating mantel.

7.21 Variac

7.22 Soxhlet extraction apparatus and glass thimbles - for purifying Tenax.

7.23 Infrared lamp - for drying Tenax.

7.24 GC column - SE-30 or alternative coating, glass capillary or fused silica.

7.25 Psychrometer - to determine ambient relative humidity. (optional).

8. Reagents and Materials

8.1 Empty Tenax cartridges - glass or stainless steel (See Figure 1a or b).
8.2 Tenax 60/80 mesh (2,6-diphenylphenylene oxide polymer).
8.3 Glasswool - silanized.
8.4 Acetone - Pesticide quality or equivalent.
8.5 Methanol - Pesticide quality, or equivalent.
8.6 Pentane - Pesticide quality or equivalent.
8.7 Helium - Ultra pure, compressed gas. (99.9999%)
8.8 Nitrogen - Ultra pure, compressed gas. (99.9999%)
8.9 Liquid nitrogen.
8.10 Polyester gloves - for handling glass Tenax cartridges.
8.11 Glass Fiber Filter - one inch diameter, to fit in filter holder. (optional)
8.12 Perfluorotributylamine (FC-43).
8.13 Chemical Standards - Neat compounds of interest. Highest purity available.
8.14 Granular activated charcoal - for preventing contamination of Tenax cartridges during storage.

9. Cartridge Construction and Preparation

9.1 Cartridge Design

9.1.1 Several cartridge designs have been reported in the literature (1-3). The most common (1) is shown in Figure 1a. This design minimizes contact of the sample with metal surfaces, which can lead to decomposition in certain cases. However, a disadvantage of this design is the need to rigorously avoid contamination of the <u>outside</u> portion of the cartridge since the entire surface is subjected to the purge gas stream during the desorption porcess.

Clean polyester gloves must be worn at all times when handling such cartridges and exposure of the open cartridge to ambient air must be minimized.

9.1.2 A second common type of design (3) is shown in Figure 1b. While this design uses a metal (stainless steel) construction, it eliminates the need to avoid direct contact with the exterior surface since only the interior of the cartridge is purged.

9.1.3 The thermal desorption module and sampling system must be selected to be compatible with the particular cartridge design chosen. Typical module designs are shown in Figures 2a and b. These designs are suitable for the cartridge designs shown in Figures 1a and 1b, respectively.

9.2 Tenax Purification

9.2.1 Prior to use the Tenax resin is subjected to a series of solvent extraction and thermal treatment steps. The operation should be conducted in an area where levels of volatile organic compounds (other than the extraction solvents used) are minimized.

9.2.2 All glassware used in Tenax purification as well as cartridge materials should be thoroughly cleaned by water rinsing followed by an acetone rinse and dried in an oven at 250°C.

9.2.3 Bulk Tenax is placed in a glass extraction thimble and held in place with a plug of clean glasswool. The resin is then placed in the soxhlet extraction apparatus and extracted sequentially with methanol and then pentane for 16-24 hours (each solvent) at approximately 6 cycles/hour. Glasswool for cartidge preparation should be cleaned in the same manner as Tenax.

9.2.4 The extracted Tenax is immediately placed in an open glass dish and heated under an infrared lamp for two

hours in a hood. Care must be exercised to avoid over heating of the Tenax by the infrared lamp. The Tenax is then placed in a vacuum oven (evacuated using a water aspirator) without heating for one hour. An inert gas (helium or nitrogen) purge of 2-3 ml/minute is used to aid in the removal of solvent vapors. The oven temperature is then increased to 110°C, maintaining inert gas flow and held for one hour. The oven temperature control is then shut off and the oven is allowed to cool to room temperature. Prior to opening the oven, the oven is slightly pressurized with nitrogen to prevent contamination with ambient air. The Tenax is removed from the oven and sieved through a 40/60 mesh sieve (acetone rinsed and oven dried) into a clean glass vessel. If the Tenax is not to be used immediately for cartridge preparation it should be stored in a clean glass jar having a Teflon-lined screw cap and placed in a desiccator.

9.3 Cartridge Preparation and Pretreatment

9.3.1 All cartridge materials are pre-cleaned as described in Section 9.2.2. If the glass cartridge design shown in Figure 1a is employed all handling should be conducted wearing polyester gloves.

9.3.2 The cartridge is packed by placing a 0.5-1cm glass-wool plug in the base of the cartridge and then filling the cartridge to within approximately 1 cm of the top. A 0.5-1cm glasswool plug is placed in the top of the cartridge.

9.3.3 The cartridges are then thermally conditioned by heating for four hours at 270°C under an inert gas (helium) purge (100 - 200 ml/min).

9.3.4 After the four hour heating period the cartridges are allowed to cool. Cartridges of the type shown in Figure 1a are immediately placed (without cooling) in clean culture tubes having Teflon-lined screw caps with a glasswool cushion at both the top and the bottom. Each tube should be shaken to ensure that the cartridge is held firmly in place. Cartridges of the type shown in Figure 1b are allowed to cool to room temperature under inert gas purge and are then closed with stainless steel plugs.

9.3.5 The cartridges are labeled and placed in a tightly sealed metal can (e.g. paint can or similar friction top container). For cartridges of the type shown in Figure 1a the culture tube, not the cartridge, is labeled.

9.3.6 Cartridges should be used for sampling within 2 weeks after preparation and analyzed within two weeks after sampling. If possible the cartridges should be stored at -20°C in a clean freezer (i.e. no solvent extracts or other sources of volatile organics contained in the freezer).

10. Sampling

10.1 Flow rate and Total Volume Selection

10.1.1 Each compound has a characteristic retention volume (liters of air per gram of adsorbent) which must not be exceeded. Since the retention volume is a function of temperature, and possibly other sampling variables, one must include an adequate margin of safety to ensure good collection efficiency. Some considerations and guidance in this regard are provided in a recent report (5). Approximate breakthrough volumes at 38°C (100°F) in liters/gram of Tenax are provided in Table 1. These retention volume data are supplied only as rough guidance and are subject to considerable variability, depending on cartridge design as well as sampling

10.1.2 To calculate the maximum total volume of air which can be sampled use the following equation:

$$V_{MAX} = \frac{V_b x W}{1.5}$$

where

V_{MAX} is the calculated maximum total volume in liters.

V_b is the breakthrough volume for the least retained compound of interest (Table 1) in liters per gram of Tenax.

W is the weight of Tenax in the cartridge, in grams.

1.5 is a dimensionless safety factor to allow for variability in atmospheric conditions. This factor is appropriate for temperatures in the range of 25-30°C. If higher temperatures are encountered the factor should be increased (i.e. maximum total volume decreased).

10.1.3 To calculate maximum flow rate use the following equation:

$$Q_{MAX} = \frac{V_{MAX}}{t} \times 1000$$

where

Q_{MAX} is the calculated maximum flow rate in millileters per minute.

t is the desired sampling time in minutes. Times greater than 24 hours (1440 minutes) generally are unsuitable because the flow rate required is too low to be accurately maintained.

10.1.4 The maximum flow rate Q_{MAX} should yield a linear flow velocity of 50-500 cm/minute. Calculate the linear velocity corresponding to the maximum flow rate using the following equation:

$$B = \frac{Q_{MAX}}{\pi r^2}$$

where

B is the calculated linear flow velocity in centimeters per minute.

r is the internal radius of the cartridge in centimeters.

If B is greater than 500 centimeters per minute either the total sample volume (V_{MAX}) should be reduced or the sample flow rate (Q_{MAX}) should be reduced by increasing the collection time. If B is less than 50 centimeters per minute the sampling rate (Q_{MAX}) should be increased by reducing the sampling time. The total sample value (V_{MAX}) cannot be increased due to component breakthrough.

10.1.4 The flow rate calculated as described above defines the maximum flow rate allowed. In general, one should collect additional samples in parallel, for the same time period but at lower flow rates. This practice yields a measure of quality control and is further discussed in the literature (5). In general, flow rates 2 to 4 fold lower than the maximum flow rate should be employed for the parallel samples. In all cases a constant flow rate should be achieved for each cartridge since accurate integration of the analyte concentration requires that the flow be constant over the sampling period.

10.2 Sample Collection

10.2.1 Collection of an accurately known volume of air is critical to the accuracy of the results. For this reason the use of mass flow controllers, rather than conventional needle valves or orifices is highly recommended, especially at low flow velocities (e.g. less than 100 milliliters/minute). Figure 3a illustrates a sampling system utilizing mass flow controllers. This system readily allows for collection of parallel samples. Figures 3b

10.2.2 Prior to sample collection insure that the sampling flow rate has been calibrated over a range including the rate to be used for sampling, with a "dummy" Tenax cartridge in place. Generally calibration is accomplished using a soap bubble flow meter or calibrated wet test meter. The flow calibration device is connected to the flow exit, assuming the entire flow system is sealed. ASTM Method D3686 describes an appropriate calibration scheme, not requiring a sealed flow system downstream of the pump.

10.2.3 The flow rate should be checked before and after each sample collection. If the sampling interval exceeds four hours the flow rate should be checked at an intermediate point during sampling as well. In general, a rotameter should be included, as showed in Figure 3b, to allow observation of the sampling flow rate without disrupting the sampling process.

10.2.4 To collect an air sample the cartridges are removed from the sealed container just prior to initiation of the collection process. If glass cartridges (Figure 1a) are employed they must be handled only with polyester gloves and should not contact any other surfaces.

10.2.5 A particulate filter and holder are placed on the inlet to the cartridges and the exit end of the cartridge is connected to the sampling apparatus. In many sampling situations the use of a filter is not necessary if only the total concentration of a component is desired. Glass cartridges of the type shown in Figure 1a are connected using teflon ferrules and Swagelok (stainless steel or teflon) fittings. Start the pump and record the following parameters on an appropriate data sheet (Figure 4): data, sampling location, time, ambient temperature, barometric

pressure, relative humidity, dry gas meter reading (if applicable) flow rate, rotameter reading (if applicable), cartridge number and dry gas meter serial number.

10.2.6 Allow the sampler to operate for the desired time, periodically recording the variables listed above. Check flow rate at the midpoint of the sampling interval if longer than four hours.
At the end of the sampling period record the parameters listed in 10.2.5 and check the flow rate and record the value. If the flows at the beginning and end of the sampling period differ by more than 10% the cartridge should be marked as suspect.

10.2.7 Remove the cartridges (one at a time) and place in the original container (use gloves for glass cartridges). Seal the cartridges or culture tubes in the friction-top can containing a layer of charcoal and package for immediate shipment to the laboratory for analysis. Store cartridges at reduced temperature (e.g. - 20°C) before analysis if possible to maximize storage stability.

10.2.8 Calculate and record the average sample rate for each cartridge according to the following equation:

$$Q_A = \frac{Q_1 + Q_2 + \ldots Q_N}{N}$$

where

Q_A = Average flow rate in ml/minute.
$Q_1, Q_2, \ldots Q_N$ = Flow rates determined at beginning, end, and immediate points during sampling.

N = Number of points averaged.

10.2.9 Calculate and record the total volumetric flow for each cartridge using the following equation:

where

V_m = Total volume sampled in liters at measured temperature and pressure.

T_2 = Stop time.

T_1 = Start time.

T = Sampling time = $T_2 - T_1$, minutes

10.2.10 The total volume (V_s) at standard conditions, 25°C and 760 mmHg, is calculated from the following equation:

$$V_s = V_m \times \frac{P_A}{760} \times \frac{298}{273 + t_A}$$

where

P_A = Average barometric pressure, mmHg

t_A = Average ambient temperature, °C.

11. GC/MS Analysis

11.1 Instrument Set-up

11.1.1 Considerable variation from one laboratory to another is expected in terms of instrument configuration. Therefore each laboratory must be responsible for verifying that their particular system yields satisfactory results. Section 14 discusses specific performance criteria which should be met.

11.1.2 A block diagram of the typical GC/MS system required for analysis of Tenax cartridges is depicted in Figure 5. The operation of such devices is described in 11.2.4. The thermal desorption module must be designed to accommodate the particular cartridge configuration. Exposure of the sample to metal surfaces should be minimized and only stainless steel, or nickel metal surfaces should be employed.

The volume of tubing and fittings leading from the cartridge to the GC column must be minimized and all areas must be well-swept by helium carrier gas.

11.1.3 The GC column inlet should be capable of being cooled to -70°C and subsequently increased rapidly to approximately 30°C. This can be most readily accomplished using a GC equipped with subambient cooling capability (liquid nitrogen) although other approaches such as manually cooling the inlet of the column in liquid nitrogen may be acceptable.

11.1.4 The specific GC column and temperature program employed will be dependent on the specific compounds of interest. Appropriate conditions are described in the literature (1-3). In general a nonpolar stationary phase (e.g. SE-30, OV-1) temperature programmed from 30°C to 200°C at 8°/minute will be suitable. Fused silica bonded phase columns are preferable to glass columns since they are more rugged and can be inserted directly into the MS ion source, thereby eliminating the need for a GC/MS transfer line.

11.1.5 Capillary column dimensions of 0.3 mm ID and 50 meters long are generally appropriate although shorter lengths may be sufficient in many cases.

11.1.6 Prior to instrument calibration or sample analysis the GC/MS system is assembled as shown in Figure 5. Helium purge flows (through the cartridge) and carrier flow are set at approximately 10 ml/minute and 1-2 ml/minute respectively. If applicable, the injector sweep flow is set at 2-4 ml/minute.

11.1.7 Once the column and other system components are assembled and the various flows established the column temperature is increased to 250°C for approximately four hours (or overnight if desired) to condition the column.

11.1.8 The MS and data system are set according to the manufacturer's instructions. Electron impact ionization (70eV) and an electron multiplier gain of approximately 5×10^4 should be employed. Once the entire GC/MS system has been setup the system is calibrated as described in Section 11.2. The user should prepare a detailed standard operating procedure (SOP) describing this process for the particular instrument being used.

11.2 Instrument Calibration

11.2.1 Tuning and mass standarization of the MS system is performed according to manufacturer's instructions and relevant information from the user prepared SOP. Perfluorotributylamine should generally be employed for this purpose. The material is introduced directly into the ion source through a molecular leak. The instrumental parameters (e.g. lens voltages, resolution, etc.) should be adjusted to give the relative ion abundances shown in Table 2 as well as acceptable resolution and peak shape. If these approximate relative abundances cannot be achieved, the ion source may require cleaning according to manufacturer's instructions. In the event that the user's instrument cannot achieve these relative ion abundances, but is otherwise operating properly, the user may adopt another set of relative abundances as performance criteria.

However, these alternate values must be repeatable on a day-to-day basis.

11.2.2 After the mass standarization and tuning process has been completed and the appropriate values entered into the data system the user should then calibrate the entire system by introducing known quantities of the standard components of interest into the system. Three alternate procedures may be employed for the calibration process including 1) direct syringe injection of dilute vapor phase standards, prepared in a dilution bottle, onto the GC column, 2) Injection of dilute vapor phase standards into a carrier gas stream directed through the Tenax cartridge, and 3) introduction of permeation or diffusion tube standards onto a Tenax cartridge. The standards preparation procedures for each of these approaches are described in Section 13. The following paragraphs describe the instrument calibration process for each of these approaches.

11.2.3 If the instrument is to be calibrated by direct injection of a gaseous standard, a standard is prepared in a dilution bottle as described in Section 13.1. The GC column is cooled to -70°C (or, alternately, a portion of the column inlet is manually cooled with liquid nitrogen). The MS and data system is set up for acquisition as described in the relevant user SOP. The ionization filament should be turned off during the initial 2-3 minutes of the run to allow oxygen and other highly volatile components to elute. An appropriate volume (less than 1 ml) of the gaseous standard is injected onto the GC system using an accurately calibrated gas tight syringe.

The system clock is started and the column is maintained at -70°C (or liquid nitrogen inlet cooling) for 2 minutes. The column temperature is rapidly increased to the desired initial temperature (e.g. 30°C). The temperature program is started at a consistent time (e.g. four minutes) after injection. Simultaneously the ionization filament is turned on and data acquisition is initiated. After the last component of interest has eluted acquisiton is terminated and the data is processed as described in Section 11.2.5. The standard injection process is repeated using different standard volumes as desired.

11.2.4 If the system is to be calibrated by analysis of spiked Tenax cartriuges a set of cartridges is prepared as described in Sections 13.2 or 13.3. Prior to analysis the cartridges are stored as described in Section 9.3. If glass cartridges (Figure 1a) are employed care must be taken to avoid direct contact, as described earlier. The GC column is cooled to -70°C, the collection loop is immersed in liquid nitrogen and the desorption module is maintained at 250°C. The inlet valve is placed in the desorb mode and the standard cartridge is placed in the desorption module, making certain that no leakage of purge gas occurs. The cartridge is purged for 10 minutes and then the inlet valve is placed in the inject mode and the liquid nitrogen source removed from the collection trap. The GC column is maintained at -70°C for two minutes and subsequent steps are as described in 11.2.3. After the process is complete the cartridge is removed from the desorption module and stored for subsequent use as described in Section 9.3.

11.2.5 Data processing for instrument calibration involves determining retention times, and integrated characteristic ion intensities for each of the compounds of interest. In addition, for at least one chromatographic run, the individual mass spectra should be inspected and compared to reference spectra to ensure proper instrumental performance. Since the steps involved in data processing are highly instrument specific, the user should prepare a SOP describing the process for individual use. Overall performance criteria for instrument calibration are provided in Section 14. If these criteria are not achieved the user should refine the instrumental parameters and/or operating procedures to meet these criteria.

11.3 Sample Analysis

11.3.1 The sample analysis process is identical to that described in Section 11.2.4 for the analysis of standard Tenax cartridges.

11.3.2 Data processing for sample data generally involves 1) qualitatively determining the presence or absence of each component of interest on the basis of a set of characteristic ions and the retention time using a reverse-search software routine, 2) quantification of each identified component by integrating the intensity of a characteristic ion and comparing the value to that of the calibration standard, and 3) tentative identification of other components observed using a forward (library) search software routine. As for other user specific processes, a SOP should be prepared describing the specific operations for each individual laboratory.

12. Calculations

12.1 Calibration Response Factors

12.1.1 Data from calibration standards is used to calculate a response factor for each component of interest. Ideally the process involves analysis of at least three calibration levels of each component during a given day and determination of the response factor (area/nanogram injected) from the linear least squares fit of a plot of nanograms injected versus area (for the characteristic ion). In general quantities of component greater than 1000 nanograms should not be injected because of column overloading and/or MS response nonlinearity.

12.1.2 In practice the daily routine may not always allow analysis of three such calibration standards. In this situation calibration data from consecutive days may be pooled to yield a response factor, provided that analysis of replicate standards of the same concentration are shown to agree within 20% on the consecutive days. One standard concentration, near the midpoint of the analytical range of interest, should be chosen for injection every day to determine day-to-day response reproducibility.

12.1.3 If substantial nonlinearity is present in the calibration curve a nonlinear least squares fit (e.g. quadratic) should be employed. This process involves fitting the data to the following equation:

$$Y = A + BX + CX^2$$

where

Y = peak area

X = quantity of component, nanograms

A,B, and C are coefficients in the equation

12.2 Analyte Concentrations

12.2.1 Analyte quantities on a sample cartridge are calculated from the following equation:

$$Y_A = A + BX_A + CX_A$$

where

Y_A is the area of the analyte characteristic ion for the sample cartridge.

X_A is the calculated quantity of analyte on the sample cartridge, in nanograms.

A,B, and C are the coefficients calculated from the calibration curve described in Section 12.1.3.

12.2.2 If instrumental response is essentially linear over the concentration range of interest a linear equation (C=0 in the equation above) can be employed.

12.2.3 Concentration of analyte in the original air sample is calculated from the following equation:

$$C_A = \frac{X_A}{V_S}$$

where

C_A is the calculated concentration of analyte in nanograms per liter.

V_S and X_A are as previously defined in Section 10.2.10 and 12.2.1, respectively.

13. Standard Preparation

13.1 Direct Injection

13.1.1 This process involves preparation of a dilution bottle containing the desired concentrations of compounds of interest for direct injection onto the GC/MS system.

13.1.2 Fifteen three-millimeter diameter glass beads and a one-inch Teflon stirbar are placed in a clean two-liter glass septum capped bottle and the exact volume is determined by weighing the bottle before and after filling with deionized water. The bottle is then rinsed with acetone and dried at 200°C.

13.1.3 The amount of each standard to be injected into the vessel is calculated from the desired injection quantity and volume using the following equation:

$$W_T = \frac{W_I}{V_I} \times V_B$$

where

W_T is the total quantity of analyte to be injected into the bottle in milligrams

W_I is the desired weight of analyte to be injected onto the GC/MS system or spiked cartridge in nanograms

V_I is the desired GC/MS or cartridge injection volume (should not exceed 500) in microliters.

V_B is total volume of dilution bottle determined in 13.1.1, in liters.

13.1.4 The volume of the neat standard to be injected into the dilution bottle is determined using the following equation:

$$V_T = \frac{W_T}{d}$$

where

V_T is the total volume of neat liquid to be injected in microliters.

d is the density of the neat standard in grams per milliliter.

13.1.6 The bottle is placed in a 60°C oven for at least 30 minutes prior to removal of a vapor phase standard.

13.1.7 To withdraw a standard for GC/MS injection the bottle is removed from the oven and stirred for 10-15 seconds. A suitable gas-tight microber syring warmed to 60°C, is inserted through the septum cap and pumped three times slowly. The appropriate volume of sample (approximately 25% larger than the desired injection volume) is drawn into the syringe and the volume is adjusted to the exact value desired and then immediately injected over a 5-10 seconds period onto the GC/MS system as described in Section 11.2.3.

13.2 Preparation of Spiked Cartridges by Vapor Phase Injection

13.2.1 This process involves preparation of a dilution bottle containing the desired concentrations of the compound(s) of interest as described in 13.1 and injecting the desired volume of vapor into a flowing inert gas stream directed through a clean Tenax cartridge.

13.2.2 A helium purge system is assembled wherein the helium flow 20-30 mL/minute is passed through a stainless steel Tee fitted with a septum injector. The clean Tenax cartridge is connected downstream of the tee using appropriate Swagelok fittings. Once the cartridge is placed in the flowing gas stream the appropriate volume vapor standard, in the dilution bottle, is injected through the septum as described in 13.1.6. The syringe is flushed several times by alternately filling the syringe with carrier gas and displacing the contents into the flow stream, without removing the syringe from the septum.

13.3 Preparation of Spiked Traps Using Permeation or Diffusion tubes

13.3.1 A flowing stream of inert gas containing known amounts of each compound of interest is generated according to ASTM Method D3609(6). Note that a method of accuracy maintaining temperature within ± 0.1°C is required and the system generally must be equilibrated for at least 48 hours before use.

13.3.2 An accurately known volume of the standard gas stream (usually 0.1-1 liter) is drawn through a clean Tenax cartridge using the sampling system described in Section 10.2.1, or a similar system. However, if mass flow controllers are employed they must be calibrated for the carrier gas used in Section 13.3.1 (usually nitrogen). Use of air as the carrier gas for permeation systems is not recommended, unless the compounds of interest are known to be highly stable in air.

13.3.3 The spiked cartridges are then stored or immediately analyzed as in Section 11.2.4.

14. Performance Criteria and Quality Assurance

This section summarizes quality assurance (QA) measures and provides guidance concerning performance criteria which should be achieved within each laboratory. In many cases the specific QA procedures have been described within the appropriate section describing the particular activity (e.g. parallel sampling).

14.1 Standard Opreating Procedures (SOPs)

14.1.1 Each user should generate SOPs describing the following activities as they are performed in their laboratory:

1) assembly, calibration, and operation of the sampling system,
2) preparation, handling and storage of Tenax cartridges,
3) assembly and operation of GC/MS system including the thermal desorption apparatus and data system, and
4) all aspects of data recording and processing.

14.1.2 SOPs should provide specific stepwise instructions and should be readily available to, and understood by the laboratory personnel conducting the work.

14.2 Tenax Cartridge Preparation

14.2.1 Each batch of Tenax cartridges prepared (as described in Section 9) should be checked for contamination by analyzing one cartridge immediately after preparation. While analysis can be accomplished by GC/MS, many laboratories may chose to use GC/FID due to logistical and cost considerations.

14.2.2 Analysis by GC/FID is accomplished as described for GC/MS (Section 11) except for use of FID detection.

14.2.3 While acceptance criteria can vary depending on the components of interest, at a minimum the clean cartridge should be demonstrated to contain less than one fourth of the minimum level of interest for each component. For most compounds the blank level should be less than 10 nanograms per cartridge in order to be acceptable. More rigid criteria may be adopted, if necessary, within a specific laboratory. If a cartridge does not meet these acceptance criteria the entire lot should be rejected.

14.3 Sample Collection

14.3.1 During each sampling event at least one clean cartridge will accompany the samples to the field and back to the laboratory, without being used for sampling, to serve as a field blank. The average amount of material found on the field blank cartridge may be subtracted from the amount found on the actual samples. However, if the blank level is greater than 25% of the sample amount, data for that component must be identified as suspect.

14.3.2 During each sampling event at least one set of parallel samples (two or more samples collected simultaneously) will be collected, preferably at different flow rates as described in Section 10.1. If agreement between parallel samples is not generally within ± 25% the user should collect parallel samples on a much more frequent basis (perhaps for all sampling points). If a trend of lower apparent concentrations with increasing flow rate is observed for a set

of parallel samples one should consider using a reduced flow rate and longer sampling interval if possible. If this practice does not improve the reproducibility further evaluation of the method performance for the compound of interest may be required.

14.3.3 Backup cartridges (two cartridges in series) should be collected with each sampling event. Backup cartridges should contain less than 20% of the amount of components of interest found in the front cartridges, or be equivalent to the blank cartridge level, whichever is greater. The frequency of use of backup cartridges should be increased if increased flow rate is shown to yield reduced component levels for parallel sampling. This practice will help to identify problems arising from breakthrough of the component of interest during sampling.

14.4 GC/MS Analysis

14.4.1 Performance criteria for MS tuning and mass calibration have been discussed in Section 11.2 and Table 2. Additional criteria may be used by the laboratory if desired. The following sections provide performance guidance and suggested criteria for determining the acceptability of the GC/MS system.

14.4.2 Chromatographic efficiency should be evaluated using spiked Tenax cartridges since this practice tests the entire system. In general a reference compound such as perfluorotoluene should be spiked onto a cartridge at the 100 nanogram level as described in Section 13.2 or 13.3. The cartridge is then analyzed by GC/MS as

described in Section 11.4. The perfluorotoluene (or other reference compound) peak is then plotted on an expanded time scale so that its width at 10% of the peak can be calculated, as shown in Figure 6. The width of the peak at 10% height should not exceed 10 seconds. More stringent criteria may be required for certain applications. The assymmetry factor (See Figure 6) should be between 0.8 and 2.0. The assymmetry factor for any polar or reactive compounds should be determined using the process described above. If peaks are observed that exceed the peak width or assymmetry factor criteria above, one should inspect the entire system to determine if unswept zones or cold spots are present in any of the fittings and is necessary. Some laboratories may chose to evaluate column performance separately by direct injection of a test mixture onto the GC column. Suitable schemes for column evaluation have been reported in the literature (7). Such schemes cannot be conducted by placing the substances onto Tenax because many of the compounds (e.g. acids, bases, alcohols) contained in the test mix are not retained, or degrade, on Tenax.

14.4.3 The system detection limit for each component is calculated from the data obtained for calibration standards. The detection limit is defined as

$$DL = A + 3.3S$$

where

DL is the calculated detection limit in nanograms injected.

A is the intercept calculated in Section 12.1.1 or 12.1.3.

S is the standard deviation of replicate determinations of the lowest level standard (at least three such determinations are required.

In general the detection limit should be 20 nanograms or less and for many applications detection limits of 1-5 nanograms may be required. The lowest level standard should yield a signal to noise ratio, from the total ion current response, of approximately 5.

14.4.4 The relative standard deviation for replicate analyses of cartridges spiked at approximately 10 times the detection limit should be 20% or less. Day to day relative standard deviation should be 25% or less.

14.4.5 A useful performance evaluation step is the use of an internal standard to track system performance. This is accomplished by spiking each cartridge, including blank, sample, and calibration cartridges with approximately 100 nanograms of a compound not generally present in ambient air (e.g. perfluorotoluene). The integrated ion intensity for this compound helps to identify problems with a specific sample. In general the user should calculate the standard deviation of the internal standard response for a given set of samples analyzed under identical tuning and calibration conditions. Any sample giving a value greater than ± 2 standard deviations from the mean (calculated

excluding that particular sample) should be identified as suspect. Any marked change in internal standard response may indicate a need for instrument recalibration.

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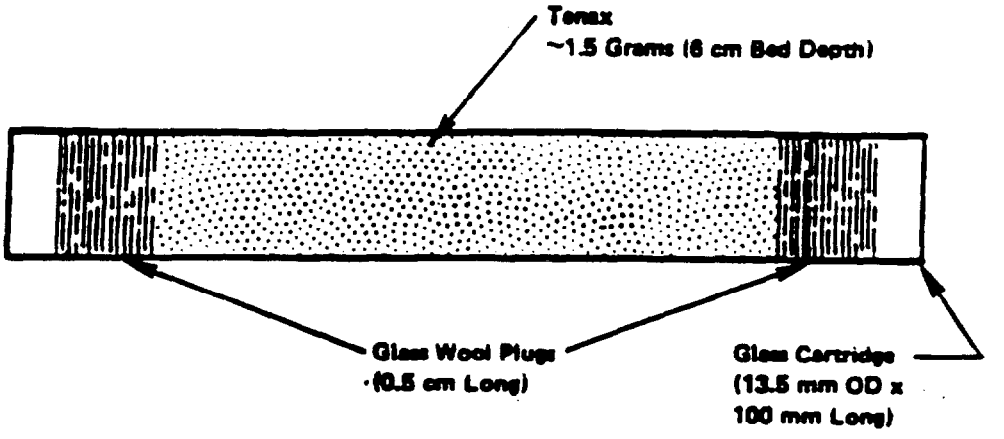
TABLE 1. RETENTION VOLUME ESTIMATES FOR COMPOUNDS ON TENAX

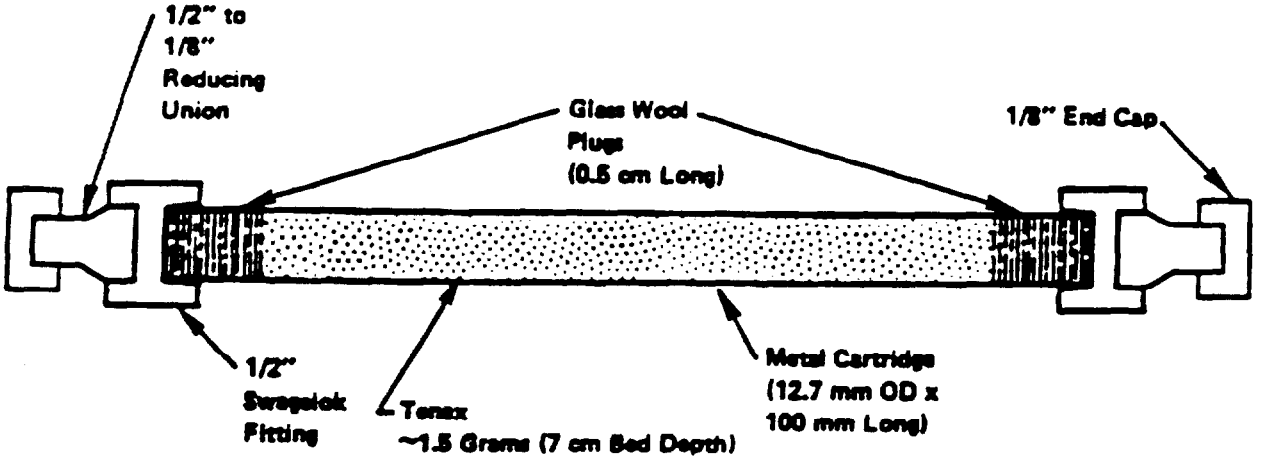
COMPOUND	ESTIMATED RETENTION VOLUME AT 100°F (38°C)-LITERS/GRAM
Benzene	19
Toluene	97
Ethyl Benzene	200
Xylene(s)	~ 200
Cumene	440
n-Heptane	20
1-Heptene	40
Chloroform	8
Carbon Tetrachloride	8
1,2-Dichloroethane	10
1,1,1-Trichloroethane	6
Tetrzchloroethylene	80
Trichloroethylene	20
1,2-Dichloropropane	30
1,3-Dichloropropane	90
Chlorobenzene	150
Bromoform	100
Ethylene Dibromide	60
Bromobenzene	300

TABLE 2. SUGGESTED PERFORMANCE CRITERIA FOR RELATIVE ION ABUNDANCES FROM FC-43 MASS CALIBRATION

M/E	% RELATIVE ABUNDANCE
51	1.8 ± 0.5
69	100
100	12.0 ± 1.5
119	12.0 ± 1.5
131	35.0 ± 3.5
169	3.0 ± 0.4
219	24.0 ± 2.5
264	3.7 ± 0.4
314	0.25 ± 0.1

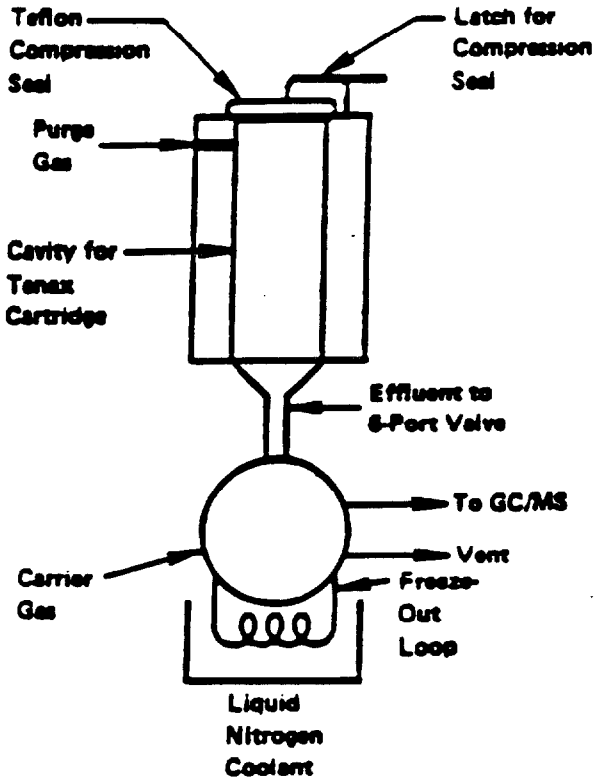


(a) Glass Cartridge

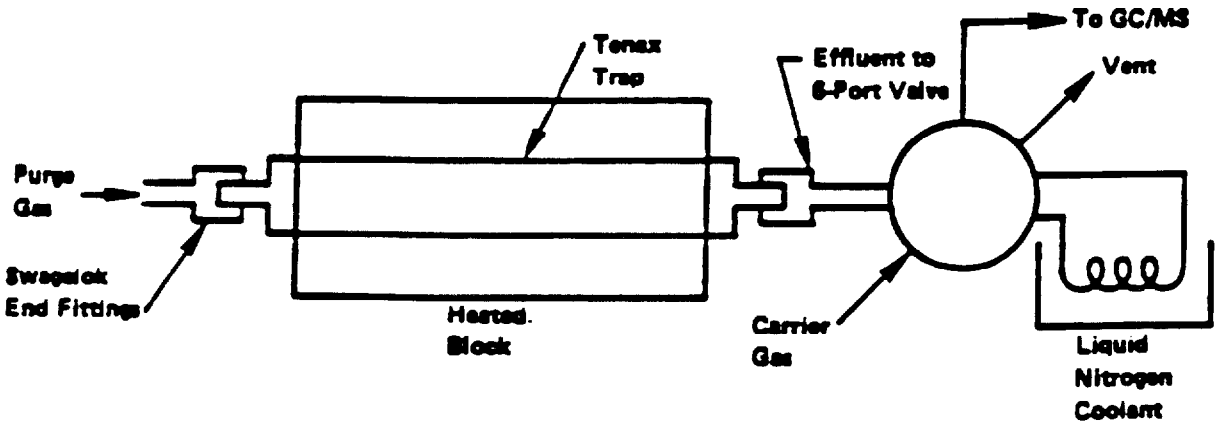


(b) Metal Cartridge

FIGURE 1. TENAX CARTRIDGE DESIGNS

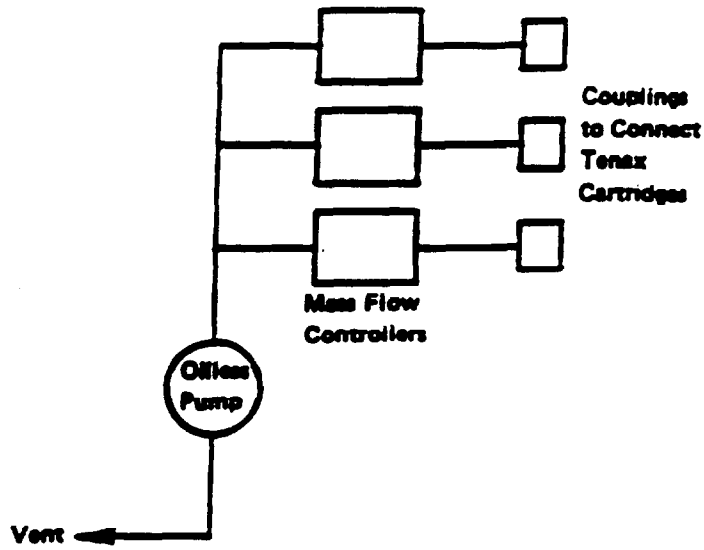


(a) Glass Cartridges (Compression Fit)

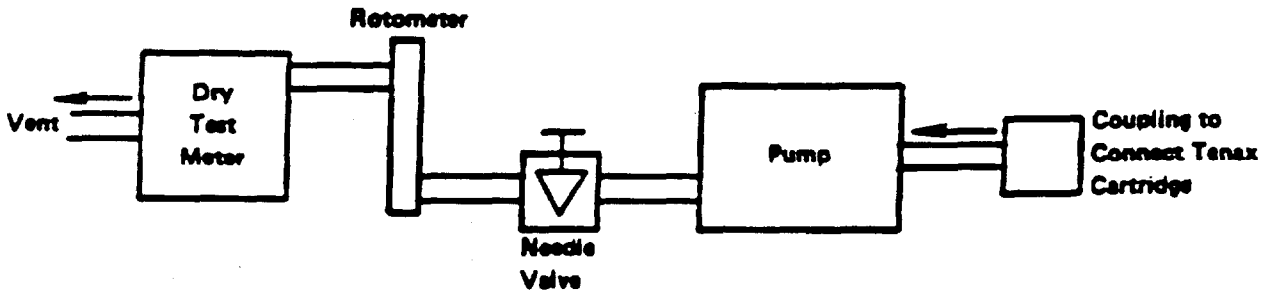


(b) Metal Cartridges (Swagelok Fittings)

FIGURE 2. TENAX CARTRIDGE DESORPTION MODULES



(a) Mass Flow Control



(b) Needle Valve Control

FIGURE 3. TYPICAL SAMPLING SYSTEM CONFIGURATIONS

SAMPLING DATA SHEET
(One Sample Per Data Sheet)

PROJECT: _____ DATE(S) SAMPLED: _____

SITE: _____ TIME PERIOD SAMPLED: _____

LOCATION: _____ OPERATOR: _____

INSTRUMENT MODEL NO: _____ CALIBRATED BY: _____

PUMP SERIAL NO: _____

SAMPLING DATA

Sample Number: _____

Start Time: _____ Stop Time: _____

	Time	Dry Gas Meter Reading	Rotameter Reading	Flow Rate,*Q ml/Min	Ambient Temperature °C	Barometric Pressure, mmHg	Relative Humidity, %	Comments
1.								
2.								
3.								
4.								
N.								

Total Volume Data**

V_m = (Final - Initial) Dry Gas Meter Reading, or = _____ Liters

$$= \frac{Q_1 + Q_2 + Q_3 \ldots Q_N}{N} \times \frac{1}{1000 \times (\text{Sampling Time in Minutes})} = \_\_\_\_\_ \text{ Liters}$$

* Flowrate from rotameter or soap bubble calibrator (specify which).

** Use data from dry gas meter if available.

FIGURE 4. EXAMPLE SAMPLING DATA SHEET

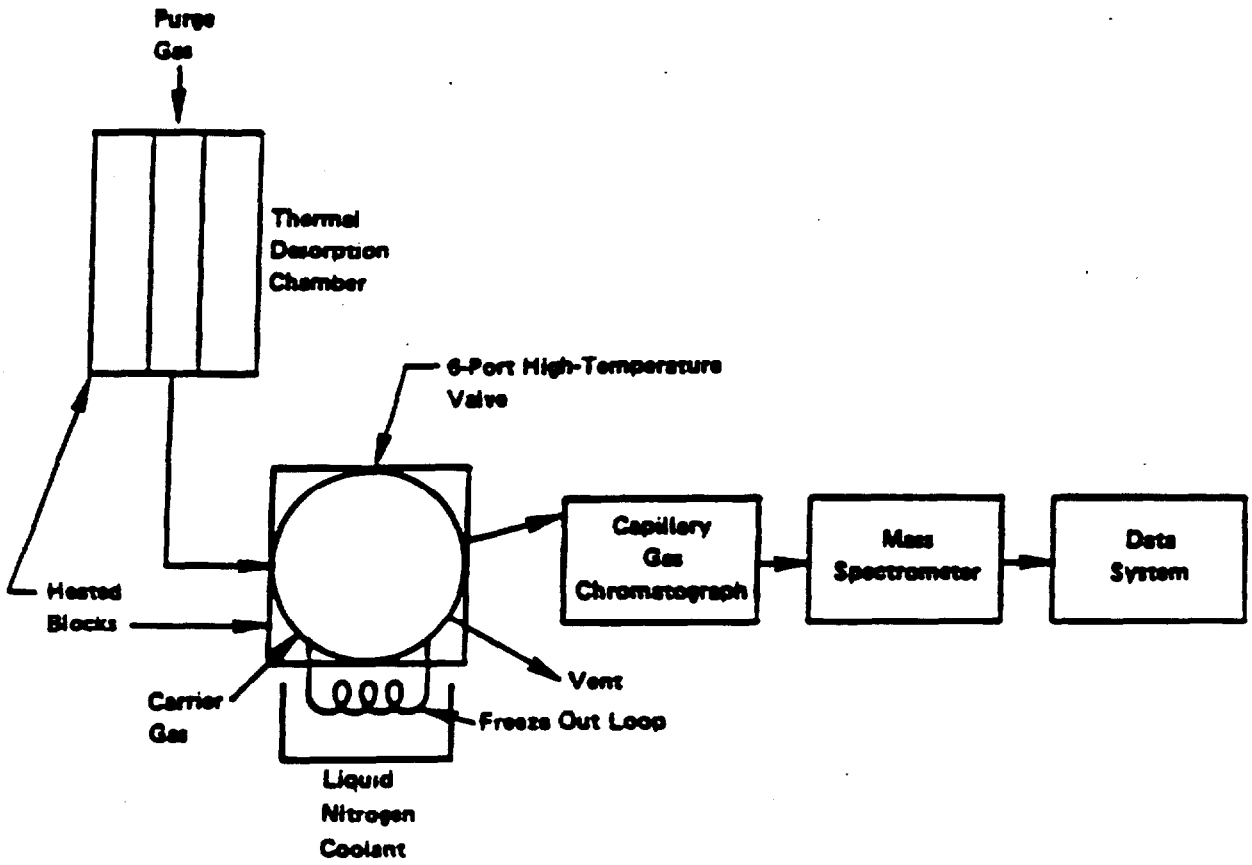
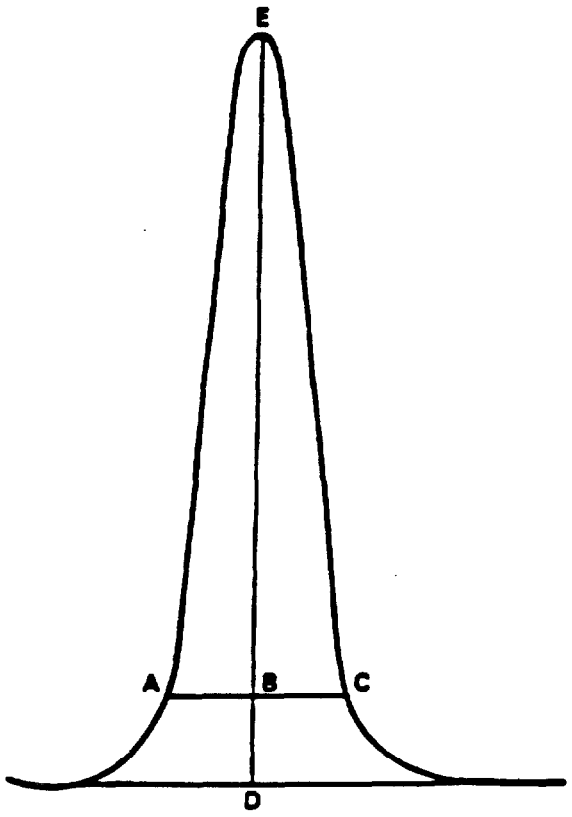


FIGURE 5. BLOCK DIAGRAM OF ANALYTICAL SYSTEM



$$\text{Asymmetry Factor} = \frac{BC}{AB}$$

Example Calculation:

Peak Height = DE = 100 mm
10% Peak Height = BD = 10 mm
Peak Width at 10% Peak Height = AC = 23 mm
AB = 11 mm
BC = 12 mm

Therefore: $\text{Asymmetry Factor} = \frac{12}{11} = 1.1$

FIGURE 8. PEAK ASYMMETRY CALCULATION

2580 OXIDATION-REDUCTION POTENTIAL (ORP) (PROPOSED)*

2580 A. Introduction

1. Significance

Oxidation and reduction (redox) reactions mediate the behavior of many chemical constituents in drinking, process, and wastewaters as well as most aquatic compartments of the environment.[1-5] The reactivities and mobilities of important elements in biological systems (e.g., Fe, S, N, and C), as well as those of a number of other metallic elements, depend strongly on redox conditions. Reactions involving both electrons and protons are pH- and Eh-dependent; therefore, chemical reactions in aqueous media often can be characterized by pH and Eh together with the activity of dissolved chemical species. Like pH, Eh represents an intensity factor. It does not characterize the capacity (i.e., poise) of the system for oxidation or reduction.

The potential difference measured in a solution between an inert indicator electrode and the standard hydrogen electrode should not be equated to Eh, a thermodynamic property, of the solution. The assumption of a reversible chemical equilibrium, fast electrode kinetics, and the lack of interfering reactions at the electrode surface are essential for such an interpretation. These conditions rarely, if ever, are met in natural water.

Thus, although measurement of Eh in water is relatively straightforward, many factors limit the interpretation of these values. These factors include irreversible reactions, electrode poisoning, the presence of multiple redox couples, very small exchange currents, and inert redox couples. Eh values measured in the field correlate poorly with Eh values calculated from the redox couples present. Nevertheless, measurement of redox potential, when properly performed and interpreted, is useful in developing a more complete understanding of water chemistry.

* Approved by Standard Methods Committee, 1990

2. Sampling and Storage

Do not store samples; analyze on collection. Minimize both atmospheric contact and delay in analysis.

3. References

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2580 B. Oxidation-Reduction Potential Measurement in Clean Water

1. General Discussion

a. Principle: Electrometric measurements are made by potentiometric determination of electron activity (or intensity) with an inert indicator electrode and a suitable reference electrode. Ideally, the indicator electrode will serve as either an electron donor or acceptor with respect to electroactive oxidized or reduced chemical species in solution. At redox equilibrium, the potential difference between the ideal indicator electrode and the reference electrode equals the redox potential of the system. However, inert indicator electrodes that behave ideally in all aqueous systems, particularly in natural waters, do not exist. Electrodes made of platinum are most commonly used for Eh measurements. They have limitations,[1] as do alternative materials such as gold and graphite.

The standard hydrogen reference electrode is fragile and impractical for routine laboratory and field use. Therefore, silver:silver-chloride or calomel reference electrodes are used commonly. The redox potential measurement is corrected for the difference between the potential of the reference electrode and that of the standard hydrogen electrode. See Section 4500-H+, pH Value.

It is not possible to calibrate Eh electrodes over a range of redox potentials (as is done with pH electrodes). Instead, stand-

ard solutions that exhibit both chemical stability and known redox potentials for specific indicator electrodes are used to check electrode response at the temperature of measurement.

The potential of the platinum (Pt) Eh electrode versus the Ag/AgCl reference electrode with KCl electrolyte in ZoBell's solution ($3 \times 10^{-3}M$ potassium ferrocyanide and $2 \times 10^{-2}M$ potassium ferricyanide in $0.1M$ KCl)[2] has been measured as a function of temperature.[3] Good agreement was obtained between Eh values measured with this electrode pair in ZoBell's solution and those calculated from the stability constants at 8 to 85°C. The potential of the ZoBell's solution with this electrode configuration as a function of temperature can be calculated:[4]

$$Eh, \text{V} = 0.428 - 0.0022\,(T - 25)$$

where T = solution temperature, °C. Alternatively, select the value from Table 2580:I.

To determine the Eh of a sample relative to the standard hydrogen electrode, measure Eh of both sample and standard solution at the same temperature (i.e., ±0.1°C). Then calculate Eh value of the sample:

$$Eh_{system} = E_{observed} + Eh_{ZoBell\,reference} - Eh_{ZoBell\,observed}$$

where:

$E_{observed}$ = sample potential relative to reference electrode,
$Eh_{ZoBell\,reference}$ = theoretical Eh of reference electrode and Zobell's solution, relative to the standard hydrogen electrode (see Table 2850:I), and
$Eh_{ZoBell\,observed}$ = observed potential of ZoBell's solution, relative to the reference electrode.

The measurements described above can be applied analogously to other indicator electrode/reference electrode pairs and standard solutions.

b. Interferences: Specific interferences may be due to operation of either indicator or reference electrode, redox capacity or poise of the sample, sample preservation and handling, and temperature equilibration.

1) Sorption and poisoning effects on electrodes—Contamination of the electrode surface, salt bridge, or internal electrolyte in the case of reference electrodes, can lead to excessive drift, poor electrode response, and artifact potentials. Organic matter, sulfide, and bromide may cause these problems, particularly in long-term electrode use.[1,5-7] If excessive drift occurs or erratic performance of paired electrodes is observed in redox standard solutions after appropriate cleaning, refilling, or regeneration procedures, discard the faulty electrode and use a new one.

2) pH variations—Redox potential is sensitive to pH if hydrogen ion or hydroxide ion is involved in the redox half-cells. Cell potentials tend to increase as proton concentration increases (i.e., pH decreases) and Eh values drop as hydroxide concentrations increase (i.e., pH increase).

3) Sample handling and preservation—The sample poise will govern the resistance of the sample to change in redox potential; this phenomenon is analogous to the resistance to pH change afforded by buffer capacity. Except in concentrated process streams, sludges, leachates, and highly reducing or treated waters, the concentrations of oxidized or reduced species may be fairly low (i.e., $<10^{-4}M$). Under these conditions, handle reduced samples very carefully to avoid exposure to atmospheric oxygen. A closed cell sampling configuration may be used.[4,8] Samples cannot be stored or preserved; analyze at sampling.

4) Temperature equilibration—Obtain Eh standard solution reading for the electrode pair at a temperature as close as possible to that of the sample. Temperature determines the Eh reference potential for a particular solution and electrode pair. It also may affect the reversibility of the redox reaction, the magnitude c the exchange current, and the stability of the apparent redox potential reading, particularly in poorly poised solutions. Hold temperature constant for all measurements and report it with Eh results.

TABLE 2580:I. POTENTIAL OF ZOBELL'S SOLUTION AS FUNCTION OF TEMPERATURE

T °C	E V	T °C	E V
1	0.481	16	0.448
2	0.479	17	0.446
3	0.476	18	0.443
4	0.474	19	0.441
5	0.472	20	0.439
6	0.470	21	0.437
7	0.468	22	0.435
8	0.465	23	0.432
9	0.463	24	0.430
10	0.461	25	0.428
11	0.459	26	0.426
12	0.457	27	0.424
13	0.454	28	0.421
14	0.452	29	0.419
15	0.450	30	0.417

2. Apparatus

a. pH or millivolt meter: Use a pH meter or other type of high-impedance potentiometer capable of reading either pH or millivolts (mV). For most applications, a meter scale readable to ±1400 mV is sufficient.

b. Reference electrode consisting of a half-cell providing a constant electrode potential. See Section 4500-H⁺.B.2*b*.

c. Oxidation-reduction indicator electrode: The platinum electrode is used most commonly. A noble metal or graphite electrode may be useful for specific applications.

1) Noble metal electrode—Noble metal (i.e., gold or platinum) foil, wire, or billet types of electrode are inert and resistant to chemical reaction. Clean and polish electrode surface to insure reliable performance. Platinum electrodes may be cleaned by strong acid soaking,[9,10] hydrogen peroxide and detergent washing,[11] and anodic activation.[10] Abrasive polishing with crocus cloth, jeweler's rouge, or 400 to 600 grit wet/dry carborundum paper may be best.[5]

2) Graphite electrode—A wax-impregnated graphite (WIG) electrode may be used, especially in aqueous suspensions or soils.[12,13] The WIG electrode is more resistant to electrode poisoning than electrodes made of platinum wire.

d. Beakers: Preferably use polyethylene, TFE, or glass beakers.

e. Stirrer: Use a magnetic TFE-coated stirring-bar-type mixer.

f. Flow cell: Use for continuous flow measurements and for poorly buffered solutions.

3. Reagents

a. Standard redox solutions: Standardize the electrode system against redox solutions that provide stable known Eh values over a range of temperatures. Although standard solutions are available, they do not cover the anticipated range of Eh values. Commercially prepared solutions may be used, particularly in field testing. The composition and Eh values of standard solutions are shown in Table 2580:II. With reasonable care, these solutions are stable for several months.

b. Eh electrode cleaners: Use either:

1) Aqua regia—Mix 1 volume conc nitric acid with 3 volumes conc hydrochloric acid. Prepare fresh and discard after use.

2) Chromic acid—Dissolve 5 g potassium dichromate, $K_2Cr_2O_7$, in 500 mL conc sulfuric acid.

4. Procedure

a. Instrument calibration: Follow manufacturer's instructions for using pH/millivolt meter and in preparing electrodes for use. Use a shorting lead to verify the zero point on the meter's millivolt scale. Equilibrate the standard solution to the temperature of the sample. Immerse electrodes in the gently stirred, standard solution in a beaker (or flow cell). Turn on meter, placing the function switch in the millivolt mode.

After several minutes for electrode equilibration, record reading to nearest millivolt. If the reading is more than ±10 mV from the theoretical redox standard value at that temperature, replace reference electrode fluid and repeat the measurement. If that procedure fails to bring the reading to within ±10 mV of the theoretical value, polish the sensing element of the indicator electrode with carborundum paper, crocus cloth, or jeweler's rouge. Rinse electrode thoroughly and recheck reading with a fresh portion of the standard solution. If the reading is within ±10 mV of the theoretical value, record it and the temperature. If the reading is not within ±10 mV, repeat the cleaning procedure above or try another electrode. Then rinse the electrode with distilled water and proceed with the sample measurement.

Useful treatments for noble metal electrodes in restoring performance after long periods of use include immersion in warm (70°C) aqua regia for 1 to 2 min or 5 min in 6*N* HNO_3 after bringing to a boil. Alternatively treat with chromic acid solution followed by 6*N* HCl and rinse with water.

b. Sample analysis: Check system for performance with the standard solution, rinse electrodes thoroughly with sample water, then immerse them in the gently stirred sample. Let equilibrate, record Eh value to the nearest millivolt, and temperature to ±0.1°C. Repeat with a second sample portion to confirm successive readings within ±10 mV. Equilibration times vary and may take many minutes in poorly poised solutions. Successive readings that vary less than ±10 mV over 10 min are adequate for most purposes.

Make continuous flow or pumped sample measurements, particularly of poorly poised solutions, in a closed flow cell after external calibration of the electrode system. Recalibrate daily and more frequently if turbid, organic-rich, or high-dissolved-solids solutions are being measured.

See Table 2580:III for recommended combinations of electrodes, standards, and sample handling.

5. Trouble Shooting

a. Meter: Use a shorting lead to establish meter reading at zero millivolts whenever possible. If the meter cannot be zeroed, follow the manufacturer's instructions for service.

TABLE 2580:II. PREPARATION OF REDOX STANDARD SOLUTIONS

Standard Solution	Potentials of Pt Electrode vs. Selected Reference Electrodes at 25°C in Standard Solution					Weight of Chemicals Needed/1000 mL Aqueous Solution at 25°C
	Calomel	Silver:Silver Chloride Ag/AgCl			Standard Hydrogen	
	Hg/Hg_2Cl_2 saturated KCl	KCl 1.00*M*	KCl 4.00*M*	KCl saturated		
Light's solution[14]	+430	+439	+475	+476	+675	39.21 g ferrous ammonium sulfate, $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ 48.22 g ferric ammonium sulfate, $Fe(NH_4)(SO_4)_2 \cdot 12H_2O$ 56.2 mL sulfuric acid, H_2SO_4, sp gr 1.84
ZoBell's solution*[3]	+183	+192	+228	+229	+428	1.4080 g potassium ferrocyanide, $K_4Fe(CN)_6 \cdot 3H_2O$ 1.0975 g potassium ferricyanide, $K_3Fe(CN)_6$ 7.4555 g potassium chloride, KCl

* Store in dark plastic bottle in a refrigerator.

TABLE 2580:III. RECOMMENDED COMBINATIONS FOR SELECTED SAMPLE TYPES

Sample Type	Indicator Electrode(s)	Reference Electrode	Type of Sample Cell
Process stream (low Br^-) (S^{2-})	Pt or Au	Calomel or silver: silver chloride	Closed continuous flow (dual indicator electrode)
(high Br^-)	Pt or Au	Calomel or silver: silver chloride with salt bridge (double junction reference electrode)	
Natural waters			
Surface waters	Pt or Au	Calomel or silver: silver chloride	Closed continuous flow (dual indicator electrode) or beaker
Groundwater	Pt or Au	Calomel or silver: silver chloride	Closed continuous flow (dual indicator electrode)
Soils, sludges	WIG, Pt wire	Calomel or silver: silver chloride	Beaker or soil core

b. Electrodes: If the potentiometer is in good working order, the fault may be in the electrodes. Frequently, renewal of the filling solution for the salt bridge for the reference electrode is sufficient to restore electrode performance. Another useful check is to oppose the emf of a questionable reference electrode with that of the same type known to be in good order. Using an adapter, plug the good reference electrode into the indicator electrode jack of the potentiometer. Then plug the questionable electrode into the reference electrode jack. With the meter in the millivolt position, immerse electrodes in an electrolyte (e.g., KCl) solution and then into a redox standard solution. The two millivolt readings should be 0 ± 5 mV for both solutions. If different electrodes are used (e.g., silver:silver chloride versus calomel or vice versa), the reading should be 44 ± 5 mV for a good reference electrode.

Unless an indicator electrode has been poisoned, physically damaged, or shorted out, it usually is possible to restore function by proper cleaning.

6. Calculation

$$Eh_{system} = E_{observed} + E_{reference\ standard} - E_{reference\ observed}$$

Report temperature at which readings were made.

7. Precision and Bias

Standard solution measurements made at stable temperature, with a properly functioning electrode system should be accurate to within ±10 mV. Calibration precision as reflected by the agreement of dual platinum electrodes versus an Ag:AgCl reference electrode for over a 2-year period has been estimated at ±15 mV (i.e., one standard deviation) in ZoBell's solution (N = 78) at approximately 12°C. Precision on groundwater samples (N = 234) over the same period has been estimated at ±22 mV (i.e., ± one standard deviation) in a closed flow cell.[15]

8. References

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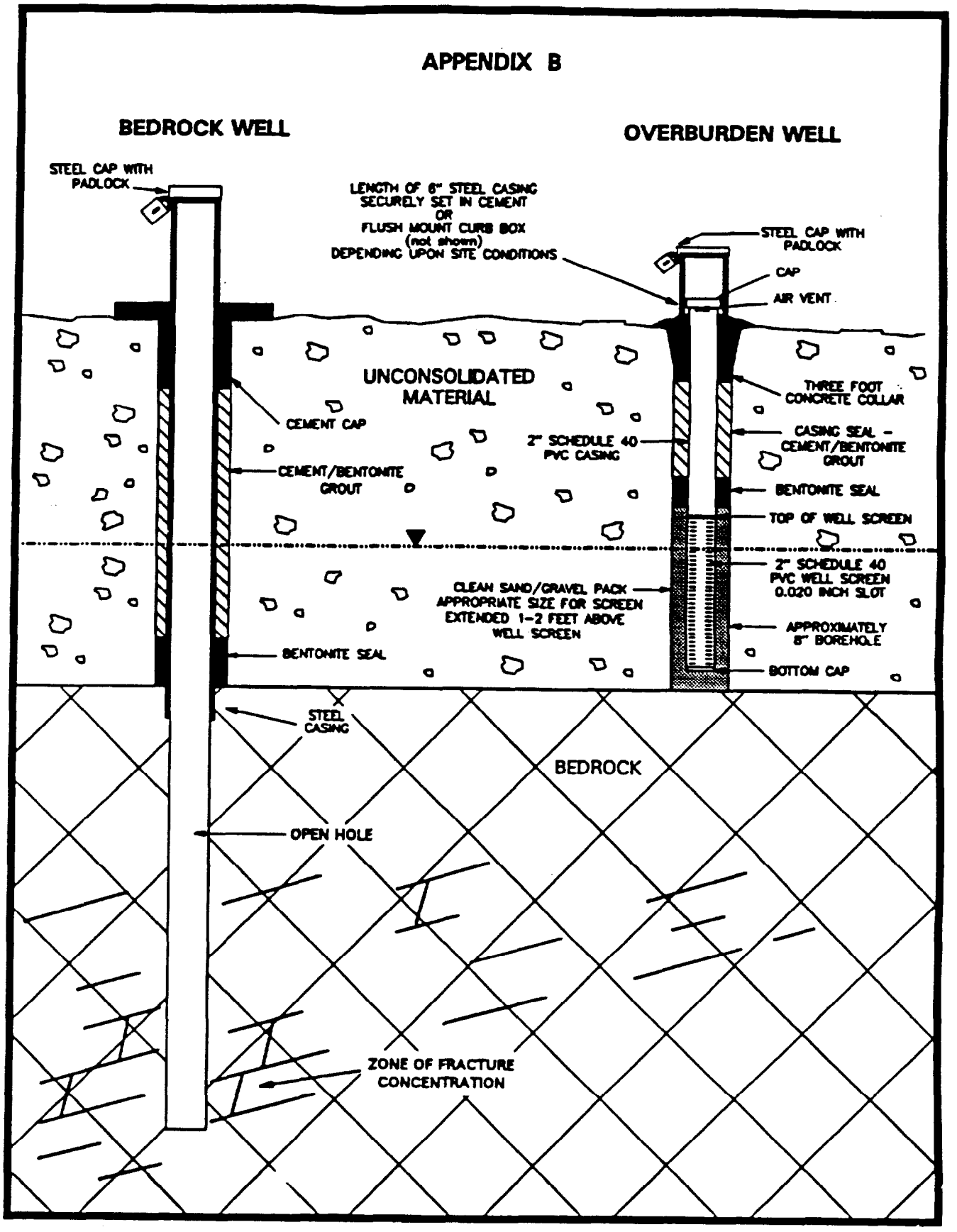
APPENDIX B

MONITORING WELL CONSTRUCTION DETAILS

APPENDIX B


BEDROCK WELL
OVERBURDEN WELL
STEEL CAP WITH PADLOCK
LENGTH OF 6" STEEL CASING SECURELY SET IN CEMENT OR FLUSH MOUNT CURB BOX (not shown) DEPENDING UPON SITE CONDITIONS
STEEL CAP WITH PADLOCK
CAP
AIR VENT
UNCONSOLIDATED MATERIAL
THREE FOOT CONCRETE COLLAR
CEMENT CAP
2" SCHEDULE 40 PVC CASING
CASING SEAL - CEMENT/BENTONITE GROUT
CEMENT/BENTONITE GROUT
BENTONITE SEAL
TOP OF WELL SCREEN
2" SCHEDULE 40 PVC WELL SCREEN 0.020 INCH SLOT
CLEAN SAND/GRAVEL PACK APPROPRIATE SIZE FOR SCREEN EXTENDED 1-2 FEET ABOVE WELL SCREEN
APPROXIMATELY 8" BOREHOLE
BENTONITE SEAL
BOTTOM CAP
STEEL CASING
BEDROCK
OPEN HOLE
ZONE OF FRACTURE CONCENTRATION