

Abbreviated Field Sampling Plan
for
**Naval Submarine Base -
New London**
Groton, Connecticut



Northern Division
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0112

February 1993



HALLIBURTON NUS
Environmental Corporation

R-49-1-93-7

**ABBREVIATED FIELD SAMPLING PLAN
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT**

**COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT**

Submitted to:

Northern Division

Environmental Branch, Code 1823

Naval Facilities Engineering Command

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Submitted by:

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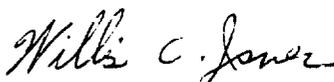
Wayne, Pennsylvania 19087-1710

Contract Number N62472-90-D-1298

Contract Task Order 0112

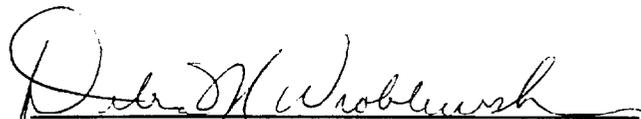
FEBRUARY 1993

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1.0 INTRODUCTION AND PROJECT BACKGROUND

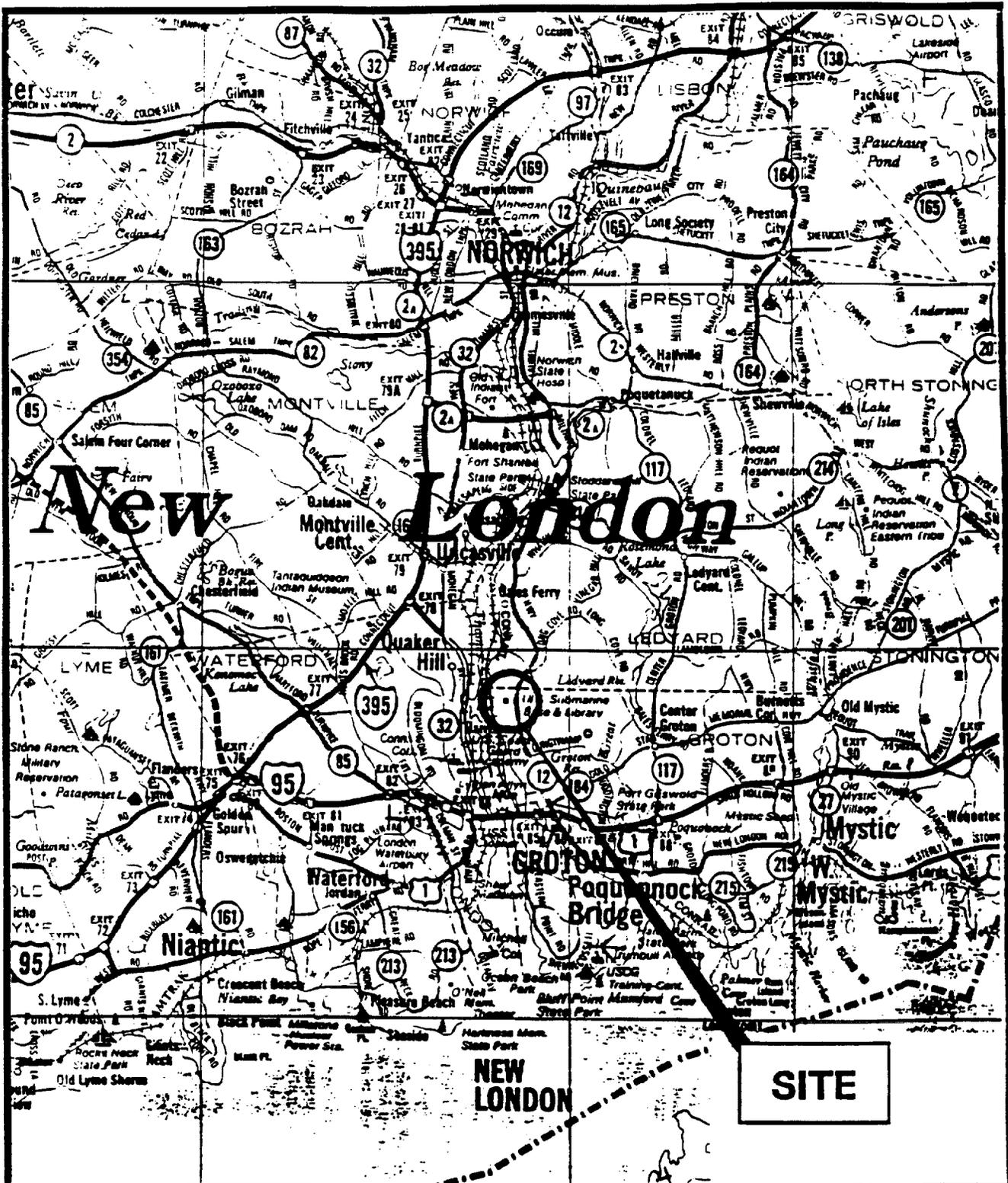
The Northern Division (NORTHDIV) of the Naval Facilities Engineering Command (NAVFAC) has issued a unilateral Contract Task Order (CTO) Number 112 to Halliburton NUS Corporation (Halliburton NUS), under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-90-D-1298.

CTO 112 is for environmental work to support an Action Memorandum for a time critical removal action at Building No. 31 of the Naval Submarine Base - New London (NSB-NLON) located in Groton, Connecticut. This Abbreviated Field Sampling Plan (AFSP) presents a plan to perform sampling and analysis work to define the extent of lead and related battery contamination at Building 31.

1.1 PROJECT BACKGROUND

NSB-NLON was placed on the National Priorities List (NPL) on August 28, 1991 by the U.S. Environmental Protection Agency (USEPA) pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980. NSB-NLON consists of approximately 547 acres of land and associated buildings in southeastern Connecticut, in the towns of Ledyard and Groton. NSB-NLON is situated on the east bank of the Thames River, approximately 6 miles north of Long Island Sound. Figures 1-1 and 1-2 show the site vicinity and the site location, respectively. The SUBASE was established as an official Navy yard in July 1886. The site initially moored small craft and obsolete warships and was used as a coaling station for the Atlantic Fleet. The property was officially established as a permanent submarine base in 1916. The overall base facilities were expanded and a submarine school training facility was established in 1917; the Submarine Medical Center was established in 1918. During World Wars I and II, the SUBASE greatly expanded in size and in the number of buildings to support the submarine fleet.

The SUBASE currently provides a base command for naval submarine fleet activities in the Atlantic Ocean. In addition, the SUBASE contains naval housing, submarine training facilities, military offices, medical facilities, and facilities for the maintenance, repair, and overhaul of submarines.



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

SOURCE: Marshall Penn-York Co. Inc.

Miles
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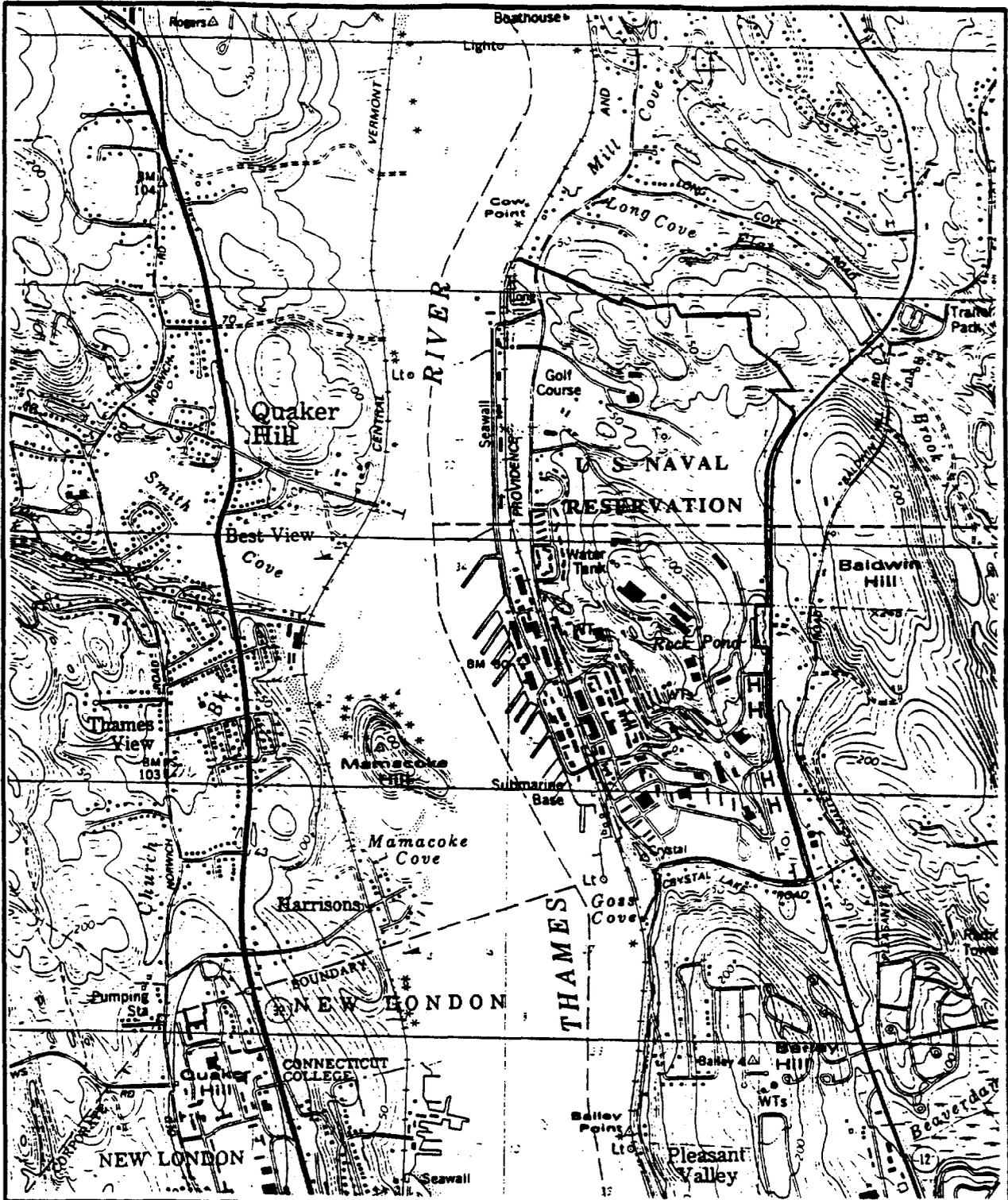
APPROXIMATE SCALE

▲ N

FIGURE 1-1
 SITE VICINITY

ATLANTIC ENVIRONMENTAL SERVICES, INC.

SOURCE: DRAFT NSB-NLON WORK PLAN, NOVEMBER 1992, ATLANTIC ENVIRONMENTAL SERVICES, INC.



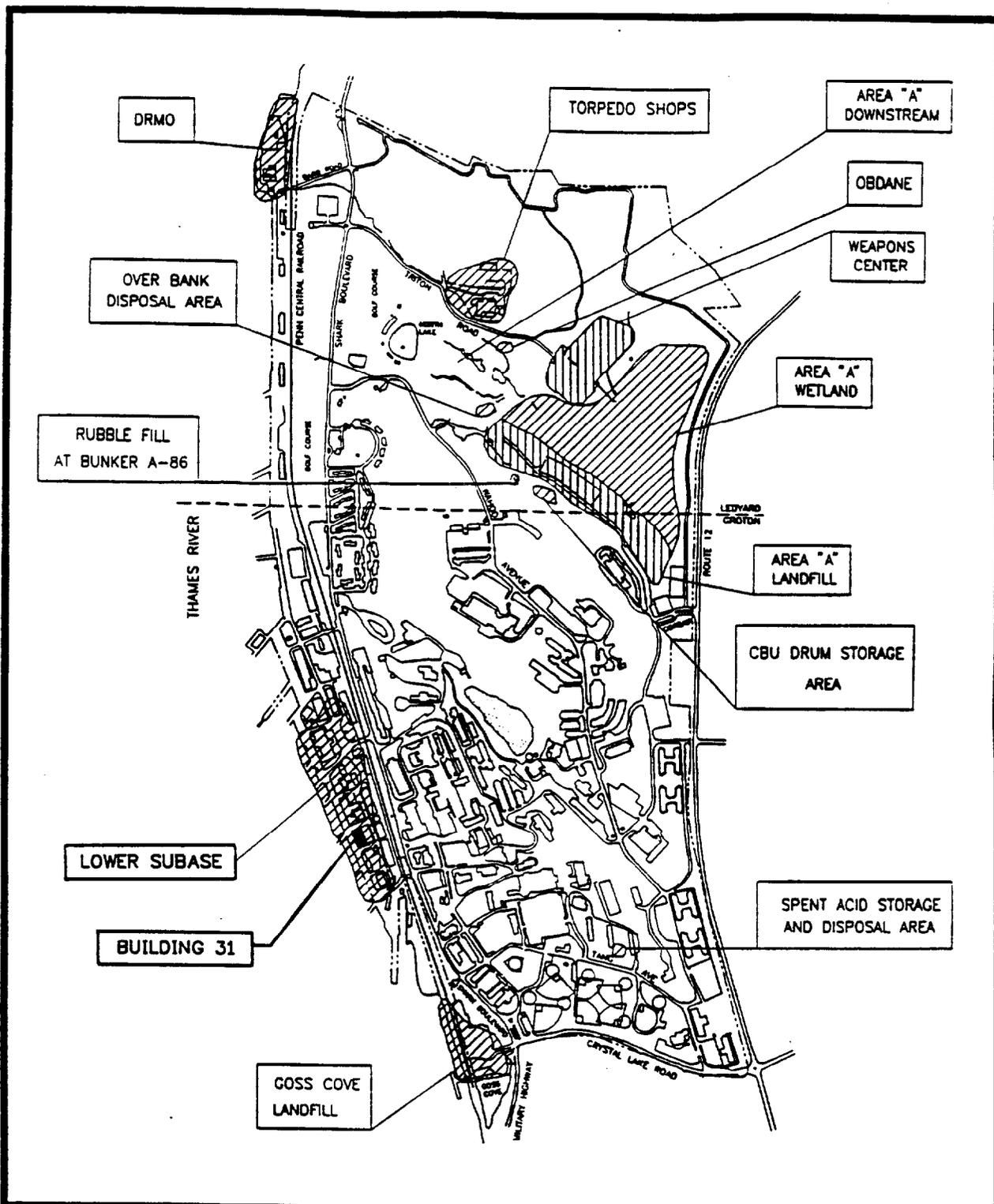
<p>INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT</p>	<p>SOURCE: Uncasville, Ct. U.S.G.S. Topographic Map 1984</p> <p style="text-align: center;">  0 1000 2000' SCALE </p>	<p style="text-align: center;">FIGURE 1-2 SITE LOCATION</p> <p style="text-align: right;">ATLANTIC ENVIRONMENTAL SERVICES, INC.</p>
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Building 31 is located in the lower SUBASE area on Albacore Road as shown in Figure 1-3. Building 31 is used as a hazardous materials storage building and is listed as a Study Area in the Federal Facilities Agreement for future investigation. It was built in 1917 and was originally used as a battery shop. The SUBASE was in the process of replacing the concrete foundation to comply with RCRA regulations when a yellow discoloration was discovered underneath on the concrete slab. Soil samples were taken at depths of 18 inches and 60 inches and elevated lead levels were found. Lead levels ranged from 0.1 to 400 ppm (TCLP). Materials that exhibit a TCLP lead concentration of 5.0 mg/L or greater are classified as a hazardous waste under RCRA (40 CFR Part 261.24). The approximate sample locations are shown on Figure 1-4 and the analytical results are listed in Table 1-1. This analytical data was not validated and the laboratory quality control level is not known. For only samples B-4 and B-10 the TCLP analysis for select metals was also completed. None of the metals analyzed exceeded the regulatory levels except for lead. An additional three soil samples and one concrete sample were analyzed for select metals, TCLP metals, and Appendix IX compounds with no detections except for metals and one soil sample which contained low levels of Polynuclear Aromatic Hydrocarbon (PAH) compounds. The metal concentrations are presented in Table 1-2. No groundwater samples were taken at Building 31. Therefore, it is not known if the lead contamination present in the soil has migrated to the water table. The water table is approximately 6 feet below the soil surface. Previous groundwater sampling at existing monitoring wells in the vicinity of Building 31 indicated very low levels of lead at about 2 ppb (dissolved lead).

Building 31 is approximately 76 feet x 140 feet. A catch basin and floor drains were uncovered when portions of the slab were removed. The footings of the building are 3 feet below the soil surface and supported by timber piles. Excavation of contaminated soil near the footings may jeopardize the structural integrity of the building.

1.2 OBJECTIVE AND SAMPLING STRATEGY

The objective of the work described in this Abbreviated Field Sampling Plan is to obtain sufficient data to define the extent of lead and related battery contaminated soils and groundwater at Building 31. The data will be used to prepare an Action Memorandum and other supporting documentation for a time critical removal action.



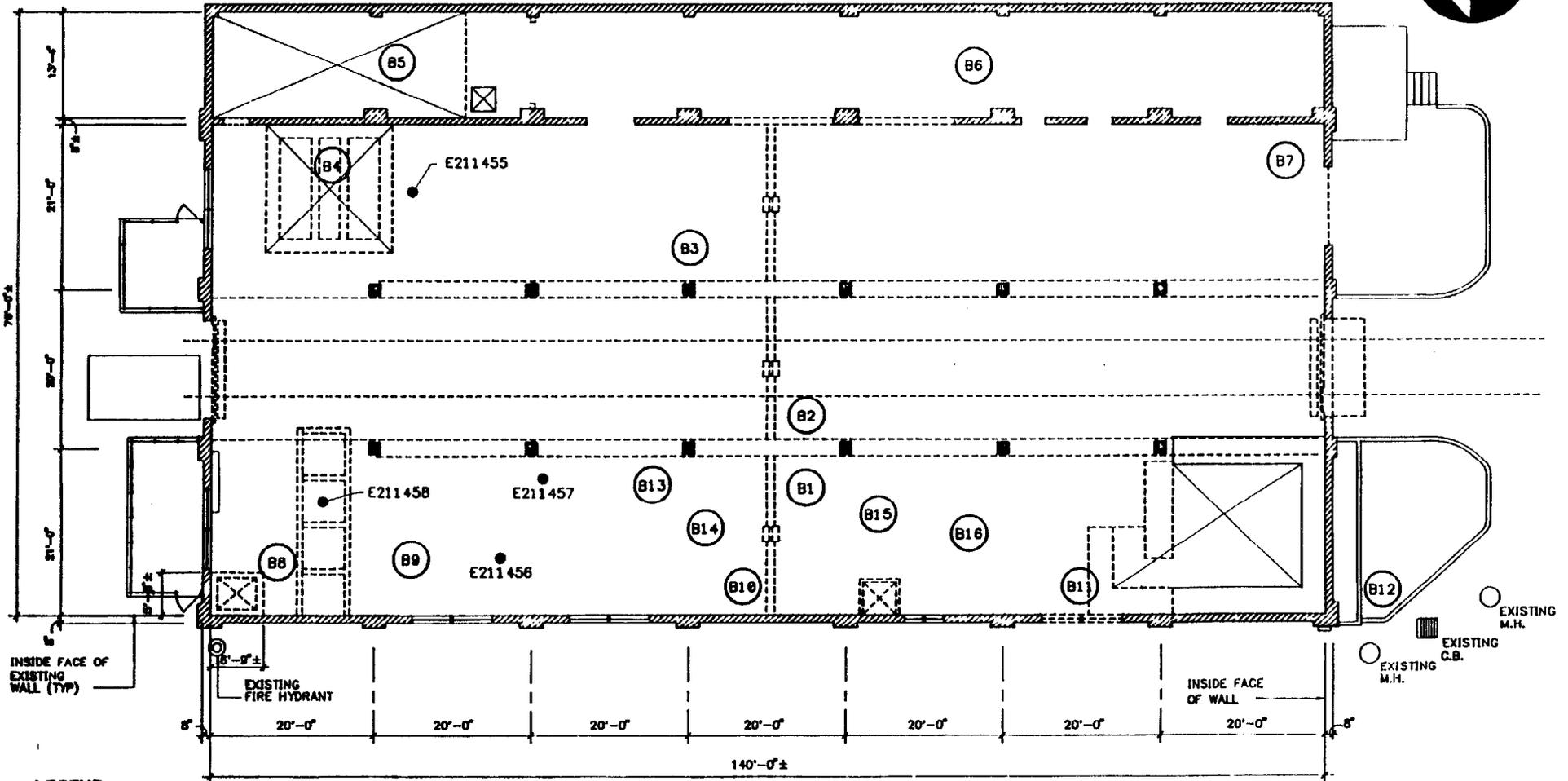
<p>INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT</p>	<p>SOURCE: Naval Submarine Base Existing Conditions April 1985 Loureira Engineering Associates</p> <p style="text-align: center;">  0 600 1200 GRAPHIC SCALE IN FEET </p>	<p>FIGURE 1-3 INSTALLATION RESTORATION STUDY SITES</p> <p>ATLANTIC ENVIRONMENTAL SERVICES, INC.</p>
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SOURCE: DRAFT NSB-NLON WORK PLAN, NOVEMBER 1992, ATLANTIC ENVIRONMENTAL SERVICES, INC.

BUILDING NO. 78



1-6



LEGEND

-  SOIL BORING LOCATION
 -  SURFACE SAMPLE
- E211455

LOCATIONS PREVIOUS SOIL SAMPLING
BUILDING No. 31
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT.

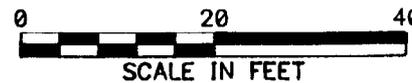


FIGURE 1-4



HALLIBURTON NUS
 Corporation

TABLE 1-1

**CHEMICAL ANALYTICAL RESULTS
SUBSURFACE SOILS - BUILDING 31
TCLP - LEAD
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT**

Sample Location	Concentration (mg/l)	
	18" Depth	60" Depth
B-1	58	19
B-2	0.24	4.2
B-3	0.97	5.3
B-4	0.18	0.13
B-5	0.22	48
B-6	400	57
B-7	BMDL	0.16
B-8	0.11	10
B-9	150	BMDL
B-10	19	1.7
B-11	1.6	BMDL
B-12	0.7	0.13
B-13	97	73
B-14	41	5.5
B-15	33	BMDL
B-16	0.28	250

BMDL - Denotes Below Method Detection Limit.

TABLE 1-2

INORGANIC ANALYTICAL RESULTS
SOILS/CONCRETE, BUILDING 31
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

Analysis	Sample E211455 (Soil) (mg/kg)	Sample E211456 (Soil) (mg/kg)	Sample E211458 (Soil) (mg/kg)	Sample E211457 (Concrete) (mg/kg)	Regulatory Level ¹ (mg/L)
Cyanide	ND	ND	ND	-	-
Antimony	17	13	ND	-	-
Arsenic	2.1	2.0	1.2	-	-
Arsenic - TCLP	ND	ND	ND	ND	5.0
Barium - TCLP	0.58	0.43	0.58	0.43	100.0
Beryllium	ND	ND	ND	-	-
Cadmium	0.7	0.5	ND	-	-
Cadmium - TCLP	ND	ND	ND	ND	1.0
Chromium	12	9.0	8.3	-	-
Chromium - TCLP	ND	ND	ND	ND	5.0
Copper	14	14	29	-	-
Lead	28	4,200	120	-	500-1,000 ²
Lead - TCLP	0.30	270	0.19	0.49	5.0
Mercury	ND	1.2	ND	-	-
Mercury - TCLP	ND	ND	ND	ND	0.2
Nickel	37	34	37	-	-
Selenium	ND	ND	ND	-	-
Selenium - TCLP	ND	ND	ND	ND	1.0
Silver	ND	ND	ND	-	-
Silver - TCLP	ND	0.11	ND	ND	5.0
Thallium	ND	ND	ND	-	-
Zinc	93	62	17	-	-

ND = None Detected/Below Stated Detection Limit.

- = Not analyzed for/no analytical result available.

¹ TCLP Level at which waste is classified as hazardous.

² EPA cleanup level for lead is 500 mg/kg to 1,000 mg/kg based on interim guidance.

1.3**PLAN FORMAT**

Section 1.0 of this Abbreviated Field Sampling Plan contains an Introduction and Background Information. Section 2.0 describe the Procedures and Methods that will be used to implement the field work. Section 3.0 contains the Site-specific Sampling Plan. Sections 4.0 and 5.0 address Field Measurements and Record Keeping. The Site Management Plan is included in Section 6.0. Forms for Field Activities, Standard Operating Procedures, Health and Safety Plan, and Quality Assurance Project Plan are included in the appendices.

2.0 FIELD OPERATIONS

The field investigation to be performed at Building 31 will consist of the sampling of soils (to a depth of approximately 72 inches) to characterize the level and extent of lead contamination present in the soils. To determine if the groundwater quality has been adversely impacted by lead contamination present in the soils, four temporary well points will be installed and sampled within Building 31. One existing upgradient monitoring well (6MW5S) will also be sampled. Approximately 84 subsurface soil samples (three per boring) within Building 31; 21 subsurface soil samples (three per boring) and 2 shallow subsurface (0-6 inch) soil samples located outside the perimeter of Building 31; and 10 groundwater samples (includes 5 wells for 2 rounds of sampling) plus additional (quality assurance/quality control) samples will be obtained for laboratory analysis. Details of the sampling and analysis program are presented in Section 3.0.

2.1 MOBILIZATION/DEMOBILIZATION

Following preliminary approval of this AFSP, Halliburton NUS will complete laboratory and drilling specifications, obtain laboratory and drilling subcontractors, and begin mobilization activities. All field team members will review this AFSP including the Health and Safety Plan (HASP) and Quality Assurance Project Plan (QAPP) contained in the appendices. In addition, a field team orientation meeting will be held to familiarize personnel with the scope of the field activities.

The Field Operations Leader (FOL) will coordinate the mobilization activities upon arrival at Submarine Base New London. The FOL will also make arrangements for all equipment required to conduct the field investigation. The equipment required for the field activities will be loaded in Pittsburgh, our warehouse location, and driven to the site by the FOL and a technician/geologist. It is anticipated that a cargo van vehicle will be rented to provide for the transportation and temporary storage of equipment and samples during the investigation. After field activities are completed, the FOL will demobilize the equipment and drive back to Pittsburgh.

2.2 BOREHOLE DRILLING

A total of 28 soil borings are proposed to be drilled within Building 31, and 7 soil borings are proposed outside Building 31. The purpose of the borings is to characterize subsurface soil contamination. The

proposed locations are shown on Figure 2-1. The hollow stem auger drilling method is the preferred method for advancing the soil borings. At those areas of the building where the existing floor slab has not been removed, concrete coring will be required using an approximately 7 inch outside diameter diamond bit corer in accordance with ASTM D 2113. During drilling operations of overburden material, Standard Penetration Tests and split-spoon sampling shall be performed in accordance with ASTM D 1586-84 (attached in Appendix B). Soil samples will be collected at 2-foot intervals, to a depth of 6 feet (the bottom of the borehole). The use of drilling fluids such as water or slurry is prohibited during soil boring activities.

A lithologic description will be made of each split-spoon sample and a complete log of each boring will be maintained by Halliburton NUS in accordance with NUS SOP GH-1.5: Section 5.0, (see Appendix B). A sample boring log is attached in Appendix A. At a minimum, the Halliburton NUS boring log will contain the following information:

- Sample numbers and types
- Sample depths
- Standard Penetration Test data
- Sample recovery/sample interval
- Soil density or cohesiveness
- Soil color and moisture
- Unified Soil Classification System (USCS) material description and symbol

In addition, depths of changes in lithology, depth to water, OVA/HNU readings, drilling methods, and total depth of each borehole shall be included in each boring log. The driller shall prepare a separate written boring log for each boring drilled, to be submitted to the field geologist at the conclusion of the field activities.

2.3 SUBSURFACE SOIL SAMPLES

Subsurface soil samples will be collected from the well borings at 2 foot intervals, to the bottom to the borehole, (approximately 6 feet), in accordance with ASTM D1586-84. The samplers will have a minimum outside diameter of 3 inches and will be at least 2 feet long to fulfill the sample volume requirements for chemical analysis. The use of drilling fluids is prohibited during soil boring activities.

All samples obtained from the boreholes shall be monitored with an organic vapor monitor. Three samples from each boring will be collected for chemical analysis as described in Section 3.2.2.

2.4 TEMPORARY WELL POINTS

Four temporary groundwater well points will be installed in Building 31. The well points shall have a minimum nominal 2-inch inner diameter and a minimum screen length of 3 feet. The well screen shall be of continuous slot, wire wound construction, with a nominal slot size of 0.01 inches (i.e., 10 slot screen). The well points shall be driven into the ground deep enough that a minimum of 2 feet of the screen is below the static water level at low tide. A screw-on cap shall be placed on the top of the riser pipe of the well point. The top of the cap shall be at least 1 foot above the existing floor grade. An orange mark shall be placed on the top of the riser indicating the reference point elevation for measuring the groundwater level.

A well construction diagram will be completed for each temporary well point installed. A sample of the well construction form is provided in Appendix A.

2.4.1 Well Developments

The temporary well points will be developed after installation to remove the fine material from the area around the monitored interval of the well. Wells will be developed by air lift, bailing and surging, or by pumping, as determined by the field geologist. Wells will be developed until water removed is visibly clear of suspended solids or until approved by the field geologist. Development water will be collected, containerized, and transported to a centralized location on the base (see Section 2.8).

2.4.2 Water Level Measurements

Two complete rounds of water level measurements will be obtained from the new temporary well points. All measurements will be taken within a period of consistent weather conditions to minimize atmospheric/precipitation effects on groundwater levels. Based on the tidal information available, an attempt will be made to measure the groundwater levels at approximately low tide to minimize the tidal influence on the groundwater. Measurements will be taken with a Slope Indicator water level meter using the top of the well point as the reference point for determining depths to water. Water-level measurements will be recorded to the nearest 0.01 foot in the appropriate field logbook. In addition, two hermits and two transducers will be installed to automatically record for a 24-hour period (at 1-hour intervals) the water level at one temporary

well point and the surface water elevation of the Thames River. This will provide a correlation between the groundwater elevation at Building 31 and the changing tidal elevation of the river.

2.4.3 Well Abandonment

After completion of the groundwater sampling and upon receiving verbal notice from the Remedial Project Manager, the temporary well points will be removed and the entire borehole will be backfilled with cement-bentonite grout. The borehole will be pressure backfilled using a tremie pipe. Approximately the top 3 feet will be backfilled with clean concrete and finished to existing grade. It is anticipated that the temporary well points will be removed and backfilled by another subcontractor at the time of the removal action. Those well points that are located in areas where the soils are to be excavated to remove contaminated hot spots, will not require backfilling. At these locations, the well points will be removed by excavation along with the contaminated soil. It is anticipated that all contaminated soils so removed will be replaced with clean soil and compacted in uniform lifts (not to exceed 8 inches in depth).

2.5 SURFACE SOIL SAMPLES

A total of two surface soil samples will be obtained from the area between Building 31 and Building 78 for lead analysis. Sample locations, shown in Figure 2-1, were chosen such that when combined with the soil boring sampling, the general horizontal extent of surface soil contamination, if present, adjacent to Building 31 could be estimated. Samples will be taken at a depth of 0 to 0.5 feet below the ground surface. Section 3.2.3 details the sampling procedures for the surface soils.

2.6 SURVEYING

To permit the plotting of sampling points, all new temporary well points, soil borings, and surface soil samples will be surveyed by Halliburton NUS staff following installation. The Halliburton NUS surveying staff are not registered or professional surveyors. Horizontal locations will be surveyed to the corners of Building 31. Well points, soil borings, and surface samples horizontal locations will be surveyed to the nearest 0.10 foot at each well point.

For each temporary well point, the elevation shall be surveyed to the nearest 0.01 foot at the measuring point where the well riser is marked. In addition, ground surface elevations will be surveyed to the nearest 0.1 foot at each well point. Vertical elevations will be referenced to an arbitrary datum (benchmark set on

Building 31). An elevation shall also be determined to the nearest 0.01 foot at the pier adjacent to the Thames River where the hermit and transducer are installed to measure the tidal range.

2.7 EQUIPMENT DECONTAMINATION

The equipment involved in field sampling activities will be decontaminated prior to and during drilling and sampling activities. This equipment includes drilling rigs, downhole tools, augers, well points and screens, and all sampling equipment. Personal decontamination is addressed in the Health and Safety Plan.

2.7.1 Major Equipment

All downhole drilling equipment and tools shall be steam cleaned prior to beginning work, between well borings, any time the drilling rig leaves the site prior to completing a boring, and at the completion of the drilling program. In addition, well points and fittings shall be steam cleaned prior to being installed.

These decontamination operations will consist of washing the equipment using a high-pressure steam wash. All decontamination activities will take place at a location determined during mobilization. It is assumed that the base will provide a suitable location for decontamination operations along with potable water and electricity. Additional requirements for drilling equipment decontamination can be found in Halliburton NUS SOP GH-1.6: Section 5.0. (see Appendix B).

2.7.2 Sampling Equipment

All direct contact sampling equipment will be decontaminated both prior to beginning field sampling and between samples. The following decontamination steps will be taken:

- Potable water rinse
- Alconox or Liquinox detergent wash
- Potable water rinse
- Nitric acid rinse^(a)
- Analyte-free water rinse^(b)
- Methanol rinse^(b)
- Distilled/deionized water rinse^(b)

- Analyte-free water rinse^(a)
- Air dry

^(a) Not required for stainless steel equipment.

^(b) Required only for volatiles, semivolatiles, or pest/PCBs samples.

^(c) Not required for volatiles, semivolatiles, or pest/PCBs.

Field analytical equipment such as pH, conductivity and temperature instrument probes will be rinsed first with analyte-free water, then with the sample liquid.

2.8 WASTE HANDLING

All development and purge liquids will be collected, containerized, and stored on site in DOT approved (Specification 17-C), 55 gallon drums. All drill cuttings will be backfilled into the boring and any excess will be consolidated within Building 31 as determined by the FOL. All drums will be sealed and labeled with drum contents, well/boring number, and date. NSB-NLON will take possession of the drums upon project completion and will determine whether off site disposal and/or treatment is required after receiving analytical results from the sampling.

3.0 ENVIRONMENTAL SAMPLING

3.1 SAMPLE ANALYSIS SUMMARY

Samples collected at the site will be submitted for the laboratory analyses presented in Tables 3-1 and 3-2. These tables indicate the analytical parameters, preservation methods, holding times, bottle requirements, and analytical methods for each sample.

3.2 SAMPLING PROCEDURES

This section discusses the procedures for performing environmental sampling at the site. Sampling to be performed at the site includes groundwater, surface soil, and subsurface soil.

3.2.1 Groundwater Sampling

Groundwater samples will be obtained from the four temporary monitoring well points (GW-1 through GW-4) during two rounds of sampling. Groundwater samples will also be collected from an existing background monitoring well (6MW5S) during the two rounds of sampling. The first round of sampling will take place as soon as the temporary well points are installed and developed. The second round will be collected at the completion of the other sampling activities, and prior to demobilization. Only groundwater will be sampled during the second round. Groundwater sampling will be conducted in accordance with Halliburton NUS SOP SA-1.1 Section 5.0 (see Appendix B).

Prior to obtaining samples, water levels will be measured and the wells will be purged using a dedicated bailer or a suction pump. Three to six well volumes will be purged. If the wells are purged dry with less than three well volumes removed, the water level in the well will be allowed to recover to at least 70 percent of the original capacity prior to sampling. In the event that recovery is slow, samples will be collected within 24-hours of purging. An attempt will be made to measure and sample the groundwater at approximately low tide to minimize the tidal influence on the groundwater. Field measurements of pH, temperature, and specific conductance will be taken for each well volume during purging according to Halliburton NUS SOP SF-1.1: Section 5.0 (see Appendix B). Stabilization of the above parameters is defined as follows:

TABLE 3-1

**ANALYTICAL PROGRAM SUMMARY
SOIL AND GROUNDWATER SAMPLES
NAVY SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT**

Parameter	Method	Sample Type	No. of Samples	Equipment Rinsate ²	Field Blanks ³	Trip Blanks ⁴	Duplicates ⁵	Total Samples
Lead	CLP Protocol (3/90)	Surface Soil	2	1	0	0	1	4
Lead	CLP Protocol (3/90)	Subsurface Soil	105	8	2	0	11	126
TCLP (lead) ¹	SW 1311 SW 6010	Subsurface Soil	28	0	0	0	0	28
pH	E 150.1	Subsurface Soil	84	0	0	0	9	93
Appendix 8 Metals	SW 6010 SW 7000	Subsurface Soil	4	1	0	0	0	5
TCL Volatiles	CLP Protocol (3/90)	Subsurface Soil	4	1	0	2	1	8
TCL Semivolatiles	CLP Protocol (3/90)	Sursurface Soil	4	1	0	0	1	6
TCL Pest/PCBs	CLP Protocol (3/90)	Subsurface Soil	4	1	0	0	1	6
TAL - Metals	CLP Protocol (3/90)	Subsurfacc Soil	4	1	0	0	1	6
TAL - Cyanide	CLP Protocol (3/90)	Subsurface Soil	4	1	0	0	1	6
TCL Volatiles (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	2	1	9
TCL Semivolatiles (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	2	1	7
TCL Pest/PCBs (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	0	1	7

**TABLE 3-1
ANALYTICAL PROGRAM SUMMARY
SOIL AND GROUNDWATER SAMPLES
NAVY SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT
PAGE TWO**

Parameter	Method	Sample Type	No. of Samples	Equipment Rinsate ²	Field Blanks ³	Trip Blanks ⁴	Duplicates ⁵	Total Samples
TAL Metals ⁶ (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	0	1	7
TAL Cyanide (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	0	1	7
Appendix-8 ⁸ Metals (total) ⁹ (2-rounds)	200 Series	Groundwater	7	1	0	0	1	9
Appendix-8 ⁸ Metals (Dissolved) ⁷ (2-rounds)	200 Series	Groundwater	7	1	2	0	1	11

¹ TCLP = Toxicity Characteristics Leaching Procedure, Lead.

² Equipment Blank - Samples obtained by pouring analyte-free water over sample collection equipment (bailer, etc.) after decontamination. Assesses the effectiveness of field decontamination procedure. Obtained at a frequency of 1/day/media/analysis but analyzed every other day unless positive detection are recorded. Number of samples reflects the number of actual laboratory analyses performed.

³ Field Blank - Samples consisting of the source water used in (1) steam cleaning and/or (2) decontamination. Obtained at a frequency of 1/event/media.

⁴ Trip Blank - Prepared at the laboratory using analyte-free deionized water, and accompanies samples for VOCs at all times until analysis at the laboratory.

⁵ Duplicates - A single sample split into two portions during a single act of sampling. Assess the overall precision of the sampling and analysis program. Obtained at a frequency of 10% of the number of samples.

⁶ Total Metals - For the determination of total metals the sample is not filtered before acidification.

⁷ Dissolved Metals - For the determination of dissolved metals the sample must be field filtered through a 0.45 micron filter before acidification.

⁸ Appendix-8 Metals shall only include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.

TABLE 3-2

**SUMMARY OF ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS,
AND HOLDING TIMES
NAVY SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT**

Media	Analysis	Number of Samples	No. of Containers Per Sample	Container Type	Preservation Requirements	Holding Times
Surface Soil	Lead (total recoverable)	4	1	4 oz. amber wide mouth glass jar	Cool to 4°C	6 months
Subsurface Soil	Lead (total recoverable)/pH TCLP (lead)/Appendix-8 Metals ^(a)	126	2	1-4 oz. amber wide mouth glass jar 1-32 oz. wide mouth glass jar	Cool to 4°C	6 months ^(b)
Subsurface Soil	TCL Volatiles	8	2	60 ml VOA vial	Cool to 4°C	14 days
Subsurface Soil	TCL Semivolatiles	6	1	4 oz. amber wide mouth glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Subsurface Soil	TCL Pest/PCBs	6	1	4 oz. amber wide mouth glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Subsurface Soil	TAL Metals and Cyanide	6	1	8 oz. wide mouth jar	Cool to 4°C	6 months ^{(b)(c)}
Groundwater	TCL Volatiles	9	2	40 ml VOA vial	HCL to pH<2, Cool to 4°C	14 days
Groundwater	TCL Semivolatiles	7	1	80 oz. amber glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Groundwater	TCL Pest/PCBs	7	1	80 oz. amber glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Groundwater	TAL Metals (total)	7	1	1-liter polyethylene bottles	HNO ₃ to pH<2 Cool to 4°C	6 months ^(b)

**TABLE 3-2
SUMMARY OF ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS,
AND HOLDING TIMES
NAVY SUBMARINE BASE, NEW LONDON
GROTON, CONNECTICUT
PAGE TWO**

Media	Analysis	Number of Samples	No. of Containers Per Sample	Container Type	Preservation Requirements	Holding Times
Groundwater	TAL Cyanide	7	1	1-liter polyethylene bottles	NAOH to pH > 12 Cool to 4°C	14 days
Groundwater	Appendix 8 Metals (total)	9	1	1-liter polyethylene bottles	HNO ₃ to pH < 2 Cool to 4°C	6 months ^(b)
Groundwater	Appendix 8 Metals (dissolved)	11	1	1-liter polyethylene bottles	HNO ₃ to pH < 2 Cool to 4°C Field filtered to .45μ	6 months ^(b)

(a) All samples will be analyzed for total recoverable lead. Additionally only 31 of these samples will be analyzed for TCLP (lead) and 6 samples will be analyzed for Appendix 8 Metals. Also, pH analyses will be performed on 93 of these samples.
 (b) The holding time for mercury analysis is 28 days.
 (c) The holding time for cyanide is 14 days.

temperature ± 1 C, pH ± 0.2 units, SC ± 5 percent. If these parameters do not stabilize after 3 volumes, up to 6 volumes may be removed, as determined by the field geologist.

Dedicated stainless steel or PVC bailers with dedicated polyethylene rope as bailing line will be used for sample collection.

Five groundwater wells will be sampled during 2-rounds for total (unfiltered) and dissolved (filtered) metals as described in the following paragraph. Dissolved analysis requires the samples to be field filtered through a 0.45μ filter immediately after sampling. Groundwater samples will be poured directly from the bailer into the appropriate sample bottles for analysis. For those samples requiring filtering, the initial sample bottle will be unpreserved. Once filtered, the sample will then be preserved as specified in Table 3-2.

Two temporary well points (GW-01 and GW-02) and one background monitoring well (to be determined) will be analyzed for the full Target Compound List (TCL) and the full Target Analyte List (TAL) plus cyanide during the first round of groundwater sampling (note that these samples are unfiltered). This sampling is proposed because the complete history of Building 31 is not available. The two remaining temporary wells will be analyzed for Appendix 8 Metals during the first round of sampling and all five wells will be analyzed for Appendix 8 Metals during the second round.

All pertinent field data shall be recorded using the appropriate sample log sheet (see Halliburton NUS SOP SA-6.3, Appendix B) and the field log book. A groundwater sample log sheet is attached in Appendix A.

Table 3-1 summarizes the groundwater and soil sampling program. Samples will be preserved in accordance with Halliburton NUS SOP SF-1.2 (see Appendix B). Sample handling and preservation requirements are shown in Table 3-2. Chain-of-Custody requirements are discussed in the Quality Assurance Project Plan attached as Appendix D.

3.2.2 Subsurface Soil Sampling

Subsurface soil samples will be collected from 35 soil borings (28 inside and 7 outside Building 31). Soil samples will be collected in accordance with Halliburton NUS SOP GH-1.3 (see Appendix B). All samples obtained from the boreholes shall be monitored with an organic vapor monitor and three samples from each boring will be collected for laboratory analysis. Soil samples for laboratory analysis will be collected from 0 to 2.0 feet, 2.0 to 4.0 feet, and 4.0 to 6.0 feet below the ground surface (three per boring). Upon sample

retrieval, the material to be analyzed will be homogenized and distributed to the required sample containers. Soil samples for volatile organics will not be homogenized prior to sampling.

All 105 subsurface soil samples will be analyzed for lead. Eighty-four of these samples (those within Building 31) will also be analyzed for pH. Also, one third of the 84 samples (28) will be analyzed for TCLP lead. The TCLP analysis for lead will only be performed on one sample per boring (the sample having the highest lead concentration as determined by the laboratory). Four of the borings having the highest TCLP lead concentrations will also be analyzed for Appendix 8 Metals. In addition, four of the subsurface samples collected will also be analyzed for the full Target Compound List (TCL) and Target Analyte List (TAL) metals plus cyanide as selected by the FOL based on field screening. Field screening for volatile organic compounds (VOCs), using an HNu or OVA, will be conducted continuously during drilling operations and on each split-spoon sample obtained. If a sufficient quantity of sample is not recovered from the split-spoon sampler to also accommodate the TCL and TAL analyses, an additional soil boring will be installed adjacent to the initial boring.

Split-spoon samplers will be decontaminated between samples as described in Section 2.7.2. Sample handling and chain-of-custody requirements are addressed in Section 3.3. All pertinent field data will be recorded using the appropriate sample log sheet (see Halliburton NUS SOP GH-1.3, see Appendix B) and the field log book. A soil sample log sheet is attached in Appendix A.

Table 3-1 summarizes the subsurface soil sampling program. Samples will be preserved in accordance with Halliburton NUS SOP SF-1.2 (see Appendix B). Sample handling and preservation requirements are shown in Table 3-2.

3.2.3 Surface Soil Sampling

Surface soil samples (SO-01 and SO-02) will be collected at two locations adjacent to Building 31. The samples will be collected in accordance with Halliburton NUS SOP GH-1.3. Soil samples will be collected using either stainless steel or disposable plastic trowels and will be homogenized prior to filling the required sample containers. All surface soil samples will be analyzed for lead to determine the approximate lateral extent of lead contamination near Building 31.

If stainless steel trowels are utilized during sampling, the samplers must be decontaminated between samples as described in Section 2.7.2. Sample handling and chain-of-custody requirements are addressed

in Section 3.3 All pertinent field data will be recorded using the appropriate sample log sheet (see Halliburton NUS SOP GH-1.3, (see Appendix B) and the field log book.

Table 3-1 summarizes the surface soil sampling program. Samples will be preserved in accordance with Halliburton NUS SOP SF-1.2, (see Appendix B). Sample handling and preservation requirements are shown in Table 3-2.

3.3 SAMPLE HANDLING

Sample handling includes the field-related considerations concerning the selection of sample containers, preservatives, allowable holding times and analyses requested. In addition, sample identification, packaging and shipping will be addressed.

The EPA User's Guide to the Contract Laboratory Program (EPA, December 1986), and the Federal Register (EPA, October 26, 1984) address the topics of containers and sample preservations. Table 3-2 provides a summary of these sample handling considerations.

3.3.1 Sampling Identification System

Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of a three-segment, alpha-numeric code that identifies the sample medium and location, sample depth (in the case of soil samples), and QA designation, if required. In addition, because groundwater will be sampled during two rounds, an additional segment will be attached to the end of groundwater sample numbers. Groundwater sample numbers will include a "-1" or "-2" depending upon whether the sample was obtained during Round I or Round II.

Any other pertinent information regarding sample identification will be recorded in the field log books.

The alpha-numeric coding to be used in the sample system is explained in the diagram and the subsequent definitions:

(AANN)	-	(NNN)	-	(A)
(Medium & Location)		(Sample depth)		(QA designation)

Character Type:

A = Alpha
N = Numeric

Medium:

GW = Groundwater from well point or monitoring well
SB = Soil sample from one the 28 soil borings
SO = Surface and shallow subsurface soil samples.

Sample Location:

Subsurface soil = soil boring number.
Surface soil = sample location number.
Groundwater sample = well number.

Sample Depth:

For soil samples = End depth, in feet, of sample.
Not used for groundwater

QA Sample Designation:

D = Duplicate (Soil/Groundwater)
B = Equipment Rinsate Blank
F = Field Blank
T = Trip Blank

For example, a groundwater sample collected during Round 1 from well point 4 would be designated as:

GWO4-1

A subsurface soil sample taken from soil boring number 4 at a depth of 4 to 6 feet would be:

SB04-6.0

All QC samples will assigned a sequential sample number. A designation which blinds the sample's QC identity will be used for all field duplicates. The field duplicate (D) matrix spike (MS) and matrix spike duplicate (MSD) samples will be collected from the same station.

For example, the first field duplicate collected during the sampling of groundwaters in support of the Building 31 investigation would be assigned the tracking number GW 31-D-1.

Information regarding sample labels and tags to be attached before shipment to a laboratory is contained in Section 5.2 of the Halliburton NUS SOP SA-6.1 (see Appendix B).

3.3.2 Sample Packaging and Shipping

Samples will be packaged and shipped in accordance with Halliburton NUS SOP SA-6.2 (see Appendix B). The FOL will be responsible for completion of the following forms:

- Sample Labels
- Chain-of-Custody Forms
- Appropriate labels applied to shipping coolers
- Chain-of-Custody Labels
- Federal Express Air Bills

3.4 SAMPLE CUSTODY

Custody of samples must be maintained and documented at all times. Chain-of-custody begins with the collection of the samples in the field. Section 5.3 of Halliburton NUS SOP SA-6.1 (see Appendix B) provides a description of the chain-of-custody procedures to be followed. A sample chain-of-custody form is attached in Appendix A.

3.5 QUALITY CONTROL SAMPLES

In addition to regular calibration of field equipment and appropriate documentation, quality control (QC) samples will be collected or generated during environmental sampling activities. QC samples include field duplicates, field blanks, and equipment rinsate blanks. Trip blanks will be provided by the analytical laboratory. Additional laboratory QA/QC sample analyses (such as laboratory duplicate and matrix spike analyses are discussed further in Appendix D. Table 3-1 presents the type and number of required QC samples. Each type of field QC sample is defined as follows:

Field Duplicates - Field duplicates are two samples collected (1) independently at a sampling location in the case of groundwater or (2) a single sample split into two portions in the case of soil. Duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. Ten percent of all samples for each media shall be field duplicates. Duplicates shall be analyzed for the same parameters in the laboratory.

Equipment Rinsate Blanks - Equipment rinsate blanks are obtained under representative field conditions by running analyte-free water through sample collection equipment (bailer, split spoon, corer, etc.) after decontamination and placing it in the appropriate sample containers for analysis. Equipment blanks will be used to assess the effectiveness of decontamination procedures. Equipment blanks will be collected for each type of non-dedicated sampling equipment used and will be submitted at a frequency of one per day per media. Equipment blanks however from only every other day will be analyzed. Equipment blanks not slated for analysis will be marked "hold" on the chain-of-custody reports. Those not analyzed will be retained by the laboratory until completion of field activities. It will be the responsibility of the FOL to communicate to the laboratory whether an equipment blank is, or is not, to be analyzed as stated above.

Field Blanks - Field blanks are obtained by sampling the water(s) used for decontamination during the field investigation. Samples consist of the source water used in (1) steam cleaning of large equipment and (2) analyte-free water used for decontamination of sampling equipment. Field blanks will be used to confirm the effectiveness of decontamination procedures, and to determine if the analyte-free water or the potable water (used for steam cleaning) may be contributing to sample contamination. Field blanks will be collected for each type of water used for decontamination and will be submitted at a frequency of one per sampling event per media.

Trip Blanks - Trip blanks are defined as samples which originate from analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with the volatile organic compound (VOC) samples. One trip blank should accompany each cooler containing VOCs, should be stored at the laboratory with the samples, and analyzed by the laboratory. Trip blanks are only analyzed for VOCs.

4.0 FIELD MEASUREMENTS

Certain field measurements will be recorded during sampling activities including temperature, pH and specific conductance. All instruments used in the field will be calibrated according to the procedures described below.

4.1 EQUIPMENT CALIBRATION

Several monitoring instruments may be used during field activities; these include:

- HNu photoionization indicator device
- OVA flame ionization indicator device
- Temperature probe
- Specific conductance meter
- pH meter
- Electronic water-level meter
- Hydrologic Monitor (Hermit and Transducer)

The electronic water-level meter will be calibrated prior to mobilization and periodically at the discretion of the FOL. The remaining instruments will be calibrated daily or according to the manufacturer's operating manual.

Calibration will be documented on an equipment calibration log. A sample calibration log is attached in Appendix A. During calibration, an appropriate maintenance check will be performed on each piece of equipment. If damaged or defective parts are identified during the maintenance check and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until the defective parts are repaired or replaced.

4.2 EQUIPMENT MAINTENANCE

Measuring equipment used in environmental monitoring or analysis and test equipment used for calibration and maintenance shall be controlled by established procedures. Measuring equipment shall have an initial

calibration and shall be recalibrated at scheduled intervals against certified standards. Equipment will be calibrated periodically.

Halliburton NUS maintains a large inventory of sampling and measurement equipment. In the event that failed equipment cannot be repaired, replacement equipment will be shipped to the site by overnight express carrier to minimize downtime.

5.0 RECORD KEEPING

In addition to chain-of-custody records, certain standard forms will be completed for sample description and documentation. These shall include sample log sheets (for soil, and groundwater samples), boring logs, well completion diagrams, daily record of subsurface investigation reports, and logbooks. These forms are attached in Appendix A.

A bound/weatherproof field notebook shall be maintained by each sampling event leader. All information related to sampling or field activities will be recorded in the field notebook. This information will include, but is not limited to, sampling time, weather conditions, unusual events, field measurements, descriptions of photographs, etc.

A bound/weatherproof site logbook shall be maintained by the FOL. The requirements of the site logbook are outlined in Halliburton NUS SOP SA-6.3 (see Appendix B) Section 5 and 7. This book will contain a summary of the day's activities and will reference the field notebooks when applicable.

Each field team leader who is supervising a drilling subcontractor activity must complete a Daily Record of Subsurface Investigation Report. This report documents the activities and progress of the daily drilling activities. The information contained within this report is used for billing verification and progress reports. The driller's signature is required at the end of each working day to verify work accomplished, hours worked, standby time, and materials used.

At the completion of field activities, the FOL shall submit to the Project Manager all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample log sheet, drilling logs, daily logs, etc.

6.0 SITE MANAGEMENT

6.1 BASE SUPPORT

The CLEAN Remedial Project Manager (RPM) is

Deborah Stockdale
Northern Division
Naval Facilities Engineering Command
10 Industrial Highway
Mail Stop 82
Lester, Pennsylvania 19113-2090
(215) 595-0567

The NSB-NLON Point of Contact is:

William L. Mansfield
Director, Environmental Division
Naval Submarine Base, New London
Code 803
Groton, Connecticut 06349-5100
(203) 449-2276

Throughout the duration of the site inspection activities, various support functions will be provided by NSB-NLON personnel as described below:

- Identify and flag underground utilities and issue digging or other appropriate permits prior to the commencement of digging or drilling operations.
- Take custody of any drill cuttings, well development fluids, and decontamination fluids, requiring proper disposal according to applicable state and/or Federal regulations.

- Make available existing engineering plans, drawings, diagrams, aerial photographs, digitized map files, etc., to facilitate evaluation of the site under investigation.
- Make available all historical data, background geological and hydrogeological information, and initial site investigation documents.

In addition, NSB-NLON personnel will aid in arranging the following:

- A supply (e.g., fire hydrant) of large quantities of potable water for equipment cleaning, etc., to be coordinated through Public Works.
- An electrical power source for ventilating Building 31 (if required).

6.2 CONTINGENCY PLAN

In the event of problems which may be encountered during the site inspection activities, the HALLIBURTON NUS Project Manager will be notified immediately, followed by the NSB-NLON Point of Contact. The Project Manager will determine a course of action so as to not interfere with the schedule or budget. All contingency plans will be approved through the NSB-NLON point of Contact and the RPM before being enacted.

APPENDIX A

FORMS FOR FIELD ACTIVITIES

**OVERBURDEN
MONITORING WELL SHEET**

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		

GROUND ELEVATION

ELEVATION OF TOP OF SURFACE CASING : _____

ELEVATION OF TOP OF RISER PIPE : _____

STICK - UP TOP OF SURFACE CASING : _____

STICK - UP RISER PIPE : _____

TYPE OF SURFACE SEAL : _____

I.D. OF SURFACE CASING : _____

TYPE OF SURFACE CASING : _____

RISER PIPE I.D. : _____

TYPE OF RISER PIPE : _____

BOREHOLE DIAMETER : _____

TYPE OF BACKFILL : _____

ELEVATION / DEPTH TOP OF SEAL : _____ / _____

TYPE OF SEAL : _____

DEPTH TOP OF SAND PACK : _____

ELEVATION / DEPTH TOP OF SCREEN : _____ / _____

TYPE OF SCREEN : _____

SLOT SIZE x LENGTH : _____

I.D. OF SCREEN : _____

TYPE OF SAND PACK : _____

ELEVATION / DEPTH BOTTOM OF SCREEN : _____ / _____

ELEVATION / DEPTH BOTTOM OF SAND PACK : _____ / _____

TYPE OF BACKFILL BELOW OBSERVATION WELL : _____

ELEVATION / DEPTH OF HOLE : _____ / _____

SAMPLE LOG SHEET



- Surface Soil
- Subsurface Soil
- Sediment
- Lagoon / Pond
- Other _____

Page _____ of _____

Case # _____

By _____

Project Site Name _____ Project Site Number _____

NUS Source No. _____ Source Location _____

Sample Method:		Composite Sample Data	
		Sample	Time
Depth Sampled:		Color / Description	
Sample Date & Time:			
Sampled By:			
Signature(s):			
Type of Sample <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite			
		Sample Data	
		Color	Description. (Sand, Clay, Dry, Moist, Wet, etc.)
Analysis:	PRESERV :	Observations / Notes	
		Organic	Inorganic
		Traffic Report #	
		Tag #	
		AB #	
		Date Sampled	
		Time Sampled	
		Lab	
		Volume	

APPENDIX B

HALLIBURTON NUS STANDARD OPERATING PROCEDURES

- GH-1.3, Section 5.0: Soil and Rock Sampling**
- GH-1.4, Section 5.0: Soil and Rock Drilling Methods**
- GH-1.5, Section 5.0: Borehole and Sample Logging**
- GH-1.6, Section 5.0: Decontamination of Drilling Rigs and Sample Equipment**
- GH-1.7, Section 5.0: Groundwater Monitoring Point Installation**
- SA-1.1, Section 5.0: Groundwater Sample Acquisition**
- SA-6.1, Section 5.0: Sample Identification and Chain-of-Custody**
- SA-6.2, Section 5.0: Sampling Packaging and Shipping**
- SA-6.3, Section 5.0: Site Logbook**
- SF-1.1, Section 5.0: On-Site Water Quality Testing**
- SF-1.2, Section 5.0: Sample Preservation**
- SF-2.3, Section 5.0: Decontamination of Chemical Sampling and Field Analytical Equipment**
- ASTM D 1586-84, Section 7.0: Penetration Test and Split-Barrel Sampling of Soils**

Subject SOIL AND ROCK SAMPLING	Number GH-1.3	Page 3 of 13
	Revision 2	Effective Date 05/04/90

5.0 PROCEDURES

5.1 SUBSURFACE SOIL SAMPLES

Subsurface soil samples are used to characterize subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants in the subsurface. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Where the remedial activities may include in-situ treatment or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Engineering and physical properties of soil may also be of interest should site construction activities be planned. Soil types, grain size distribution, shear strength, compressibility, permeability, plasticity, unit weight, and moisture content are some of the physical characteristics that may be determined for soil samples.

Penetration tests are also described in this procedure. The tests can be used to estimate various physical and engineering parameters such as relative density, unconfined compressive strength, and consolidation characteristics of soils.

The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, DQOs, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

5.1.1 Equipment

The following equipment is used for subsurface soil sampling and test boring:

- Drilling equipment, provided by subcontractor.
- Split barrel (split spoon) samplers, OD 2 inches, ID 1-3/8 inches, either 20-inch or 26 inches long. Larger O.D. samplers are available if a larger volume of sample is needed. A common size is 3-inch O.D. (2-1/2-inch I.D.).
- Thin walled tubes (Shelby), O.D. 2 to 5 inches, 18 to 54 inches long.
- Drive weight assembly, 140-lb. (± 2 lb.) weight, driving head and guide permitting free fall of 30 inches (± 1 inch).
- Drive weight assembly, 300-lb. (± 2 lb.) weight, driving head and guide permitting free fall of 18 inches (± 1 inch).
- Accessory equipment, including labels, logbook, paraffin, and sample jars.

Subject SOIL AND ROCK SAMPLING	Number GH-1.3	Page 4 of 13
	Revision 2	Effective Date 05/11/90

5.1.2 Split Barrel (Split Spoon) Sampling (ASTM D1586-84)

The following methods will be used for split barrel sampling:

- Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation. In saturated sands and silts, withdraw the drill bit slowly to prevent loosening of the soil around the hole and maintain the water level in the hole at or above groundwater level.
- Side-discharge bits are permissible. A bottom-discharge bit shall not be used. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
- Install the split barrel sampler and sampling rods into the boring to the desired sampling depth. After seating the sampler by means of a single hammer blow, three 6-inch increments shall be marked on the sampling rod so that the progress of the sampler can be monitored.
- The 2-inch OD split barrel sampler shall be driven with blows from a 140-lb. (± 2 lb.) hammer falling 30 inches (± 1 inch) until either a total of 50 blows have been applied during any one of the three 6-inch increments, a total of 100 blows have been applied, there is no observed advance of the sampler for 10 successive hammer blows, or until the sampler has advanced 18 inches without reaching any of the blow count limitation constraints described herein. This process is referred to as the Standard Penetration Test.
- A 300-lb weight falling 18 inches is sometimes used to drive a 2-1/2-inch or 3-inch O.D. spoon sampler. This procedure is used where dense materials are encountered or when a large volume of sample is required. However, this method does not conform the ASTM specifications.
- Repeat this operation at intervals not greater than 5 feet in homogeneous strata, or as specified in the sampling plan.
- Record the number of blows required to effect each 6 inches of penetration or fraction thereof. The first 6 inches is considered to be seating drive. The sum of the number of blows required for the second and third 6 inches of penetration is termed the penetration resistance, N . If the sampler is driven less than 18 inches, the penetration resistance is that for the last 1 foot penetrated.
- Bring the sampler to the surface and remove both ends and one half of the split barrel so that the soil recovered rests in the remaining half of the barrel. Describe carefully the sample interval, recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil then put a representative portion of each sample into a jar, without ramming. Jars with samples not taken for chemical analysis shall be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture, if the sample is to be later evaluated for moisture content. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms. Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area. Pertinent data which shall be noted on the label or written on the jar lid for each sample includes the project number, boring number, sample number, depth interval, blow counts, and date of sampling.

Subject SOIL AND ROCK SAMPLING	Number GH-1.3	Page 5 of 13
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- An addition to the sampler mentioned above is an internal liner, which is split longitudinally and has a thin-wall brass, steel, or paper liner inserted inside, which will preserve the sample. However, since the development of the thin-walled samplers (mentioned below) the split barrel sampler with liner has declined in use.

5.1.3 Thin Walled Tube (Shelby Tube) Sampling (ASTM D1587-83)

When it is desired to take undisturbed samples of soil, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method will be used:

- Clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated materials, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and maintain the water level in the hole at or above groundwater level.
- The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.
- A stationary piston-type sampler may be required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the sampling rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
- To minimize chemical reaction between the sample and the sampling tube, brass tubes may be required, especially if the tube is stored for an extended time prior to testing. While steel tubes coated with shellac are less expensive than brass, they are more reactive, and shall only be used when the sample will be tested within a few days after sampling or if chemical reaction is not anticipated. With the sampling tube resting on the bottom of the hole and the water level in the boring at the groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.
- Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape in the caps place, and dip the ends in wax.
- Affix labels to the tubes as required and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms. Do not allow tubes to freeze and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the

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sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Denison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and therefore their use shall be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt shall be made with a split barrel sampler at the same depth so that at least a sample can be obtained for classification purposes.

5.1.4 Continuous Core Soil Samples

The CME continuous sample tube system provides a method of sampling soil continuously during hollow stem augering. The 5-foot sample barrel fits within the lead auger of a hollow auger column. The sampling system can be used with a wide range of I.D. hollow stem augers (from 3-1/4-inch to 8-1/4-inch I.D.). This method has been used to sample many different materials such as glacial drift, hard clays and shales, mine tailings; etc. This method is particularly used when SPT samples are not required and a large volume of material is needed. Also, this method is useful when a visual description of the subsurface lithology is required.

5.2 SURFACE SOIL SAMPLES

For loosely packed earth or waste pile samples, stainless steel scoops or trowels can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

- Use a soil auger for deep samples (6 to 24 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collection of soil. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site.
- Use a new or freshly-decontaminated sampler for each sample taken. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, Chain-of-Custody record, and other required forms.
- Pack and ship accordingly.
- When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles shall be full) shall be placed in a decontaminated stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected.

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5.3 WASTE PILE SAMPLES

The use of stainless steel scoops or trowels to obtain small discrete samples of homogeneous waste piles is usually sufficient for most conditions. Layered (nonhomogeneous) piles require the use of tube samplers to obtain cross-sectional samples.

- Collect small, equal portions of the waste from several points around the pile, penetrating it as far as practical. Use numbered stakes, if possible, to mark the sampling locations and locate sampling points on the site sketch.
- Place the waste sample in a glass container. Attach a label and identification tag. Record all the required information in the field logbook and on the sample log sheet and other required forms.

For layered, nonhomogeneous piles, grain samplers, sampling triers, or waste pile samplers must be used at several representative locations to acquire a cross-section of the pile. The basic steps to obtain each sample are

- Insert a sampler into the pile at a 0- to 45-degree angle from the horizontal to minimize spillage.
- Rotate the sampler once or twice to cut a core of waste material. Rotate the grain sampler inner tube to the open position and then shake the sampler a few times to allow the material to enter the open slits. Move the sampler into position with slots upward (grain sampler closed) and slowly withdraw from the pile.

5.4 ROCK SAMPLING (CORING) (ASTM D2113-83)

Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. It can, however, proceed for thousands of feet continuously, depending on the size of the drill rig. It yields better quality data than air rotary drilling, although at a substantially reduced drilling rate. Rate of drilling varies widely, depending on the characteristics of lithologies encountered, drilling methods, depth of drilling, and condition of drilling equipment. Average output in a 10-hour day ranges from 40 to over 200 feet. Downhole geophysical logging or television camera monitoring is sometimes used to complement the data generated by coring.

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Attachment No. 1.

Core drilling is used when formations are too hard to be sampled by soil sampling methods and a continuous solid sample is desired. Usually, soil samples are used for overburden, and coring begins in sound bedrock. Casing is set into bedrock before coring begins to prevent loose material from entering the borehole, to prevent loss of drilling fluid, and to prevent cross contamination of aquifers.

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ATTACHMENT 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring bit size	Nominal *		Set size *	
	O.D.	I.D.	O.D.	I.D.
RWT	1 $\frac{5}{32}$	$\frac{3}{4}$	1.160	.735
EWT	1 $\frac{1}{2}$	$\frac{29}{32}$	1.470	.905
EX, EXL, EWG, EWM	1 $\frac{1}{2}$	$\frac{13}{16}$	1.470	.845
AWT	1 $\frac{7}{8}$	1 $\frac{9}{32}$	1.875	1.281
AX, AXL, AWG, AWM	1 $\frac{7}{8}$	1 $\frac{3}{8}$	1.875	1.185
BWT	2 $\frac{1}{8}$	1 $\frac{3}{4}$	2.345	1.750
BX, BXL, BWG, BWM	2 $\frac{1}{8}$	1 $\frac{5}{8}$	2.345	1.655
NWT	3	2 $\frac{5}{16}$	2.965	2.313
NX, NXL, NWG, NWM	3	2 $\frac{1}{8}$	2.965	2.155
HWT	3 $\frac{29}{32}$	3 $\frac{3}{8}$	3.889	3.187
HWG	3 $\frac{29}{32}$	3	3.889	3.000
2 $\frac{3}{4}$ x 3 $\frac{7}{8}$	3 $\frac{7}{8}$	2 $\frac{3}{4}$	3.840	2.690
4 x 5 $\frac{1}{2}$	5 $\frac{1}{2}$	4	5.435	3.970
6 x 7 $\frac{3}{4}$	7 $\frac{3}{4}$	6	7.655	5.970
AX Wire line \perp	1 $\frac{7}{8}$	1	1.875	1.000
BX Wire line \perp	2 $\frac{3}{8}$	1 $\frac{7}{8}$	2.345	1.457
NX Wire line \perp	3	1 $\frac{13}{16}$	2.965	1.957

* All dimensions are in inches; to convert to millimeters, multiply by 25.4.
 \perp Wire-line dimensions and designations may vary according to manufacturer.

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Size Designations		Casing O.D., inches	Casing coupling		Casing bit, O.D., inches	Core barrel bit O.D., inches*	Drill rod O.D., inches	Approximate core diameter	
Casing, Casing coupling, Casing bits, Core barrel bits	Rod; Rod couplings		O.D., inches	I. D., inches				Normal, inches	Thinwall, inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	—	735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	845	905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush joint	No coupling	1.485	1.160	1.094	—	735
EW	EW	1.812			1.875	1.470	1.375	845	905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	—	5.500			5.650	—	—	—	—
SW	—	6.625			6.790	—	—	—	—
UW	—	7.625			7.800	—	—	—	—
ZW	—	8.625			8.810	—	—	—	—
—	AX <u>U</u>	—	—	—	—	1.875	1.750	1.000	—
—	BX <u>U</u>	—	—	—	—	2.345	2.250	1.437	—
—	NX <u>U</u>	—	—	—	—	2.965	2.813	1.937	—

* For hole diameter approximation, assume $\frac{1}{16}$ inch larger than core barrel bit.

U Wire line size designation, drill rod only, serves as both casing and drill rod. Wire line core bit, and core diameters vary slightly according to manufacturer.

NOMINAL DIMENSIONS FOR DRILL CASINGS AND ACCESSORIES. (DIAMOND CORE DRILL MANUFACTURERS ASSOCIATION). 288-D-2889.

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Drilling through bedrock is initiated by using a diamond-tipped core bit threaded to a drill rod (outer core barrel) with a rate of drilling determined by the downward pressure, rotation speed of drill rods, drilling fluid pressure in the borehole, and the characteristics of the rock (mineralogy, cementation, weathering).

5.4.1 Diamond Core Drilling

A penetration of typically less than 6 inches per 50 blows using a 140-lb. hammer dropping 30 inches with a 2-inch split spoon sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

When formations are encountered that are too hard to be sampled by soil sampling methods, the following diamond core drilling procedure may be used.

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross contamination of aquifers in the unconsolidated materials is unlikely, it may be omitted.
- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole, and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equipment is the most commonly used size.
- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split Barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling) for Sampling of Soils (see Section 5.1.1 and 5.1.2). Resume diamond core drilling when refusal materials are again encountered.
- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as the conditions warrant.
- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

5.4.2 Rock Sample Preparation and Documentation

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in Procedure GH-1.5. If moisture content will be determined or if it is desirable to prevent drying (e.g.,

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to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Site Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. A wooden partition (wooden block) shall be placed at the end of each run with the depth of the bottom of the run written on the block. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box (see Attachment 2). The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

- Project name
- Project number
- Boring number
- Run numbers
- Footage (depths)
- Recovery
- RQD.(%)
- Box number and total number of boxes for that boring (Example: Box 5 of 7).

For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number. Attachment No. 2 illustrates a typical rock core box.

Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

ATTACHMENT 2

BOX 2 of 3

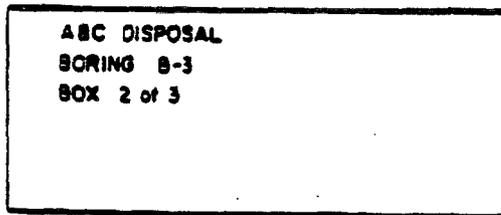
BORING B-3		ABC DISPOSAL	
RUN	DEPTH, FT	RECOVERY %	ROD %
6	55.0-65.0	90	85
7	65.0-70.0	100	100

SCREW HOLES

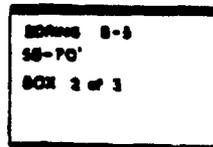
HINGES

SEPARATORS

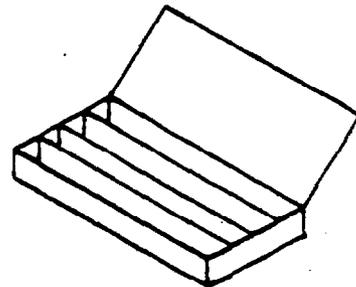
CORE BOX (OBLIQUE VIEW)



CORE BOX (TOP VIEW)



CORE BOX (END VIEW)



TYPICAL ROCK CORE BOX

NOT TO SCALE



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4.0 RESPONSIBILITIES

Site Manager - In consultation with the project geologist, responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. He should also determine the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Site Geologist/Rig Geologist - Responsible for insuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see Attachment A of Procedure GH-1.7). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

Determination of the exact location for borings is the responsibility of the site geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan.

Field Operations Leader - Responsible for overall supervision and scheduling of drilling activities.

Drilling Subcontractor - Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical or analytical problems encountered in the field to the Field Operations Leader within 24 hours, and must provide advance written notification for any changes in field procedures describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the Field Operations Leader.

The drilling subcontractor will be responsible for following decontamination procedures specified in the Work Plan. Upon completion of the work, the Drilling Subcontractor will be responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

5.0 PROCEDURES

5.1 GENERAL

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site, and
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned using appropriate decontamination procedures (see Procedure GH-1.6 and SF-2.3) between samples and borings. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist as they proceed (see Procedure GH-1.5) unless the FSAP specifically states that

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logging is not required. Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5.2 DRILLING METHODS

The selected drilling methods described below apply to drilling in subsurface materials, including, but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, purpose of drilling, waste conditions at the site, and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

5.2.1 Continuous-Flight Hollow-Stem Auger Drilling

This method of drilling consists of screwing augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole: However, this is a poor method for obtaining grab samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations will require the use of split-barrel or thin-wall tube samplers advanced through the hollow core of the auger.
- No drilling fluids are required.
- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.
- The inside diameter of hollow stem augers used for well installation should be at least four inches greater than the well casing. Use of such large diameter hollow stem augers is more expensive than the use of small diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths become more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.
- The maximum effective depth for drilling is 150 feet or less, depending on site conditions and the size of augers used.
- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. If the condition of "running" or "flowing" sands is persistent at a site, an alternative method of drilling is recommended, in particular for wells or boreholes deeper than 25 feet. Hollow stem auger drilling is the preferred method of drilling. Most alternative

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methods require the introduction of water or mud downhole (air rotary is the exception) to maintain the open borehole. With these other methods great care must be taken to ensure that the method does not interfere with the collection of a representative sample which is the object of the construction. With this in mind, the preferred order of choice of drilling method after hollow stem augering (HSA) is:

- Cable tool
- Casing drive (air)
- Air rotary
- Mud rotary
- Drive and wash
- Jetting

However, the use of any method will also depend on efficiency and cost-effectiveness. In many cases, mud rotary is the only feasible alternative to hollow stem augering. Thus, mud rotary drilling is generally acceptable as a first substitute for HSA.

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The hollow stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

When taking soil samples for chemical analysis, the hollow-stem auger shall be plugged until the desired sampling depth is reached. Samples can be taken using split-spoon or thin wall tube samplers driven into the formation in advance of the auger (see Procedure GH-1.3). If the sample is to be taken at a relatively deep point, the auger may be advanced without a plug to within five feet of the sample depth. Then clean out the auger stem, insert a plug and continue to the sampling depth. The plug is then removed and samples taken as specified by the rig geologist. Samples should be taken according to the specifications of the sampling plan. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. The sequence shall be repeated for each sample desired.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation.

When drilling below the water table, specially-designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see GH-1.7 for Well Development Procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

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At the option of the Field Operations Leader, when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted. In some formations it may be prudent to also grout borings which only penetrate the water table aquifer, since loose soil backfill in the boring would still provide a preferred pathway for surface liquids to reach the water table.

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

This method is similar to hollow-stem augering. Practical application of this method is severely restricted as compared with hollow stem augers. Split barrel (split-spoon) sampling cannot be done without pulling the augers which may allow the hole to collapse. The method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable as in the case of the hollow stem auger, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to remain open after the augers are withdrawn. Alternatively, the technique can be used to find depth to bedrock in an area when no other information is required from drilling.

5.2.3 Rotary Drilling

Direct rotary drilling includes air-rotary and fluid-rotary drilling. Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole. Advantages of this method include:

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injected to keep down dust).
- The borehole diameter is large, to allow room for proper well installation procedures.

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.
- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.
- In-situ samples cannot be taken, unless the hole is cased.
- Casing must generally be used in unconsolidated materials.
- Air rotary drill rigs are large and heavy.

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A variation of the typical air-rotary drill bit is a down hole hammer which hammers the drill bit down as it drills. This makes drilling in hard rock faster. Air-rotary drills can also be adapted to use for rock coring although they are generally slower than other types of core drills. A major application of the air-rotary drilling method would be to drill holes in rock for well installation.

Fluid-Rotary drilling operates in a similar manner to air rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite slurry and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (i.e., bentonite) and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split barrel (split-spoon) or thin-wall tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.
- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow stem auger method if split barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).
- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).
- No information on depth to water is obtainable while drilling.
- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on water samples obtained. For this reason as well, extensive well development may be required.
- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This will require either constant replenishment of the drilling fluid, or the use of casing through this formation.
- Drill rigs are large and heavy, and must be supported with supplied water.
- Ground water samples can be potentially diluted with drilling fluid.

The procedures for performing direct rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83, and D1586-84.

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For air or fluid-rotary drilling, the rotary drill may be advanced to the desired depth by any power-operated drilling machine having sufficient torque and ram range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Soil samples shall be taken as specified by the Work Plan or more frequently if requested by the field geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool.

When field conditions prevent the advancement of the hole to the desired depth, a new boring may be drilled at the request of the Field Operations Leader. The original boring shall be backfilled using methods and materials appropriate for the given site and a new boring started a short distance away at a location determined by the site geologist.

5.2.4 Reverse Circulation Rotary Drilling

The common reverse-circulation rig is a water or mud rotary rig with a large diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud rotary). This type of rig is used for the construction of large-capacity production water wells and is not suited for small, water-quality sampling wells because of the use of drilling muds and the large diameter hole which is created. A few special reverse-circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

Advantages of the latter method include:

- The formation water is not contaminated by the drilling water.
- Formation samples can be obtained, from known depths.
- When drilling with air, immediate information is available regarding the water-bearing properties of formations penetrated.
- Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air rotary rig.

Disadvantages include:

- Double-wall, reverse-circulation drill rigs are very rare and expensive to operate.
- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

5.2.5 Drill-through Casing Driver

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig or an air hammer and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage). A continuous record is kept of the blows per foot in driving the casing (see Procedure GH-1.5). The casing is normally advanced by a 300-pound

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hammer falling freely through a height of 30-inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations between which water is used in driving the casing should be recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used for later well installation, the driven casing used should be at least four inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split barrel (split-spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water-bearing layers; therefore multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).
- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.
- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.
- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

5.2.6 Cable Tool Drilling

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water need be added.

When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

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Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators.
- The cable-tool rig can operate satisfactorily in all formations, but is best suited for caving, boulder, coarse or coarse gravel type formations (e.g., glacial till) or formations with large cavities above the water table (such as limestones).
- When casing is used, the casing seals formation water out of the hole, preventing down-hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.
- Split barrel (split spoon) or thin-wall tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.
- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.
- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required, such as use of a hollow stem auger.
- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

5.2.7 Jet Drilling (Washing)

Jet drilling, which should be used only for piezometer or vadose zone sampler installation, consists of pumping water or drilling mud down through a small diameter (1/2 to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch diameter casing in shallow, unconsolidated sand formations but has been used to install 3- to 4-inch diameter casings to 200 feet.

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Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement. Advantages of this method include:

- Jetting is fast and inexpensive.
- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.
- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.
- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.
- The diameter of the casing is usually limited to 2 inches; therefore, samples must be obtained by methods applicable to small diameter casings.
- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).
- Large quantities of water are often needed.

5.2.8 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the Work Plan. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are lwan samplers (which are rotated) or post hole diggers (which are operated like tongs). This technique is slow but effective where larger pieces of equipment do not have access and where very shallow holes are desired (less than 5 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

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5.2.9 Rock Drilling and Coring

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113.

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond studded bit attached to the outer core barrel in a double tube core barrel. The use of single tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation to this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required.

Core borings are made through the casing used for the soil borings. The casing must be driven and sealed into the rock formation to prevent seepage from the overburden into the hole to be cored (see Section 5.3 of this guideline). A double-tube core barrel with a diamond bit and reaming shell or equivalent should be used to recover rock cores of a size specified in the Work Plan. The most common core barrel diameters are listed in Attachment A. Soft or decomposed rock should be sampled with a driven split-barrel whenever possible or cored with a Denison or Pitcher sampler.

When coring rock, including shale and claystone, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled. Should any rock formation be so soft or broken that the pieces continually fall into the hole, causing unsatisfactory coring, the hole should be reamed and a flush joint casing installed to a point below the broken formation. The size of the flush joint casing must permit securing the core size specified. When soft or broken rock is anticipated, the length of core runs should be reduced to less than 5 feet to avoid core loss and minimize core disturbance.

Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).

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- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install larger diameter wells in coreholes, the hole must be reamed out to the proper size after boring, using air or mud rotary drilling methods.

5.2.10 Drilling & Support Vehicles.

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment, and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain, to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment, such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

Some of the typical vehicles which are usually available for drill rigs and support equipment are:

- Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand-carried to the borehole site. Drilling/sampling methods used with such equipment include:
 - Hand augers and lightweight motorized augers
 - Retractable plug samplers-driven by hand (hammer)
 - Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small diameter cased borings. This rig is sometimes called a "monkey on a stick."
- Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismounted tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.
- Small truck-mounted drilling equipment uses a jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.
- Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.
- Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided

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with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on and off the road vehicle having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.

- Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles includes:
 - Barrel float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallon drums or similar flotation units.
 - Barge-mounted drill rigs.
 - Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.
 - Drill ships - for deep ocean drilling.

In addition to the mobility for the drilling equipment, similar consideration must be given for equipment to support the drilling operations. Such vehicles or floating equipment are needed to transport drill water, drilling supplies and equipment, samples, drilling personnel, etc. to and/or from various boring locations.

5.2.11 Equipment Sizes

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so that they will fit properly in the boring or well.

For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5-7/8" or 7-7/8" bits will nominally drill 6" and 8" holes, respectively).

For obtaining split-barrel samples of a formation, samplers are manufactured in sizes ranging from 2-inches to 4-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler is used, and driven by a 140-pound (± 2 pound) hammer dropping 30-inches (± 1 inch), the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into the formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow stem augers or casing, in which thin-wall tube samples or diamond core drilling will be performed, refer to the various sizes and clearances provided in Attachment A of this guideline. Sizes selected must be stated in the Work Plan.

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5.2.12 Estimated Drilling Progress

To estimate the anticipated rates of drilling progress for a site the following must be considered:

- The speed of the drilling method employed.
- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).
- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5-foot intervals, for moderate depth (30' to 50') boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud Rotary Drilling	100' (cuttings samples)
Reverse Circulation Rotary	100' (cuttings samples)
Skid Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'

5.3 PREVENTION OF CROSS-CONTAMINATION

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe, (a method similar to the rock coring method described in Section 5.2.9, except that larger casing is used) or a driven-casing method (see Section 5.2.5 of this guideline), and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing usually of 8-inch diameter is installed followed by installation of the well casing (6-inch diameter is common for 2-inch wells). This well casing is driven into the confining layer to insure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end is installed to the surface.

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Clean sand is placed in the annulus around and to a point about 2 feet above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 feet above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

5.4 CLEANOUT OF CASING PRIOR TO SAMPLING

The boring hole must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward directed jet which will disturb the underlying soil. When clean-out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to surge these large particles upward out of the hole. As a time saver, the drilling contractor may be permitted to use a split barrel (split-spoon) sampler with the ball check valve removed as the clean out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split spoon bit, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard-cemented soils are encountered. If water markedly softens the soils above the water table, clean out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up-turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the cleanout auger, a split-barrel sample can be taken to remove it. Bailers and sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions on the validity of the sample.
- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.

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- In cased borings, should sampling be attempted through cuttings which remain in the lower portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.
- When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string; then to measure the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches for cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

5.5 MATERIALS OF CONSTRUCTION

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in FT-7.01. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

The use of synthetic or organic polymer slurries is not permitted at any location where soil samples for chemical analysis are to be collected. These slurry materials could be used for installation of long term monitoring wells, but the early time data in time series collection of ground water data may then be suspect. If synthetic or organic polymer muds are proposed for use at a given site, a complete written justification including methods and procedures for their use must be provided by the site geologist and approved by the site manager. The specific slurry composition and the concentration of selected chemicals for each site must be known.

For many drilling operations, potable water is an adequate lubricant for drill stem and drilling tool connections. However, there are instances, such as drilling in tight clayey formations or in loose gravels, when threaded couplings must be lubricated to avoid binding. In these instances, to be determined in the field at the judgment of the site geologist and noted in the Site Logbook, and only after approval by the site manager, a vegetable oil or silicone based lubricant should be used. Petroleum based greases, etc. will not be permitted. Samples of lubricants used must be provided and analyzed for chemical parameters appropriate to the given site.

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1.0 PURPOSE

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

2.0 SCOPE

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist - Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used onsite the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

5.0 PROCEDURES

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

5.1 MATERIALS NEEDED

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute HCl
- Ruler (marked in tenths and hundredths of feet)
- Hand Lens

5.2 CLASSIFICATION OF SOILS

All data shall be written directly on the boring log (Exhibit 4-1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

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5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Exhibit 4-2. This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse grained soils shall be divided into rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as (1/4 inch ϕ -1/2 inch ϕ) or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

5.2.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.2. Those designations are:

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Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140 pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, and SC (see Exhibit 4-2).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Exhibit 4-3. Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Exhibit 4-2).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength) or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are as follows:

Consistency	Unc. Compressive Str. Tons/Square Foot	Standard Penetration Resistance (Blows per Foot)	Field Identification Methods
Very soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb
Medium stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb
Very stiff	1.0 to 2.0	8 to 15	Readily indented by thumb
Hard	2.0 to 4.0	15 to 30	Readily indented by thumbnail
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail

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5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
trace	0 - 10 percent
some	11 - 30 percent
and or adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory tests for water content shall be performed if the natural water content is important.

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Exhibit 4-4.

5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

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5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

5.3 CLASSIFICATION OF ROCKS

Rocks are grouped into three main divisions, including sedimentary, igneous and metamorphic rocks. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.
- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.
- Claystone - Vary fine grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.
- Shale - A fissile very fine grained rock. Fractures along bedding planes.
- Limestone - Rock made up predominantly of calcite (CaCO₃). Effervesces strongly upon the application of dilute hydrochloric acid.
- Coal - Rock consisting mainly of organic remains.
- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. These include conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Weathering
- Other characteristics

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5.3.1 Rock Type

As described above, there are numerous names of sedimentary rocks. In most cases a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Exhibit 4-5 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

5.3.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock Color Charts shall not be used unless specified by the project manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification will also be used for rock classification.

5.3.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the works "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

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5.3.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- Very broken (V. BR.) - Less than 2 in. spacing between fractures
- Broken (BR.) - 2 in. to 1 ft. spacing between fractures
- Blocky (BL.) - 1 to 3 ft. spacing between fractures
- Massive (M.) - 3 to 10 ft. spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD (After Deere, 1964)

$$RQD \% = r/l \times 100$$

r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

l = Total length of the coring run.

5.3.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.
- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.
- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.
- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified)
- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic)

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- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inch or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone - some shale seams."
- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone - few shale seams."
- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."
- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.
- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.
- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.
- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.
- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse grained dark igneous rock.

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The following are some basic names that are applied to metamorphic rocks:

- Slate - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- Phyllite - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- Schist - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- Gneiss - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- Quartzite - A fine to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

5.4 ABBREVIATIONS

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine grained
Tr - Trace		

5.5 BORING LOGS AND DOCUMENTATION

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Exhibit 4-6. The field geologist/engineer shall use this example as a guide in completing each borings log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided on the back of the boring log, for field use.

5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.
- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology a 13.7 feet, shall be lined off at the proportional location between the 13 and 14 foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.

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- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.
- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.
- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart of back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.
- Enter color of the material in the appropriate column.
- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:
 - Trace 0 - 10 percent
 - Some 11 - 30 percent
 - And 31 - 50 percent
- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.
- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.
- The following information shall be entered under the Remarks Column and shall include, but is not limited by the following:
 - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.
 - Angularity - describe angularity of coarse grained particles using Angular, Subangular, Subrounded, Rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
 - Particle shape - flat, elongated, or flat and elongated.
 - Maximum particle size or dimension.
 - Water level observations.
 - Reaction with HCl - none, weak or strong.

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- Additional comments:

- Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
- Indicate odor and HNu or OVA reading if applicable.
- Indicate any change in lithology by drawing in line through the lithology change column and indicate the depth. This will help later on when cross-sections are constructed.
- At the bottom of the page indicate type of rig, drilling method, hammer size and drop and any other useful information (i.e., borehole size, casing set, changes in drilling method).
- Vertical lines shall be drawn (as shown in Exhibit 4.6) in columns 5 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
- Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 Rock Classification

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.
- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.
- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.
- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.

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- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:
 - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
 - Indicate calcareous zones, description of any cavities or vugs.
 - Indicate any loss or gain of drill water.
 - Indicate drop of drill tools or change in color of drill water.
- Remarks at the bottom of Boring Log shall include:
 - Type and size of core obtained.
 - Depth casing was set.
 - Type of Rig used.
- As a final check the boring log shall include the following:
 - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.
 - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5 foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock" bag for future reference, and label the jar or bag (i.e. hole number, depth, date etc.). Cuttings shall be closely examined to determine general lithology.
- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Exhibit 4-1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split barrel and rock core sampling methods be used at selected boring locations during the field investigation to

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provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 REVIEW

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs
- Checking for conformance to the guideline
- Checking to see that all information is entered in their respective columns and spaces

6.0 REFERENCES

Unified Soil Classification System (USCS)

ASTM D2488, 1985

Earth Manual, U.S. Department of the Interior, 1974

7.0 RECORDS

Originals of the boring logs shall be retained in the project files.

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EXHIBIT 4-3

CONSISTENCY FOR COHESIVE SOILS

Consistency	(Blows per Foot)	Uncombined Compressive Strength (tons/square foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented by thumbnail

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EXHIBIT 4-4

BEDDING THICKNESS CLASSIFICATION

Thickness (Metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	< 1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

EXHIBIT 4-5

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4-64 mm
Granules	2-4 mm
Very Coarse Sand	1-2 mm
Coarse Sand	0.5-1 mm
Medium Sand	0.25-0.5 mm
Fine Sand	0.125-0.25 mm
Very Fine Sand	0.0625-0.125 mm
Silt	0.0039-0.0625 mm

After Wentworth, 1922

EXHIBIT 4-6

BORING LOG	NUS CORPORATION
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PROJECT: WESTLINE SITE	BORING NO: MW 013
PROJECT NO.: 473 Y	DATE: 7-7-87
ELEVATION: 1462.37	DRILLER: 3 ERICSON
WATER LEVEL DATA: 5.54' @ 9:30 AM 7-23-87 T-PVC	PEJU - DRILL ACKER AD-11
(Date, Time & Conditions)	

SAMPLE NO. & TYPE OR ROD	DEPTH (FT) OR RUN NO.	BLOWS 1' OR 100 (1')	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (COLOR, GRAIN, OR SILT)	MATERIAL DESCRIPTION		MOISTURE (%)	REMARKS (HWS) (NEED SP)	
					SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR			
S-1	0.0	3	14/1.5		LOOSE	BLK BRN	CLAYEY SILT AND CLINED	ML	MOIST (OPPM)
		2			TR. COLL. FRAG.				3/4" Ø FRAG - NEAR OLD RR. LINE.
								(FILL)	
S-2	5.0			6.0	V. LOOSE	RED BLEN TO GRAY	SANDY SILT - TR. FRG. TO SILTY SAND - TO GRAVEL	GM	MOIST TO WET (OPPM)
	6.5	3	1.7/1.5						GRAY SAND 2 G. ± HICAL. EXIS L. OF - N. 100' ±
									DRILLER NOTE H2O 8-10'
S-3	10.0				DENSE	BRN	SILTY SAND INC. S.S.	GM	WET (OPPM)
	11.5	23	1.2/1.5				FRAGS. (G.P. 1)		1" Ø SIZE MAX SIZE SUBANGULAR TO SUBROUND GRAVEL
		27							
S-4	15.0				V. DENSE	BRN	SILTY FINE TO C. SAND AND GRAVEL	GM	WET (OPPM)
	16.5	47	1.0/1.5						1" Ø SIZE MAX SIZE SUBANGULAR TO SUBROUND GRAVEL
		43							
S-5	20.0				V. DENSE	DRNG BRN	SILTY SAND - SOME GRAVEL AND S.S. FRAGS	GM	WET (OPPM)
	20.9	17	1.4/1.9						MOIST BECOMES MORE LIKE SANDY SILT AT BOTM OF SAMPLE

REMARKS: START 1:15 PM - 7-7-87 USING 4 1/2" ID HOLLOW DRILLS
 S-4 @ 3:30 PM TO LOCATE THE BOP LYS USING
 S-5 @ 4:30 PM ACKER DRILL - MOISTENED ON FUEL 8000 TRUCK

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SAMPLES TAKEN USING 140 LB WT AND 30 INCH DROP.

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BORING LOG				NUS CORPORATION					
PROJECT: WESTLINE SITE		BORING NO.: MW013		PROJECT NO.: 473Y		DATE: 7-7-87			
ELEVATION:		DRILLER: Y EPSON		FIELD GEOLOGIST: SJ CONTI		WATER LEVEL DATA:			
(Date, Time & Conditions)									
SAMPLE NO. S TYPE OR ADD	DEPTH (ft) OR RUN NO	BLOWS 1' OR ADD (ft)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (SOUNDING OR SCREEN) IN FT	MATERIAL DESCRIPTION			REMARKS (HINT)	
					SOIL DENSITY, CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION		
S-6	25.0	17	1.5		V.DENSE	BLUE GRAY	SILTY SLUD - SOME GRAVEL - TR CLAY	GM	MIST C.S. IS FRIBLE FIRST ONLY IN COLOR. NOT ENOUGH CLAY TO BE CONFINING NOTES MAY SET ZONE 2 CASING 28'
	26.5	30							
7/7	30.0								
S-7	31.5	17	1.5		V.DENSE	BLUE GRAY	SILTY SLUD - SOME GRAVEL - TR CLAY	GM	MIST C.S. IS FRIBLE - GRAY - FRIBLE. SUFFICIENT CLAY NOT FRIBLE CLAY - BUT MAY BE SEMI-CONFINING.
	35.0	27							
S-8	35.9	30	0.7/0.9		V.DENSE	BLUE GRAY	SILTY F TO C SAND - SOME GRAVEL - TR. SS. FRAG.	SM/GM	MIST V. SL. TR CLAY - LESS SMALL FRAG. - MORE SAND. SHD THAN ANY.
	40.0	30							
S-9	41.5	31	1.5		V.DENSE	BLUE GRAY	SILTY SAND (FINE TO M.) SOME GRAVEL - TR CLAY	SM/GM	MIST POSSIBLE STONS SCREEN LOC. SUFFICD HOLD TO-FINE WHEN MOIST - WET (OPPM) LITTLE MORE CLAY THAN S-8 SUBMINED GRAVEL
	45.0	34							
S-10	46.5	34	1.5		V.DENSE	BLUE GRAY	SILTY SAND (FINE TO M.) SOME GRAVEL - TR CLAY	SM/GM	MIST NO SIZE - HOLDS TO-GETHER WHEN SUFFICD BUT NOT COHESIVE CLASSIFICATION VERY SLOW SETTLING 40-45 (RIG STALLS) LESS CLAY LAST 3" OF SAMPLE
		50							

REMARKS
 S-6 @ 4:40 PM
 S-8 @ 8:36 PM 7-6-87
 S-10 @ 10:40 PM 5-11-87

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Subject

BOREHOLE AND SAMPLE LOGGING

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BORING LOG

NUS CORPORATION

PROJECT: WESTLINE SITE

BORING NO: MW 013

PROJECT NO.: 473 Y

DATE: 7-9-87

DRILLER: B. BRISQ

ELEVATION:

FIELD GEOLOGIST: SJ CONTI

WATER LEVEL DATA:

(Date, Time & Conditions)

SAMPLE NO. & TYPE OR BBO	DEPTH (FT) OR RUN NO.	BLOWN FT OR ROD NO.	SAMPLE RECOVERY (%)	LITHOLOGY CHANGES (Depth Ft.) OR METER INT.	MATERIAL DESCRIPTION		REMARKS & USES	REMARKS	
					LOG. DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR			
S-11	50.0	15	1.9	55.0	V. DENSE	MDP.D BL. SF GRY	SM	MOIST - (OPPH)	
	51.3	41	1.3		TE CLAY	PROBLE WY PCS OF BLACK (DRY) LIGHTER MOIST CLAY THIN ABOVE PORTIONS OF SHALE - COHESIVE S.L. CLAY.			
S-12	56.5	11	1.5	60.0	V. STIFF TO STIFF	GRAY ORNG BRN	SC	MOIST - WET (OPPH)	
	60.0	15	1.5		SOME GRAVEL	NOTE COLOR CHANGE ALSO - MORE CLAY THAN ANY SAMPLES - ROUNDED GRAINS FIRST COHESIVE TYPE CLASSIF.			
S-13	60.9	37	0.9	65.0	V. DENSE	ORNG BRN	SC	MOIST - WET (OPPH)	
	65.0	40	0.9		GRAVEL	1" BT FC TRUCK WY AS S-17 BUT VERY COARSE. ROUNDED GRAINS SET CAS. 8' 2".			
7/13 S-14	65.8	37	0.8	68.0	V. DENSE	BRN ORNG	SM	MOIST (OPPH)	
	70.0	41	0.8		AND ROCK FRAG - TR. CLAY	NOTE - CLAY TOWARDS TOP OF SAMPLE MAX 3/4" D SIZE COLOR CHANGE AT 5' 6" MORE SAND PER DRILLER - BOTH OF SAND COH. LAYER?			
7/14 S-15	71.5	37	1.5	71.5	V. DENSE	YELLOW BRN	SC	MOIST - WET (OPPH)	
	71.5	41	1.5		GRAVEL - TR	1" MAX GRAVEL			
								ROCK FRAG.	NOTE GRAVEL 0.2' PER DRILLER

REMARKS: USING HOLLOW STEM TO ADVANCE BORING - WASHING OUT
 THIN LINES, UNITS DEPEND ON DRILLER'S REPORT
 S-12 @ 1:46 PM
 S-13 @ 3:32 AM - LOGGED IN BY 3:47 PM
 SET 6" Ø STEEL CASING TO 62' - WILL DRILL BEYOND CASING
 AFTER GROUT SETS UP. S-14 @ 3:00 PM 7-13-87
 S-15 @ 7:57 AM 7-14-87

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BORING LOG					NUS CORPORATION				
PROJECT: WESTLINE SITE					BORING NO.: MW013				
PROJECT NO.: 437Y					DATE: 7-13-87 / 7-14-87				
ELEVATION:					DRILLER: B. ERICSON				
WATER LEVEL DATA:					FIELD GEOLOGIST: S.J. CONTI				
(Date, Time & Conditions)									
SAMPLE NO. & TYPE OR ROD	DEPTH (ft.) OR ELEV. NO.	BLOWS 1' OR 100 (ft.)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (DEPTH) OR SEC. CAR 75	MATERIAL DESCRIPTION			REMARKS (HNU)	
					SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION		
S-16	75.0	37	0.9/1.0		V. DENSE	GRAY GRAY	FINE TO C. CLAYEY SAND - SOME	3C WET (OPPM)	
	76.0						GRAVEL - TR	NOT AS MUCH CLAY AS S-15 - BOTTOM OF SAMPLE BELONGS MORE SANDY MAX 1" Ø PC.	
							ROCK FRAG (S.S.)		
	80.0							NO SAND @ 80' - DEC. OF C TO GO TO 85'	
	85.0	30	0.4/0.4		V. DENSE	GRAY GRAY	SILTY F. TO C. SAND - SOME FINE	WET (OPPM)	
S-17	85.4	4			85		BRN	GRAVEL - TR	SURROUNDED GRAINS
							S.S. FRAG - TR	V. SL TR CLAY - WILL GET SCREEN @ 75 TO 85' IN THIS BORING.	
							CLAY		
							BOTM. OF HOLE @ 85.0'		

REMARKS S-17 @ 2:20 PM 7-14-87 - METEORIC HEAVY 6" CASING
SPIN 4" Ø - 5 7/8" OD CASING TO BOTM. USING WILCOX LS
CRILLING FLUID

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Subject DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS	Number GH-1.6	Page 2 of 3
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1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the appropriate procedures to be followed when conducting decontamination activities of drilling equipment and monitoring well materials used during field investigations.

2.0 SCOPE

This procedure addresses only drilling equipment and monitoring well materials decontamination, and shall not be considered for use with chemical sampling and field analytical equipment decontamination.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Field Operations Leader - Responsible for ensuring that project specific plans and the implementation of field investigations are in compliance with these procedures.

5.0 PROCEDURES

To insure that analytical chemical results are reflective of the actual concentrations present at sampling locations, various drilling equipment involved in field investigations must be properly decontaminated. This will minimize the potential for cross-contamination between sampling locations, and the transfer of contamination off site.

Prior to the initiation of a drilling program, all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental sample. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens.

The steam cleaning area shall be designed to contain decontamination wastes and waste waters, and can be a lined excavated pit or a bermed concrete or asphalt pad. For the latter, a floor drain must be provided which is connected to a holding facility. A shallow above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases, due to budget constraints, such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate decontamination area. The location of the steam cleaning area shall be on site in order to minimize potential impacts at certain sites.

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Guidance to be used when decontaminating equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Rinsate samples of well casing and screens may be necessary if specifically required for a given site. If required, at least 1 percent, and no more than 5 percent of steam cleaned lengths of casing and screens combined shall be sampled.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

6.0 RECORDS

None.

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5.0 PROCEDURES

5.1 EQUIPMENT/ITEMS NEEDED

Below is a list of items that may be needed while installing a monitoring well.

- Health and safety equipment as required by the site safety officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineers tape, water level indicator, retractable engineers rule electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installations tools (Sledge Hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 WELL DESIGN

The objectives for each monitoring well and its intended use must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials to be used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity)

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, these can be determined through the review of geologic data and the site terrain. In addition, production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary phase to determine groundwater flow direction.

5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the levels at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contamination plume, since groundwater samples collected in wells that are screened over the full thickness of the water bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of

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contamination in water bearing zone. The well diameter would depend upon the hydraulic characteristics of the water bearing zone. Sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following information:

- The vertical location of the contaminant source in relation to the water bearing zone.
- The depth, thickness and uniformity of the water bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (1 to 2 feet) are usually required where flow lines are not horizontal, (ie., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs

Standard monitoring well diameters are 2, 4, 6, or 8 inches. However, drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open hole monitoring wells are required. In the smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced, however, the type of sampling devices that can be used are limited. In specifying well diameter, sampling requirements must be considered. Up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples. The water in the monitoring well available for sampling is dependent on the well diameter as follows:

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Casing Inside Diameter, Inch	Standing Water Depth to Obtain 1 Gal Water (feet)	Total Depth of Standing Water for 4 Gal. (feet)
2	6.13	25
4	1.53	6
6	0.68	3

However, if a specific well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells; however, in small diameter wells, in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength" and Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials in which the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC, galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive discussion on this topic). The two most commonly used materials are PVC and stainless steel for wells in which screens are installed and are compared in Attachment B. Stainless steel is preferred where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, and ease of manipulation; however, there are also some questions about organic chemical sorption and leaching that are currently being researched (see Barcelona et al., 1983). Concern about the use of PVC can be minimized if PVC wells are used strictly for geohydrologic measurements and not for chemical sampling. The crushing strength of PVC may limit the depth of installation, but schedule 80 materials normally used for wells greater than 50 feet deep may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps to be used for sampling or testing. Due to this problem, the minimum well pipe size recommended for schedule 80 wells is 4 inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe, may corrode and release metal ions or chemically react with organic constituents, but this is considered by some to be less of a problem than the problem associated with PVC material. Galvanized steel is not recommended for metal analyses, as zinc and cadmium levels in groundwater samples may be elevated from the zinc coating.

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Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints at slightly more costs. Welded-joint steel casing is also acceptable. Glued PVC may release organic contamination into the well and therefore should not be used if the well is to be sampled for organic contaminants.

When the water bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary and the screened interval is artificially packed with a fine sand. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The rig geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. (For example, as a standard procedure, a Morie No. 1 or Ottawa sand may be used with a 0.010-inch slot screen; however, with a 0.020-inch slot screen, the filter pack material must be the material retained on a No. 20 to No. 30 U.S. standard sieve.)

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a fine to medium grained well graded, silica sand. The quantity of sand placed in the annular space is dependent upon the length of the screened interval but should always extend at least 1 foot above the top of the screen. At least one to three feet of bentonite pellets or equivalent shall be placed above the sand pack. The cement-bentonite grout or equivalent extends from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally, i.e., no artificial sand pack will be installed, and the natural formation material will be allowed to collapse around the well screen after the well is installed. This method has been utilized where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets to the surface. The grout effectively seals the well and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom of the hole upward, to prevent bridging and to provide a better seal. However, in boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of two assemblages of material, i.e., a cement-bentonite grout. A cement bentonite grout normally is a mixture of cement, bentonite and water at a ratio of one 90-pound bag of Portland Type I cement, 3-5 pounds of granular or flake-type bentonite and 6 gallons of water. A neat cement is made up of one ninety-pound bag of Portland Type I cement and 6 gallons of water.

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In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets or equivalent. A short (1'-2') section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is often placed over the top for the well. This casing generally has a hinged cap and can be locked to prevent vandalism. A vent hole shall be provided in the cap to allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A Protective casing which is level with the ground surface is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter protective sleeve is set into the wet cement around the well with the top set level with the pavement. A manhole type lid placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 MONITORING WELL INSTALLATION

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineers rule to ensure proper well placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, then the sand pack can be installed. A weighted tape measure must be used during the procedure in order to carefully monitor installation progress. The sand is poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur.

After the sand pack is installed to the desired depth, (at least 1 foot above the top of the screen) then the bentonite pellet seal or equivalent, can be installed, in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack.

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The cement-bentonite grout is then mixed and either poured or tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

In stable formations where borehole collapse does not occur, the well can be installed as discussed above, and the use of a temporary casing is not needed. However, centralizers may have to be installed, one above, and one below the screen, to assure enough annular space for sand pack placement. A typical overburden monitoring well sheet is shown.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large diameter boring through the upper aquifer, 1 to 3 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting the outer casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells, with the exception of not using a temporary casing during installation. Sufficient time which will be determined by the rig geologist; must be allowed for setting of the grout prior to drilling through the confined layer. A typical confining layer monitoring well sheet is shown in Attachment C.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 feet into the bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout is cured, a smaller diameter boring is continued through the bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. However, if a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be installed temporary until final well installation is completed. Typical well construction forms for bedrock monitoring wells are shown in Attachment C.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be driven to depths exceeding 10 feet.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only one or two small-diameter tubes extending to the surface. Manufacturers of these types of samplers claim that four samplers can be installed in a 3-inch diameter borehole. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross contamination from sampling equipment. These samplers also perform well when the water table is within 25 feet from the surface (the typical range of suction pumps). Two manufacturers of these samplers are Timco Manufacturing Company, Inc., of

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Prairie du Sac, Wisconsin, and BARCAD Systems, Inc., of Concord, Massachusetts. Each offers various construction materials.

Two additional types of multilevel sampling systems have been developed. Both employ individual screened openings through a small-diameter casing. One of these systems (marketed by Westbay Instruments Ltd. of Vancouver, British Columbia, Canada) uses a screened port and a sampling probe to obtain samples and head measurements or perform permeability tests. This system allows sampling ports at intervals as close as 5 feet, if desired, in boreholes from 3 to 4.8 inches in diameter.

The other system, developed at the University of Waterloo at Waterloo, Ontario, Canada, requires field assembly of the individual sampling ports and tubes that actuate a simple piston pump and force the samples to the surface. Where the depth to ground water is less than 25 feet, the piston pumps are not required. The assembly is made of easily obtained materials; however, the cost of labor to assemble these monitoring systems may not be cost-effective.

5.4 WELL DEVELOPMENT METHODS

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity and temperature taken during development may yield information (stabilized values) that sufficient development is reached. The selection of the well development method (shall) be made by the rig geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

Overpumping and Backwashing - Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

Surging with a Surge Plunger - A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is used to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

Compressed Air - Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level

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to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping the well is subsequently done with the air lift method.

High Velocity Jetting - In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 REFERENCES

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U.S. EPA, 1980. Procedures Manual for Groundwater Monitoring of Solid Waste Disposal Facilities. Publication SW-611, Office of Solid Waste, U.S. EPA, Washington, D.C.

Driscoll, Fletcher G., 1986. Groundwater and Wells. Johnson Division, St. Paul, Minnesota, 1989 p.

7.0 RECORDS

A critical part of monitoring well installation is recording of significant details and events in the field notebook. The Geologist must record the exact depths of significant hydrogeological features screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (Attachment C) shall be used which allows the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information (shall) include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. The documentation is very important to prevent problems involving questionable sample validity. Somewhat different information will need to be recorded depending on whether the well is completed in overburden, in a confined layer, in bedrock with a cased well, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The Geologist shall calculate the annular space volume and have a general idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in. Any problems with rig operation or down time shall be recorded and may determine the driller's final fee.

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ATTACHMENT A

TABLE 7-4 RELATIVE COMPATIBILITY OF RIGID WELL-CASING MATERIAL (PERCENT)

	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless steel 304	Stainless steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Miner Acid/High Solids	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials

- 1 Teflon®
- 2 Stainless Steel 316
- 3 Stainless Steel 304
- 4 PVC 1
- 5 Lo-Carbon Steel
- 6 Galvanized Steel
- 7 Carbon Steel
- * Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton®	Silicone	Neoprene	Teflon®
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/High Solids	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials

- 1 Teflon®
 - 2 Polypropylene (PP)
 - 3 PVC flexible/PE linear
 - 4 Viton®
 - 5 PE Conventional
 - 6 Plexiglas/Lucite (PMM)
 - 7 Silicone/Neoprene
- Source: Barcelona et al., 1983
* Trademark of DuPont

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ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength not critical.
Weight	Relatively heavier	Lightweight, floats in water
Cost	Relatively expensive	Relatively inexpensive
Corrosivity	Deteriorates more rapidly in corrosive water	Non-corrosive—may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated HC
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work in the field.
Preparation for Use	Should be steam-cleaned for organics sampling	Never use glue fittings—pipes should be threaded or pressure-fitted. Should be steam cleaned if used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized	May sorb or release organic substances.

* See also Attachment A.

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

2.0 SCOPE

This procedure provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methodology.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Hydrogeologist or Geochemist - responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, documenting these in the Project Operations Plan (POP), and properly briefing the site sampling personnel.

Site Geologist - The Site Geologist is primarily responsible for the proper acquisition of the groundwater samples. When appropriate, such responsibilities may be performed by other qualified personnel (engineers, field technicians).

Site Manager - The Site Manager is responsible for reviewing the sampling procedures used by the field crew and for performing in-field spot checks for proper sampling procedures.

5.0 PROCEDURES

5.1 GENERAL

To be useful and accurate, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to keep any changes in water quality parameters to a minimum.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach shall be followed prior to sample acquisition:

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1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended for a representative sample. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, evacuation prior to sample withdrawal is not as critical.
2. For wells that can be purged to dryness with the sampling equipment being used, the well shall be evacuated and allowed to recover prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is preferred.
3. For high-yielding monitoring wells which cannot be evacuated to dryness, there is no absolute safeguard against contaminating the sample with stagnant water. One of the following techniques shall be used to minimize this possibility:
 - A submersible pump, intake line of a surface pump or bailer shall be placed just below the water surface when removing the stagnant water and lowered as the water level decreases. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. Once this is accomplished a bailer may be used to collect the sample for chemical analysis.
 - The inlet line of the sampling pump (or the submersible pump itself) shall be placed near the bottom of the screened section, and approximately one casing volume of water shall be pumped from the well at a rate equal to the well's recovery rate.

Stratification of contaminants may exist in the aquifer formation, both in terms of a concentration gradients due to mixing and dispersion processes in a homogeneous layer, and in layers of variable permeability into which a greater or lesser amount of the contaminant plume has flowed. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, and thus result in the collection of a non-representative sample.

5.2 SAMPLING, MONITORING, AND EVACUATION EQUIPMENT

Sample containers shall conform with EPA regulations for the appropriate contaminants.

The following equipment shall be on hand when sampling ground water wells:

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate packing containers and filler, ice, labels and chain-of-custody documents.
- Field tools and instrumentation - Thermometer; pH paper/meter; camera and film; tags; appropriate keys (for locked wells); engineers rule; water-level indicator; where applicable, specific-conductivity meter.
- Pumps
 - Shallow-well pumps--Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing) where applicable.
 - Deep-well pumps--submersible pump and electrical power generating unit; or air-lift apparatus where applicable.

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- Other sampling equipment - Bailers and monofilament line with tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.
- Pails - Plastic, graduated.
- Decontamination solutions - Distilled water, Alconox, methanol, acetone.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, sterilized, and reused, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

5.3 CALCULATIONS OF WELL VOLUME

To insure that the proper volume of water has been removed from the well prior to sampling it is first necessary to know the volume of standing water in the well pipe. This volume can be easily calculated by the following method. Calculations shall be entered in the field logbook and on the field data form (Attachment A):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).
- Determine depth of well (if not known from past records) by sounding using a clean, decontaminated weighted tape measure.
- Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).
- Calculate one static well volume in gallons ($V = 0.163Tr^2$).

where:

- V = Static volume of well in gallons.
- T = Thickness of water table in the well measured in feet, i.e., linear feet of static water.
- r = Inside radius of well casing in inches.
- 0.163 = A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.

- Determine the minimum amount to be evacuated before sampling.

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5.4 EVACUATION OF STATIC WATER (PURGING)

5.4.1 General

The amount of flushing a well shall receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately the well can be pumped until the parameters such as temperature, electrical conductance, and pH have stabilized. Onsite measurements of these parameters shall be recorded on the field data form.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from other areas. Generally three to five well volumes are considered effective for purging a well.

The site hydrogeologist, geochemist and risk assessment personnel shall define the objectives of the groundwater sampling program in the Work Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment B provides guidance on the proper evacuation device to use for given sampling situations. Note that all of these techniques involve equipment which is portable and readily available.

5.4.2.1 Bailers

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Bailers are inexpensive, and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- There is minimal outgassing of volatile organics while the sample is in the bailer.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

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5.4.2.2 Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (therefore not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause significant loss of dissolved gases and volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

5.4.2.3 Gas-Lift Samplers

This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift samplers are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics.

5.4.2.4 Submersible Pumps

Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed gas or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for 2-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- They may have low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

5.5 SAMPLING

5.5.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the POP prior to the field work:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).

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- Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
- Sample preservation requirements.
- Working schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

5.5.2 Sampling Methods

The collection of a groundwater sample is made up of the following steps:

1. HSO or designee will first open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data in a well sampling data sheet (Attachment A); then calculate the fluid volume in the well pipe.
3. Calculate well volume to be removed as stated in Section 5.3.
4. Select appropriate purging equipment (see Attachment B). If an electric submersible pump with packer is chosen, go to Step 10.
5. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner. Lower the purging device, as required, to maintain submergence.
6. Measure rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.
7. Observe peristaltic pump intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. Never collect volatile organics samples using a vacuum pump.
8. Purge a minimum of three-to-five casing volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice.
9. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to sampling level before filling (this requires use of other than a 'bucket-type' bailer)

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Purged water shall be collected in a designated container and disposed of in an acceptable manner.

10. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
11. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.
12. Add preservative if required. Label, tag, and number the sample bottle(s).
13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
14. Pack the samples for shipping. Attach a custody seal to the front and back of the shipping package. Make sure that traffic reports and chain-of-custody forms are properly filled out and enclosed or attached.
15. Decontaminate all equipment

5.5.3 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory.

5.5.4 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. Procedure SF-1.2 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Procedure SA-4.3 describes the preservation requirement for microbial samples.

5.5.5 Handling and Transporting Samples

After collection, samples shall be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it shall be bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged and thus possibly become cross-contaminated. All sample containers shall be enclosed in plastic bags or cans to prevent cross-contamination. Samples shall be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SA-6.2.

5.5.6 Sample Holding Times

Holding times (i.e. allowed time between sample collection and analysis) for routine samples are given in Procedure SF-1.2.

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5.6 RECORDS

Records will be maintained for each sample that is taken. The sample log sheet will be used to record the following information:

- Sample identification (site name, location, project number; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Purge data - prior to removal of each casing volume and before sampling, pH, electrical conductance, temperature, color, and turbidity shall be measured and recorded.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method).
- Sample disposition (preservatives added; lab sent to, date and time; lab sample number, EPA Traffic Report or Special Analytical Services number, chain-of-custody number.
- Additional remarks - (e.g., sampled in conjunction with state, county, local regulatory authorities; samples for specific conductance value only; sampled for key indicator analysis; etc.).

5.7 CHAIN-OF-CUSTODY

Proper chain-of-custody procedures play a crucial role in data gathering. Procedure SA-6.1 describes the requirements for a correct chain-of-custody.

6.0 REFERENCES

U.S. EPA, 1980. Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities. Office of Solid Waste, United States Environmental Protection Agency, Washington, D.C.

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4.0 RESPONSIBILITIES

Field Operations Leader - Responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record and maintaining custody of samples until they are relinquished to another custodian, to the shipper, or to the common carrier.

Remedial Investigation Leader - Responsible for determining that chain-of-custody procedures have been met by the sample shipper and analytical laboratory.

5.0 PROCEDURES

5.1 OVERVIEW

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is what it is represented to be. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom and, secondly, provide security for the evidence as it is moved and/or passes from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain of possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

5.2 SAMPLE IDENTIFICATION

The method of identification of a sample depends on it performed. When in-situ measurements are made, the data is or other field data records, with identifying information.

MISSING
PAGES

5.2.1 Sample Label

Samples, other than in-situ measurements, are removed and a laboratory or other location for analysis. Before removal, portions, depending upon the analyses to be performed. I with the Sampling Plan. Each sample container is identify Sample labels are provided by the PMO. The information recd

- **Project:** EPA Work Assignment Number (can be ob
- **Station Location:** The unique sample number il from the Sampling Plan).
- **Date:** A six-digit number indicating the day, month, and year of sample collection; e.g., 12/21/85.
- **Time:** A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 a.m., and 1629 is 4:29 p.m.).
- **Medium:** Water, soil, sediment, sludge, waste, etc.

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- **Concentration:** The expected concentration (i.e., low, medium, high).
- **Sample Type:** Grab or composite.
- **Preservation:** Type of preservation added and pH levels.
- **Analysis:** VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- **Sampled By:** Printed name of the sampler.
- **Case Number:** Case number assigned by the Sample Management Office.
- **Traffic Report Number:** Number obtained from the traffic report labels.
- **Remarks:** Any pertinent additional information.

Using just the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

5.2.2 Sample Identification Tag

A Sample Identification Tag (Attachment F) must also be used for samples collected for CLP (Contract Laboratory Program) analysis. The Sample Identification Tag is a waterproof paper label, approximately 3-by-6 inches, with a reinforced eyelet, and string or wire for attachment to the neck of the sample bottle. The Sample Tag is a controlled document, and is provided by the regional EPA office. Following sample analysis, the Sample Tag is retained by the laboratory as evidence of sample receipt and analysis.

The following information is recorded on the tag:

- **Project Code:** Work Assignment Number.
- **Station Number:** The middle portion of the Station Location Number, (between the hyphens).
- **Month/Day/Year:** Same as Date on Sample Label.
- **Time:** Same as Time on Sample Label.
- **Designate - Comp/Grab:** Composite or grab sample.
- **Station Location:** Same as Station Location on Sample Label.
- **Samplers:** Same as Sampled By on Sample Label.
- **Preservative:** Yes or No.
- **Analyses:** Check appropriate box(es).

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- **Remarks:** Same as Remarks on Sample Label (make sure the Case Number and Traffic Report numbers are recorded).
- **Lab Sample Number:** For laboratory use only.

The tag is then tied around the neck of the sample bottle.

If the sample is to be split, it is aliquoted into similar sample containers. Identical information is completed on the label attached to each split.

Blank, duplicate, or field spike samples shall not be identified as such on the label, as they may compromise the quality control function. Sample blanks, duplicates, spikes, and splits are defined in Procedure SA-6.6.

5.3 CHAIN-OF-CUSTODY PROCEDURES

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed of.

5.3.1 Field Custody Procedures

- Samples are collected as described in the site-specific Sampling Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the sample log sheet and Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions.
- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label because a ballpoint pen would not function in freezing weather.

5.3.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. Chain-of-Custody Record Forms used in EPA Regions I-IV are shown in Attachments A through D. The appropriate form shall be obtained from the EPA Regional Office. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as follows:

- Enter header information (project number, samplers, and project name – project name can be obtained from the Sampling Plan).
- Sign, date, and enter the time under "Relinquished by" entry.

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- Enter station number (the station number is the middle portion of the station location number, between the hyphens).
- Check composite or grab sample.
- Enter station location number (the same number as the station location on the tag and label).
- Enter the total number of containers per station number and the type of each bottle.
- Enter either the inorganic traffic report number, the organic traffic report number, or the SAS number for each station number in the remarks column.
- Enter the tag number from the bottom of the sample identification tag in the remarks column for each station location.
- Make sure that the person receiving the sample signs the "Received by" entry, or enter the name of the carrier (e.g., UPS, Federal Express) under "Received by." Receiving laboratory will sign "Received for Laboratory by" on the lower line and enter the date and time.
- Enter the bill-of-lading or Federal Express airbill number under "Remarks," in the bottom right corner, if appropriate.
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in the appropriate sample shipping package. Retain the pink copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment G is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals are provided by ZPMO on an as-needed basis.
- Place the seal across the shipping container opening so that it would be broken if the container is opened.
- Complete other carrier-required shipping papers.

The custody record is completed using black waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the sample container (enclosed with other documentation in a plastic zip-lock bag). As long as custody forms are sealed inside the sample container and the custody seals are intact, commercial carriers are not required to sign off on the custody form.

If sent by mail, the package will be registered with return receipt requested. If sent by common carrier or air freight, proper documentation must be maintained.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

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5.3.3 Receipt for Samples Form

Whenever samples are split with a private party or government agency, a separate Receipt for Samples Record Form is prepared for those samples and marked to indicate with whom the samples are being split. The person relinquishing the samples to the party or agency shall require the signature of a representative of the appropriate party acknowledging receipt of the samples. If a representative is unavailable or refuses to sign, this is noted in the "Received by" space. When appropriate, as in the case where the representative is unavailable, the custody record shall contain a statement that the samples were delivered to the designated location at the designated time. This form must be completed and a copy given to the owner, operator, or agent-in-charge even if the offer for split samples is declined. The original is retained by the Field Operations Leader.

6.0 REFERENCES

U.S. EPA, 1984. User's Guide to the Contract Laboratory Program, Office of Emergency and Remedial Response, Washington, D.C.

7.0 ATTACHMENTS

- Attachment A - Chain-of-Custody Record Form for use in Region I
- Attachment B - Chain-of-Custody Record Form for use in Region II
- Attachment C - Chain-of-Custody Record Form for use in Region III
- Attachment D - Chain-of-Custody Record Form for use in Region IV
- Attachment E - Sample Label
- Attachment F - Sample Identification Tag
- Attachment G - Chain-of-Custody Seal

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Reportable Quantity (RQ) - A parenthetical note of the form "(RQ-1000/454)" following an entry in the DOT Hazardous Materials table (49 CFR 172.101) indicates the reportable quantity of the substance in pounds and kilograms. If a spill of that amount or more of the substance occurs during transit or storage, a report must be filed with DOT according to 49 CFR 171.15-15 concerning hazardous materials incidents reports. If the material spilled is a hazardous waste, a report must always be filed, regardless of the amount, and must include a copy of the manifest. If the RQ notation appears, it must be shown either immediately before or after the proper shipping name on the shipping paper (or manifest). Most shipping papers and manifests will have a column designated "HM" which may be used for this purpose.

4.0 RESPONSIBILITIES

Field Operations Leader or Team Sampling Leader - responsible for determining that samples are properly packaged and shipped.

Sampling Personnel - responsible for implementing the packaging and shipping requirements.

5.0 PROCEDURES

5.1 INTRODUCTION

Samples collected for shipment from a site shall be classified as either environmental or hazardous material (or waste) samples. In general, environmental samples are collected off-site (for example from streams, ponds, or wells) and are not expected to be grossly contaminated with high levels of hazardous materials. On-site samples (for example, soil, water, and materials from drums or bulk storage tanks, obviously contaminated ponds, lagoons, pools, and leachates from hazardous waste sites) are considered hazardous. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples. If there is any doubt, a sample shall be considered hazardous and shipped accordingly.
- Protect the health and safety of laboratory personnel receiving the samples. Special precautions are used at laboratories when samples other than environmental samples are received.

5.2 ENVIRONMENTAL SAMPLES

5.2.1 Packaging

Environmental samples may be packaged following the procedures outlined in Section 5.4 for samples classified as "flammable liquids" or "flammable solids." Requirements for marking, labeling, and shipping papers do not apply.

Environmental samples may also be packed without being placed inside metal cans as required for flammable liquids or solids.

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- Place sample container, properly identified and with a sealed lid, in a polyethylene bag, and seal the bag.
- Place sample in a fiberboard container or metal picnic cooler which has been lined with a large polyethylene bag.
- Pack with enough noncombustible, absorbent, cushioning materials to minimize the possibility of the container breaking.
- Seal large bag.
- Seal or close outside container.

5.2.2 Marking Labeling

Sample containers must have a completed sample identification tag and the outside container must be marked "Environmental Sample". The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling are required.

5.2.3 Shipping Papers

No DOT shipping papers are required. However, the appropriate chain-of-custody forms must be included with the shipment.

5.2.4 Transportation

There are no DOT restrictions on mode of transportation.

5.3 DETERMINATION OF SHIPPING CLASSIFICATION FOR HAZARDOUS MATERIAL SAMPLES

Samples not determined to be environmental samples, or samples known or expected to contain hazardous materials, must be considered hazardous material samples and transported according to the requirements listed below.

5.3.1 Known Substances

If the substance in the sample is known or can be identified, package, mark, label and ship according to the specific instructions for that material (if listed) in the DOT Hazardous Materials Table, 49 CFR 172.101.

Unz and Company have published the following steps to help in locating a proper shipping name from the Hazardous Materials Table, 49 CFR 172.101.

1. Look first for the chemical or technical name of the material, for example, ethyl alcohol. Note that many chemicals have more than one technical name, for example, perchloroethylene (not listed in 172.101) is also called tetrachloroethylene (listed 172.101). It may be useful to consult a chemist for all possible technical names a material can have. If your material is not listed by its technical name then.

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2. Look for the chemical family name. For example, pentyl alcohol is not listed but the chemical family name is: alcohol, n.o.s. (not otherwise specified). If the chemical family name is not listed then.
3. Look for a generic name based on end use. For example, Paint, n.o.s or Fireworks, n.o.s. If a generic name based on end use is not listed then.
4. Look for a generic family name based on end use, for example, drugs, n.o.s. or cosmetics, n.o.s. Finally, if your material is not listed by a generic family name but you suspect or know the material is hazardous because it meets the definition of one or more hazardous classes, then.
5. You will have to go to the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s, or Oxidizer, n.o.s.

5.3.2 Unknown Substances

For samples of hazardous substances of unknown content, select the appropriate transportation category according to the DOT Hazardous Materials Classification (Attachment A), a priority system of transportation categories.

The correct shipping classification for an unknown sample is selected through a process of elimination, utilizing Attachment A. Unless known or demonstrated otherwise (through the use of radiation survey instruments), the sample is considered radioactive and appropriate shipping regulations for "radioactive material" followed.

If a radioactive material is eliminated, the sample is considered to contain "Poison A" materials (Attachment B), the next classification on the list. DOT defines "Poison A" as extremely dangerous poisonous gases or liquids of such a nature that a very small amount of gas, or vapor of the liquids, mixed with air is dangerous to life. Most Poison A materials are gases or compressed gases and would not be found in drum-type containers. Liquid Poison A would be found only in closed containers; however, all samples taken from closed drums do not have to be shipped as Poison A, which provides for a "worst case" situation. Based upon information available, a judgment must be made whether a sample from a closed container is a Poison A.

If Poison A is eliminated as a shipment category, the next two classifications are "flammable" or "nonflammable" gases. Since few gas samples are collected, "flammable liquid" would be the next applicable category. With the elimination of radioactive material, Poison A, flammable gas, and nonflammable gas, the sample can be classified as flammable liquid (or solid) and shipped accordingly. These procedures would also suffice for shipping any other samples classified below flammable liquids in the DOT classification table (Attachment A). For samples containing unknown materials, categories listed below flammable liquids/solids on Attachment A are generally not used because showing that these materials are not flammable liquids (or solids) requires flashpoint testing, which may be impractical and possibly dangerous at a site. Thus, unless the sample is known to consist of materials listed as less hazardous than flammable liquid (or solid) on Attachment A, it is considered a flammable liquid (or solid) and shipped as such.

For any hazardous material shipment, utilize the shipping checklist (Attachment C) as a guideline to ensure that all sample-handling requirements are satisfied.

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5.4 **PACKAGING AND SHIPPING OF SAMPLES CLASSIFIED AS FLAMMABLE LIQUID (OR SOLID)**

5.4.1 **Packaging**

Applying the word "flammable" to a sample does not imply that it is in fact flammable. The word prescribes the class of packaging according to DOT regulations.

1. Collect sample in the prescribed container with a nonmetallic, Teflon-lined screw cap. To prevent leakage, fill container no more than 90 percent full.
2. Complete sample label and sample identification tag and attach securely to sample container.
3. Seal container and place in 2-mil thick (or thicker) polyethylene bag, one sample per bag. Position sample identification tag so that it can be read through bag. Seal bag.
4. Place sealed bag inside metal can and cushion it with enough noncombustible, absorbent material (for example, vermiculite or diatomaceous earth) between the bottom and sides of the can and bag to prevent breakage and absorb leakage. Pack one bag per can. Use clips, tape, or other positive means to hold can lid securely, tightly and permanently. Mark can as indicated in Paragraph 1 of Section 5.4.2, below.
5. Place one or more metal cans (or single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans with noncombustible, absorbent cushioning materials for stability during transport. Mark container as indicated in Paragraph 2 of Section 5.4.2.

5.4.2 **Marking/Labeling**

1. Use abbreviations only where specified. Place the following information, either hand-printed or in label form, on the metal can (or 1-gallon bottle):
 - Laboratory name and address.
 - "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325."

Not otherwise specified (n.o.s) is not used if the flammable liquid (or solid) is identified. Then the name of the specific material is listed before the category (for example, Acetone, Flammable Liquid), followed by its appropriate UN number found in the DOT Hazardous Materials table (49 CFR 172.101).

2. Place all information on outside shipping container as on can (or bottle), specifically:
 - Proper shipping name.
 - UN or NA number.
 - Proper label(s).
 - Addressee and sender.

Place the following labels on the outside shipping container: "Cargo Aircraft Only" and "Flammable Liquid" (or "Flammable Solid"). "Dangerous When Wet" label shall be used if the solid has not been exposed to a wet environment. "Laboratory Samples" and "THIS SIDE UP" or "THIS END UP" shall also be marked on the top of the outside container, and upward-pointing arrows shall be placed on all four sides of the container.

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5.4.3 Shipping Papers

1. Use abbreviations only where specified. Complete the carrier-provided bill of lading and sign certification statement (if carrier does not provide, use standard industry form, see Attachment D). Provide the following information in the order listed (one form may be used for more than one exterior container).
 - "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325."
 - "Limited Quantity" (or "Ltd. Qty.").
 - "Cargo Aircraft Only."
 - Net weight (wt) or net volume (vol), just before or just after "Flammable Liquid, n.o.s." or "Flammable Solid, n.o.s.," by item, if more than one metal can is inside an exterior container.
 - "Laboratory Samples" (if applicable).
2. Include Chain-of-Custody Record, properly executed in outside container.
3. "Limited Quantity" of "Flammable Liquid, n.o.s." is limited to one pint per inner container. For "Flammable Solid, n.o.s.," net weight of inner container plus sample shall not exceed one pound; total package weight shall not exceed 25 pounds.

5.4.4 Transportation

1. Transport unknown hazardous substance samples classified as flammable liquids by rented or common carrier truck, railroad, or express overnight package services. Do not transport by any passenger-carrying air transport system, even if they have cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that only carry cargo.
2. For transport by government-owned vehicle, including aircraft, DOT regulations do not apply. However, procedures described above, with the exception of execution of the bill of lading with certification, shall still be used.

6.0 REFERENCES

U.S. Department of Transportation, 1983. Hazardous Materials Regulations, 49 CFR 171-177.

NUS Standard Operating Procedure SA-6.1 - Sample Identification and Chain-of-Custody

NUS Standard Operating Procedure SA-1.2 - Sample Preservation

NUS Standard Operating Procedure SF-1.5 - Compatibility Testing

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1.0 PURPOSE

This procedure describes the process for keeping a site logbook.

2.0 SCOPE

The site logbook is a controlled document which records all major on-site activities during a Remedial Investigation/Feasibility Study. At a minimum, the following activities/events shall be recorded in the site logbook:

- Arrival/departure of site visitors
- Arrival/departure of equipment
- Sample pickup (chain-of-custody form numbers, carrier, time)
- Sampling activities/sample logsheet numbers
- Start or completion of borehole/trench/monitoring well installation or sampling activities
- Health and Safety issues

The site logbook is initiated at the start of the first on-site activity (e.g., initial reconnaissance survey). Entries are made for every day that on-site activities take place which involve RI/FS contractor personnel. One current site logbook is maintained per site.

The site logbook becomes part of the permanent site file maintained in the RI contractor's office. Because information contained in the site logbook may be admitted as evidence in cost recovery or other legal proceedings, it is critical that this document be properly maintained.

3.0 GLOSSARY

Site Logbook - The logbook is a bound notebook with consecutively numbered pages that cannot be removed. Upon entry of data, the logbook requires signature by the responsible site leader (see Section 5.1).

4.0 RESPONSIBILITIES

The site logbook is issued by the Regional Manager (or his designee) to the Site Manager for the duration of the project. The Site Manager releases the site logbook to the Field Operations Leader or other person responsible for the direction of on-site activities (e.g., Reconnaissance Survey Team Leader, Sampling Team Leader). It is the responsibility of this person (or his designee) to keep the site logbook current while in his possession, and return it to the Site Manager or turn it over to another field team. Following the completion of all fieldwork, the site logbook is returned to the Site Manager for inclusion in the permanent site files.

5.0 PROCEDURES

5.1 GENERAL

The cover of each site logbook contains the following information:

- Project Name
- NUS Project Number
- RI/FS Contractor and Site Manager's Name
- Sequential Book Number

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- Start Date
- End Date

Daily entries into the logbook may contain a variety of information. At the beginning of each day the following information must be recorded:

- Date
- Start time
- Weather
- All field personnel present
- Any visitors present

During the day, a summary of all site activities and level of personal protection shall be recorded in the logbook. The information need not duplicate that recorded in other field notebooks (e.g., sample logbook, Site Geologist's notebook, Health and Safety Officer's notebook, etc.), but shall summarize the contents of these other notebooks and refer to the page locations in these notebooks for detailed information. An example of a site logbook page is shown in Attachment A.

The sample logsheet for each sample collected (see Procedure SA-6.6) must be referenced. If measurements are made at any location, the measurements and equipment used must either be recorded in the site logbook or reference must be made to the notebook and page number(s) on which they are recorded (see Attachment A).

All entries shall be made in black pen. No erasures are permitted. If an incorrect entry is made, the data shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook must be signed. It must also be signed by the Field Operations Leader or responsible site leader at the end of each day.

5.2 PHOTOGRAPHS

When movies, slides, or photographs are taken of a site or any monitoring location, they are numbered to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions are entered in the logbook as the photographs are taken. A series entry may be used for rapid-sequence photographs. The photographer is not required to record the aperture settings and shutter speeds for photographs taken within the normal automatic exposure range. However, special lenses, films, filters, and other image-enhancement techniques must be noted in the logbook. If possible, such techniques shall be avoided, since they can adversely affect the admissibility of photographs as evidence. Chain-of-custody procedures depend upon the subject matter, type of film, and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Adequate logbook notation and receipts may be used to account for routine film processing. Once processed, the slides of photographic prints shall be serially numbered and labeled according to the logbook descriptions.

6.0 REFERENCES

None.

7.0 ATTACHMENTS

Attachment A - Typical Site Logbook Entry

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**ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY**

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL:

NUS	DRILLER	EPA
_____	_____	_____
_____	_____	_____
_____	_____	_____

WEATHER: Clear, 68°F, 2-5 mph wind from SE

ACTIVITIES:

1. Steam jenny and fire hoses were set up.
2. Drilling activities at well _____ resumes. Rig geologist was _____ See Geologist's Notebook, No.1, page 29-30, for details of drilling activity. Sample No. 123-21-S4 collected; see sample logbook, page 42. Drilling activities completed at 11:50 and a 4 inch stainless steel well installed. See Geologist's Notebook, No. 1, page 31, and well construction details for well _____.
3. Drilling rig No.2 steam-cleaned at decontamination pit. Then set up at location of well _____.
4. Well _____ drilled. Rig geologist was _____ See Geologist's Notebook, No.2, page _____ for details of drilling activities. Sample numbers 123-22-S1, 123-22-S2, and 123-22-S3 collected; see sample logbook, pages 43, 44, and 45.
5. Well _____ was developed. Seven 55-gallon drums were filled in the flushing stage. The well was then pumped using the pitcher pump for 1 hour. At the end of the hour, water pumped from well was "sand free."
6. EPA remedial project manger arrives on-site at 14:25 hours.
7. Large dump truck arrives at 14:45 and is steam-cleaned. Backhoe and dump truck set up over test pit _____.
8. Test pit _____ dug with cuttings placed in dump truck. Rig geologist was _____ See Geologist's Notebook, No. 1, page 32, for details of test pit activities. Test pit subsequently filled. No samples taken for chemical analysis. Due to shallow groundwater table, filling in of test pit _____ resulted in a very soft and wet area. A mound was developed and the area roped off.
9. Express carrier picked up samples (see Sample Logbook, pages 42 through 45) at 17:50 hours. Site activities terminated at 18:22 hours. All personnel offsite, gate locked.

Field Operations Leader

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5.0 GUIDELINES

5.1 MEASUREMENT OF pH

5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH can also be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis, and specific techniques are not described.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required, and the pH meter when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or basicity of the solution with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to hydrogen ion concentration across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Accumet 150 portable pH meter, or equivalent.
- Combination electrode with polymer body to fit the above meter (alternately a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs.
- pH indicator paper, such as Hydrion or Alkacid, to cover the pH range 2 through 12.
- Buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

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5.1.4 Measurement Techniques for Field Determination of pH

1. pH Meter

The following procedure is used for measuring pH with a pH meter (Standardization is according to manufacturers instructions):

- a. The instrument and batteries shall be checked and calibrated prior to initiation of the field effort.
- b. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
- c. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- d. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- e. Immerse the electrode(s) in a pH-7 buffer solution.
- f. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). Alternately, the buffer solution may be immersed in the sample and allowed to reach temperature equilibrium before equipment calibration. It is best to maintain buffer solution at or near expected sample temperature before calibration.
- g. Adjust the pH meter to read 7.0.
- h. Remove the electrode(s) from the buffer and rinse well with demineralized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.
- i. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
- j. Read and record the pH of the solution, after adjusting the temperature compensator to the sample temperature. pH shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature.
- k. Rinse the electrode(s) with deionized water.
- l. Keep the electrode(s) immersed in deionized water when not in use.

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The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

2. pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

5.2 MEASUREMENT OF SPECIFIC CONDUCTANCE

5.2.1 General

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

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5.2.3 Equipment

The following equipment is needed for taking specific conductance measurements:

- YSI Model 33 portable conductivity, meter, or equivalent
- Probe for above meter

A variety of conductivity meters are available which may also be used to monitor salinity and temperatures. Probe types and lengths vary, so equipment may be obtained to meet the specific requirement of the sampling program.

5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturers instructions):

- Check batteries and calibrate instrument before going into the field.
- Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used. Attachment A may be used for guidance.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature.
- Read and record the results in a field logbook or sample log sheet.

If the specific conductance measurements become erratic, or inspection shows that any platinum black has flaked off the electrode, replatinization of the electrode is necessary. See the manufacturer's instructions for details.

Note that specific conductance is occasionally reported at temperatures other than ambient.

5.3 MEASUREMENT OF TEMPERATURE

5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled or dial-type thermometers. In addition various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

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5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field logbook or sample log sheet.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to manufacturer's recommendations with an approved thermometer before each measurement or group of closely spaced measurements.

5.4 MEASUREMENT OF DISSOLVED OXYGEN CONCENTRATION

5.4.1 General

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time if the sample is not adequately preserved.

The method monitoring discussed herein is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible, and are free from interference caused by color, turbidity, colloidal material or suspended matter.

5.4.2 Principles of Equipment Operation

Dissolved oxygen probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, but to leave the surface of the solution undisturbed.

Dissolved oxygen probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not

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easily depolarized from the indicating electrode. If the gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer.

5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- YSI Model 56 dissolved oxygen monitor or equivalent.
- Dissolved oxygen/temperature probe for above monitor.
- Sufficient cable to allow the probe to contact the sample.

5.4.4 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration:

- The equipment shall be calibrated and have its batteries checked in the laboratory before going to the field.
- The probe shall be conditioned in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a water sample of known dissolved oxygen concentration (i.e., determined by Winkler method) or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment B).
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers placed in wells can be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.
- Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or if a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

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5.5 MEASUREMENT OF OXIDATION-REDUCTION POTENTIAL

5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The technique therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of oxidized to reduced species in the sample.

5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and will be dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as dissolved oxygen, may be correlated with ORP to provide a knowledge of the quality of the solution, water, or wastewater.

5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Accumet 150 portable pH meter or equivalent, with a millivolt scale.
- Platinum electrode to fit above pH meter.
- Reference electrode such as a calomel, silver-silver chloride, or equivalent.

5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be calibrated and have its batteries checked before going to the field.
- Check that the platinum probe is clean and that the platinum bond or tip is unoxidized. If dirty, polish with emery paper or, if necessary, clean the electrode using aqua regia, nitric acid, or chromic acid, in accordance with manufacturer's instructions.
- Thoroughly rinse the electrode with demineralized water.
- Verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of the test solution is altered. The ORP will increase when the pH of the test solution decreases and the ORP will decrease if the test solution pH is increased. Place the sample in a clean glass beaker and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added, the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions. If the ORP does not respond as above when the caustic is added, the electrodes shall be cleaned and the above procedure repeated.
- After the assembly has been checked for sensitivity, wash the electrodes with three changes of water or by means of a flowing stream of water from a wash bottle. Place the sample in a clean glass beaker or sample cup and insert the electrodes. Set temperature

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compensator throughout the measurement period. Read the millivolt potential of the solution, allowing sufficient time for the system to stabilize and reach temperature equilibrium. Measure successive portions of the sample until readings on two successive portions differ by no more than 10 mV. A system that is very slow to stabilize properly will not yield a meaningful ORP. Record all results in a field logbook, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

5.6 SPECIFIC ION ELECTRODE MEASUREMENTS

5.6.1 General

Use of specific ion electrodes can be beneficial in the field for determining the presence and concentration of dissolved inorganic species which may be associated with contaminant plumes or leachate. Thus, electrodes can be used for rapid screening of water quality and determination of water migration pathways.

This procedure provides generic information for specific ion electrodes commonly used in groundwater quality monitoring programs and describes the essential elements of a field investigation program. Analytical methods using some specific ion electrodes have not been approved by the USEPA. In addition, calibration procedures and solutions, interferences and conditions and requirements for use for various electrodes vary greatly. Consequently, review of manufacturer's literature is mandatory prior to use.

5.6.2 Principles of Equipment Operation

All specific ion electrode measurements involve the use of a reference electrode, a pH meter, and a specific ion electrode (SIE). When the SIE and the reference electrode are immersed in a solution of the ion to be measured, a potential difference is developed between the two electrodes. This potential can be measured by a pH meter and related to the concentration of the ion of interest through the use of standard solutions and calibration curves.

Several different types of SIEs are in use: glass, solid-state, liquid-liquid membrane, and gas-sensing. All of the electrodes function using an ion exchange process as the potential determining mechanism. Glass electrodes are used for pH measurement. The glass in the tip of the electrode actually acts as a semi-permeable membrane to allow solution. Solid-state electrodes replace the glass membrane with an ionically-conducting membrane, (but act in essentially the same manner) while liquid-liquid membrane electrodes have an organic liquid ion exchanger contained in the pores of a hydrophobic membrane. Maintenance of the conducting interface, in combination with a reference electrode, allows completion of the electrical circuit and subsequent measurement of the potential difference. Gas-sensing electrodes have a membrane that permits the passage of gas only, thus allowing for the measurement of gas concentration. Regardless of the mechanism involved in the electrode, most SIEs are easy to use under field conditions. The sensitivity and applicable concentration range for various membranes and electrodes will vary.

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5.6.3 Equipment

The following equipment is required for performing quantitative analyses using a specific ion electrode:

- A pH meter with a millivolt scale, or equivalent.
- The specific ion electrode for the parameter to be measured. A partial list of ions which can be measured includes cyanide, sulfide, ammonia, lead, fluoride and chloride.
- A suitable reference electrode to go with the above SIE.

Specific electrodes for other ions have also been developed, but are not widely used for field investigation efforts at this time. Note that of the specific electrodes referenced above, only fluoride and ammonia have analytical methods approved by the U.S. EPA.

5.6.4 Measurement Techniques for Inorganic Ions Using Specific Ion Electrodes

Different types of electrodes are used in slightly different ways and are applicable for different concentration ranges. Following the manufacturer's instructions, the general steps given below are usually followed:

- Immerse the electrode in water for a suitable period of time prior to sample analysis.
- Standardize the electrode according to the manufacturer's instructions, including necessary chemical additions for ionic strength adjustment, etc. Standard solutions normally differ by factors of ten in concentration. Constant stirring is needed for accurate readings.
- Immerse the electrode in the sample. Allow the reading to stabilize and record the results in a site logbook. Stir the sample at the same rate as the standards. Air bubbles near the membrane shall be avoided, since this may cause interference in millivolt readings.

(NOTE: Each SIE has substances which interfere with proper measurement. These may be eliminated using pretreatment methods as detailed by the manufacturer. It is important to know if interferences are present so that suspect readings may be noted as such.)

- If the pH meter does not read out directly, plot millivolts versus concentration for the standards and then determine sample concentration.

6.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

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1.0 PURPOSE

This procedure describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped offsite for chemical analysis.

2.0 SCOPE

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, while many organic chemicals may dissolve various types of plastic containers. It is therefore critical to select the correct container in order to maintain the quality of the sample prior to analysis.

Many water and soil samples are unstable, and therefore require preservation when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s) requiring analysis. While complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected.

Preservation techniques are usually limited to pH control, chemical addition(s) and refrigeration/freezing. Their purpose is to (1) retard biological activity, (2) retard hydrolysis of chemical compounds/complexes, (3) reduce constituent volatility, and (4) reduce adsorption effects.

3.0 GLOSSARY

HCl - Hydrochloric Acid
H₂SO₄ - Sulfuric Acid
HNO₃ - Nitric Acid
NaOH - Sodium Hydroxide

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing one gram-atom of replaceable hydrogen or its equivalent. Thus, a one molar solution of HCl, containing one gram-atom of H, is "one-normal," while a one molar solution of H₂SO₄ containing two gram-atoms of H, is "two-normal."

4.0 RESPONSIBILITIES

Field Operations Leader - retains overall responsibility for the proper storage and preservation of samples. During the actual collection of samples, the sampling technician(s) will be directly responsible for the bottling, preservation, labeling, and custody of the samples they collect until released to another party for storage or transport to the analytical laboratory.

5.0 PROCEDURES

5.1 SAMPLE CONTAINERS

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be determined is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then the container shall be plastic. Since container specification will depend on the analyte and sample matrix types (as indicated in Attachment A) duplicate samples shall be taken when both organic and inorganic analyses are required. Containers shall be kept in the

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dark (to minimize biological or photooxidation/photolysis breakdown of constituent) until they reach the analytical laboratory. The sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (1 liter of water at 4°C expands by 15 ml if heated to 130°F/55°C), however, head space for volatile organic analyses shall be omitted.

For CLP laboratories, containers will be obtained through the CLP Sample Management Office. For Responsible party actions or non-CLP laboratories, the laboratory shall provide containers that have been cleaned according to U.S. EPA procedures. Sufficient lead time shall be allowed. Shipping containers for samples, consisting of sturdy ice chests, are provided by the laboratory of the remedial investigation contractor.

Once opened, the container must be used at once for storage of a particular sample. Unused but opened containers are to be considered contaminated and must be discarded; because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or missing Teflon liner (if required for the container) shall be discarded.

General sample container and sample volume requirements are listed in Attachment A. Specific container requirements are listed in Attachment B.

5.2 PRESERVATION TECHNIQUES

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the Field or added in the Field. In general, aqueous samples of low concentration organics (or soil samples of low or medium concentration organics) are cooled to 4°C. Medium concentration aqueous samples and high hazard organics sample are not preserved. Low concentration aqueous samples for metals are acidified with HNO₃, while medium concentration and high hazard aqueous metal samples are not preserved. Low or medium concentration soil samples for metals are cooled to 4°C while high hazard samples are not preserved.

The following subsections describe the procedures for preparing and adding chemical preservatives. Attachments A and B indicate the specific analytes which require these preservatives.

5.2.1 Addition of Acid (H₂SO₄, HCl, or HNO₃) or Base

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade and shall be diluted to the required concentration with double-distilled, deionized water in the laboratory, before Field sampling commences:

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Acid Base	Concentration	Normality	Amount for Acidification*
HCl	1:1 dilution of concentrated HCl	6N	5-10 ml
H ₂ SO ₄	1:1 dilution of concentrated H ₂ SO ₄	18N	2-5 ml
HNO ₃	Undiluted concentrated HNO ₃	16N	2-5 ml
NaOH	400 grams solid NaOH in 870 ml water	10N	2 ml**

- * Amount of acid to add (at the specified strength) per liter of water to reduce the sample pH to less than 2, assuming that the water is initially at pH 7, and is poorly buffered and does not contain particulate matter.
- ** To raise pH of 1 liter of water to 12.

The approximate volumes needed to acidify one liter of neutral water to a pH of less than 2 (or raise the pH to 12) are shown in the last column of the above table. These volumes are only approximate; if the water is more alkaline, contains inorganic or organic buffers, or contains suspended particles, more acid may be required. The final pH must be checked using narrow-range pH paper.

Sample acidification or base addition shall proceed as follows:

- Check initial pH of sample with wide range (0-14) pH paper.
- Fill sample bottle to within 5-10 ml of final desired volume and add about 1/2 of estimated acid or base required, stir gently and check pH with medium range pH paper (pH 0-6 or pH 7.5-14, respectively).
- Add acid or base a few drops at a time while stirring gently. Check for final pH using narrow range (0-2.5 or 11-13, respectively) pH paper; when desired pH is reached, cap sample bottle and seal.

Never dip pH paper into the sample; apply a drop of sample to the pH paper using the stirring rod.

5.2.2 Cyanide Preservation

Pre-sample preservation is required if oxidizing agents such as chlorine are suspected to be present. To test for oxidizing agents, place a drop of the sample on KI-starch paper; a blue color indicates the need for treatment. Add ascorbic acid to the sample, a few crystals at a time, until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 g of ascorbic acid for each liter of sample volume. Add NaOH solution to raise pH to greater than 12 as described in 5.2.1. If oxidizing agents are not suspected, add NaOH as directed.

5.2.3 Sulfide Preservation

Samples for sulfide analysis must be preserved by addition of 4 drops (0.2 ml) of 2N zinc acetate solution per 100 ml sample. The sample pH is then raised to 9 using NaOH. The 2N zinc acetate solution is made by dissolving 220 g of zinc acetate in 870 ml of distilled water to make 1 liter of solution.

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5.2.4 Preservation of Organic Samples Containing Residual Chlorine

Some organic samples containing residual chlorine must be treated to remove this chlorine upon collection (See Attachment A). Test the samples for residual chlorine using EPA methods 330.4 or 330.5 (Field Test Kits are available for this purpose). If residual chlorine is present, add 0.008% sodium thiosulfate (80 mg per liter of sample).

5.2.5 Field Filtration

When the objective is to determine concentration of dissolved inorganic constituents in a water system, the sample must be filtered through a non-metallic 0.45 micron membrane filter immediately after collection. A filtration system is recommended if large quantities of samples must be filtered in the field. The filtration system shall consist of a Büchner funnel inserted into a single-hole rubber stopper, sized to form a seal when inserted into the top of a vacuum filter flask equipped with a single side arm. Heavy-wall Tygon tubing shall be attached to the single side arm of the vacuum filter flask and the suction port of a vacuum pump. The stem of the Büchner funnel shall extend below the level of the side arm of the vacuum filter flask to prevent any solvent from entering the tubing leading to the vacuum pump. Before filtration, the filter paper, which shall be of a size to lay flat on the funnel plate, shall be wetted with the solvent in order to "seal" it to the funnel. Slowly pour the solvent into the funnel and monitor the amount of solvent entering the vacuum filter flask. When the rate of solvent entering the flask is reduced to intermittent dripping and the added aliquot of solvent in the funnel has passed through the filter, the used filter paper shall be replaced with new filter paper. If the solvent contains a high percentage of suspended solids, a coarser-sized nonmetallic membrane filter may be used prior to usage of the 0.45 micron membrane filter. This "prefiltering" step may be necessary to expedite the filtration procedure. Discard the first 20 to 50 ml of filtrate from each sample to rinse the filter and filtration apparatus to minimize the risk of altering the composition of the samples by the filtering operation. For analysis of dissolved metals, the filtrate is collected in a suitable bottle (see Section 5.1) and is immediately acidified to pH 2.0 or less with nitric acid whose purity is consistent with the measurement to be made. Inorganic anionic constituents may be determined using a portion of the filtrate that has not been acidified.

Samples used for determining temperature, dissolved oxygen, Eh, and pH should not be filtered. Do not use vacuum filtering prior to determining carbonate and bicarbonate concentration because it removes dissolved carbon dioxide and exposes the sample to the atmosphere. Pressure filtration can be done using water pressure from the well. If gas pressure is required, use an inert gas such as argon or nitrogen.

Do not filter samples for analysis of volatile organic compounds. If samples are to be filtered for analyzing other dissolved organic constituents, use a glass-fiber or metal-membrane filter and collect the samples in a suitable container (see Section 5.1). Because most organic analyses require extraction of the entire sample, do not discard any of it. After filtering, the membrane containing the suspended fraction can be sealed in a glass container and analyzed separately as soon as practicable. Total recoverable inorganic constituents may be determined using a second, unfiltered sample collected at the same time as the sample for dissolved constituents.

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1.0 PURPOSE

The purpose of these procedures is to provide a general methodology, protocol, and reference information on the proper decontamination procedures to be used on chemical sampling and field analytical equipment.

2.0 SCOPE

This procedure addresses chemical sampling and field analytical equipment only, and should be consulted when equipment decontamination procedures are being developed as part of project-specific plans.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Manager - responsible for ensuring that project-specific plans and the implementation of field investigations are in compliance with these guidelines.

Field Operations Leader - responsible for ensuring that decontamination procedures for all chemical sampling and field analytical equipment are programmed prior to the actual field effort and that personnel required to accomplish the task have been briefed and trained to execute the task.

5.0 PROCEDURES

In order to assure that chemical analysis results are reflective of the actual concentrations present at sampling locations, chemical sampling and field analysis equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sample points) and at the conclusion of the sampling program. This will minimize the potential for cross-contamination between sample points and the transfer of contamination offsite.

This procedure incorporates only those aspects of decontamination not addressed in other procedures. Specifically it incorporates those items involved in decontamination of chemical sampling and field analytical equipment.

5.1 ACCESS FOR SAMPLING

5.1.1 Bailers and Bailing Line

The potential for cross-contamination between sampling points via the use of common bailer, or its attached line, is high unless strict procedures for decontamination are followed. It is preferable, for the aforementioned reason, to dedicate an individual bailer and its line to each sample point, although this does not eliminate the need for decontamination of dedicated bailers. For non-dedicated sampling equipment, the following conditions and/or decontamination procedures should be followed.

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Before the initial sampling and after each succeeding sampling point, the bailer must be decontaminated. The following steps should be followed if sampling for organic contaminants:

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush may be required at the sample point if heavily contaminated with heavy or extremely viscous compounds
- Potable water rinse
- Rinse with 10 percent nitric acid solution*
- Deionized water rinse
- Acetone or methanol rinse
- Hexane rinse**
- Distilled/Deionized water rinse
- Air dry

If sampling for organics only, the nitric acid, acetone, methanol, and hexane rinses may be omitted. Contract-specific requirements may permit alternative procedures.

Braided nylon or polypropylene lines may be used with a bailer, however, the same line must not come in contact with the sample medium, otherwise, the line must be discarded in an approved receptacle and replaced. Prior to use, the bailer should be wrapped in aluminum foil or polyethylene sheeting.

5.1.2 Sampling Pumps

Most sampling pumps are normally low volume (less than 2 gpm) pumps. These include peristaltic, diaphragm, air-lift, pitcher and bladder pumps, to name a few. If these pumps are used for sampling from more than one sampling point, they must be decontaminated.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except the 10 percent nitric acid solution is omitted. Each of the liquid fractions is to be pumped through the system. The amount of pumping is dependent upon the size of the pump and the length of the intake and discharge hoses. Certain types of pumps are unacceptable for sampling purposes.

An additional problem is introduced when the pump relies on absorption of water via an inlet or outlet hose. For organic sampling, this hose should be Teflon. Other types of hoses leach organics into the water being sampled (especially the phthalate esters) or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (in order of preference). Whenever possible, dedicated hoses should be used.

* Due to the leaching ability of nitric acid, on stainless steel, this step is to be omitted if a stainless steel sampling device is being used and metals analysis is required with detection limits less than approximately 50 ppb; or the sampling equipment is dedicated.

** If sampling for pesticides, PCBs, or fuels.

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5.1.3 Filtering Equipment

Part of the sampling plan may incorporate the filtering of groundwater samples, and subsequent preservation. This should occur as soon after sample retrieval as possible; preferably in the field as soon as the sample is obtained. To this end, three basic filtration systems are most commonly used - the in-line disposable Teflon filter, the inert gas over-pressure filtration system, and the vacuum filtration system.

For the in-line filter, decontamination is not required since the filter cartridge is disposable, however, the cartridge must be disposed of in an approved receptacle and the intake and discharge lines must still be decontaminated.

For the over-pressure and the vacuum filtration systems, the portions of the apparatus which come in contact with the sample must be decontaminated as outlined in the paragraphs describing the decontamination of bailers. (Note: Varieties of both of these systems come equipped from the manufacturer with Teflon-lined surfaces for those that would come into contact with the sample. These filtration systems are preferred when decontamination procedures must be employed.)

5.2 FIELD ANALYTICAL EQUIPMENT

5.2.1 Water Level Indicators

Water level indicators that come into contact with groundwater must be decontaminated using the following steps:

- Rinse with potable water
- Rinse with deionized water
- Acetone or methanol rinse
- Rinse with deionized water

Water level indicators that do not come in contact with the groundwater but may encounter incidental contact during installation or retrieval need only undergo the first and last steps stated above.

5.2.2 Probes

Probes, e.g., pH or specific ion electrodes, geophysical probes, or thermometers which would come in direct contact with the sample, will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise; in those cases, the methods of decontamination must be clearly described in the FSAP. Probes that contact a volume of groundwater not used for laboratory analyses can be rinsed with deionized water. For probes which make no direct contact, e.g., OVA equipment, the probe will be wiped with clean paper-towels or cloth wetted with alcohol.

6.0 REFERENCES

None.

7.0 RECORDS

None.

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Standard Method for PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS¹

This standard is issued under the fixed designation D 1586; 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 approval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or approval.

This method has been approved for use by members of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

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.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 ASTM Standards:

D 2487 Test Method for Classification of Soils for Engineering Purposes²

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D 4220 Practices for Preserving and Transporting Soil Samples²

3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the ham-

mer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The N-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.9 ΔV —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the

¹ This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1974. Published November 1974. Originally published as D 1586 - 49 F. Last previous edition D 1586 - 67 (1974).

² Formal Method of ASTM Standards, Vol. 04.04.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do

not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance", or the "N-value". If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb

(63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. ($0.76 \text{ m} \pm 25 \text{ mm}$) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than $2\frac{1}{4}$ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either $1\frac{1}{4}$ or $2\frac{1}{4}$ rope turns, depending upon whether or not the rope comes off the top ($1\frac{1}{4}$ turns) or the bottom ($2\frac{1}{4}$ turns) of the cathead. It is generally known and accepted that $2\frac{1}{4}$ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

- 8.1.1 Name and location of job.
- 8.1.2 Names of crew.
- 8.1.3 Type and make of drilling machine.
- 8.1.4 Weather conditions.
- 8.1.5 Date and time of start and finish of boring.
- 8.1.6 Boring number and location (station and coordinates, if available and applicable).
- 8.1.7 Surface elevation, if available.
- 8.1.8 Method of advancing and cleaning the boring.
- 8.1.9 Method of keeping boring open.
- 8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made.
- 8.1.11 Location of strata changes.
- 8.1.12 Size of casing, depth of cased portion of boring.
- 8.1.13 Equipment and method of driving sampler.
- 8.1.14 Type sampler and length and inside diameter of barrel (note use of liners).
- 8.1.15 Size, type, and section length of the sampling rods, and
- 8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

- 8.2.1 Sample depth and, if utilized, the sample number.
- 8.2.2 Description of soil.
- 8.2.3 Strata changes within sample.
- 8.2.4 Sampler penetration and recovery lengths, and
- 8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 Variations in N -values of 100% or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, N -values in the same soil can be reproduced with a coefficient of variation of about 10%.

9.2 The use of faulty equipment, such as an extremely passive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or passive or poorly lubricated rope sheaves, can significantly contribute to differences in N -values.

APPENDIX C

HEALTH AND SAFETY PLAN

R-49-1-93-7

**Health and Safety Plan
Naval Submarine Base - New London
Groton, Connecticut**

**Submitted to:
Northern Division
Environmental Branch, Code 1823
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
Lester, Pennsylvania 19113-2090**

**Submitted by:
Halliburton NUS Corporation
993 Old Eagle School Road, Suite 415
Wayne, Pennsylvania 19087-1710**

**Contract Number N62472-90-D-1298
Contract Task Order 0112**

FEBRUARY 1993

SUBMITTED BY:

Willis C. Isner

**WILLIS C. ISNER, P.E.
PROJECT MANAGER
HALLIBURTON NUS CORPORATION
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APPROVED FOR SUBMISSION BY:

John D. Milani, CIH for
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CLEAN HEALTH AND SAFETY MANAGER
HALLIBURTON NUS CORPORATION
PITTSBURGH, PENNSYLVANIA**

1.0 INTRODUCTION

This Health and Safety Plan (HASP) is designed to provide practices and procedures for HALLIBURTON NUS and subcontractor personnel engaged in investigatory activities within and around Building 31, Naval Submarine Base - New London, Groton, Connecticut. This plan has been developed to conform to the requirements of OSHA Standard 29 CFR 1910.120 - "Hazardous Waste Operations and Emergency Response: Final Rule" and is based on available information regarding possible contaminants and physical hazards that may, or may not, exist on the site. If more information concerning the nature and/or concentrations of contaminants becomes available, this HASP will be modified accordingly. It will be the HALLIBURTON NUS Project Manager's responsibility to communicate any such information to the CLEAN Health and Safety Manager (Matthew M. Soltis) who will, in turn, determine the need for modifying the HASP.

1.1 KEY PROJECT PERSONNEL AND ORGANIZATION

This section refers to Table 1-1 and establishes responsibility for site safety and health. The HALLIBURTON NUS Project Manager (PM) is responsible for the overall direction and implementation of health and safety for this project. The HALLIBURTON NUS Field Team Leader (FTL) is responsible for implementation of this HASP with the assistance of an appointed Site Safety Officer (SSO). The activities of the SSO are monitored by the CLEAN Health and Safety Manager (HSM) for compliance with this HASP and the CLEAN Health and Safety Management Plan.

**Table 1-1
Key Project Personnel and Responsibilities**

NAME	RESPONSIBILITY
Willis C. Isner	Project Manager
TBA	Field Team Leader
TBA	Site Safety Officer
Matthew M. Soltis	CLEAN Health and Safety Manager

1.2 SITE/PROJECT BACKGROUND

Building 31 is located in the lower Naval Submarine Base area on Albacore Road. It is approximately 76 feet x 140 feet and was originally used as a battery shop. Naval Submarine Base - was in the process of replacing the concrete foundation to comply with RCRA regulations when a yellow discoloration was discovered underneath on the concrete slab. Soil samples were taken at depths of 18 inches and 60 inches and elevated lead levels were found. Lead levels ranged from 0.1 to 400 ppm (TCLP). A catch basin and floor drains were uncovered when portions of the slab were removed. No groundwater samples were taken so it is not known if the lead contamination has migrated to the water table approximately 6 feet below the soil surface.

1.3 SCOPE OF WORK

The objective of the work to be performed is to obtain sufficient data to define the extent of lead and related battery contamination within soils and groundwater at building 31. The data will be used to prepare an Action Memorandum and other supporting documentation for a time-critical removal action. Specifically,

soil and groundwater samples will be collected at various points strategically located under the concrete slab of Building 31 and outside of Building 31. Soil samples will be obtained using a drill rig equipped with a hollow stem auger, a drop hammer, and split-spoon sampling tools. Groundwater samples will be obtained from temporary monitoring wells installed using the drill rig and drop hammer.

2.0 HAZARD ASSESSMENT

This section describes the chemical and physical hazards associated with the tasks and operations described in Section 1.3 of this HASP. Measures to control the hazards presented below can be found in Sections 3.0, 4.0, and 5.0 of this plan.

2.1 SITE CONTAMINANTS

Based upon the nature and extent of contamination associated with Building 31, the potential exists for workers to inhale and/or ingest lead particulate. Overexposure to this material can reduce the oxygen-carrying capacity of the blood; and can damage the central nervous system, the peripheral nervous system, the gastrointestinal system, and the renal (kidney) system. In addition, lead can adversely effect the reproductive functions of both males and females (See Attachment 1).

Exposures to lead will likely be greatest during drilling operations and anytime contaminated hands, food, and/or tobacco products are brought into contact with the mouth. However, it is believed that such exposures will be insignificant. Specifically, it appears unlikely that inhalation exposures will exceed the current limit of 50 $\mu\text{g}/\text{m}^3$ and, subsequently, the amount of lead likely to be ingested is expected to be negligible providing some basic work practices are enforced.

Aside from the potential for exposure to lead, site personnel may also encounter potentially corrosive (pH < 2) battery wastes. Of particular concern is direct skin contact with these wastes which could occur during drilling and sampling activities. Such contact could result in chemical burns and permanent damage to the skin, eyes, and mucous membranes.

2.2 CARBON MONOXIDE

Because the drilling will be performed indoors, carbon monoxide emissions from the drill rig will be of particular importance. Carbon monoxide is a lethal, colorless and odorless gas that, even at non-lethal concentrations, can temporarily impair a worker's coordination and thinking due to a decrease in the amount of oxygen being carried to the body tissues (including the brain). The extent of this impairment is highly dependent upon the workers health, the work load, and the amount of carbon monoxide intake from non-occupational sources such a cigarette smoking. If the impairment is significant, a worker performing potentially dangerous operations, such as drilling, could become fatally injured as a result of the worker's inability to avoid the hazards of their work. Additional information on the effects of carbon monoxide exposure have been presented as Attachment 2 of this HASP. In order to control this hazard, the level of carbon monoxide in the work area will be closely monitored and, as necessary, the area will be mechanically ventilated to maintain exposures below 25 ppm.

2.3 PHYSICAL HAZARDS

In addition to the chemical hazards presented above, certain physical hazards may also be encountered. The most significant of these hazards include:

- The potential for a worker to become entangled in the rotating tools of the drill rig
- The lifting of heavy objects
- Overexposure to noise
- Contact with underground and/or overhead utilities
- Uneven/unstable walking and working surfaces

Entanglement within the rotating tools of the drill rig can occur anytime a worker or his clothing contacts the moving machinery and can result in a worker being fatally crushed and/or dismembered. The need to lift heavy objects will most likely arise during mobilization/demobilization activities and during drilling operations. If objects are improperly lifted, debilitating back strain and/or other injuries can result. The potential for overexposure to noise (> 85 dBA) may exist during drilling operations, especially since drilling will be performed indoors. Excessive noise exposure can cause permanent hearing loss. Contact with underground or overhead utilities can occur during drilling operations and can result in electrocution and/or an explosion. Uneven/unstable walking and working surfaces will be encountered due to the concrete debris piled within the building. This debris could cause workers to lose their footing thereby resulting in strained muscles, sprained ligaments, cuts, and/or abrasions.

In order to control these hazards, the Standard Work Practices specified in Section 5.0 of this HASP (as well as the other requirements stated in this document) will be implemented and enforced throughout site operations.

3.0 AIR MONITORING

This section presents requirements for the use of real-time air monitoring instruments during site activities involving potential for exposure to site contaminants. It establishes the types of instruments to be used, the frequency of which they are to be used, techniques for their use, action levels for upgrading/downgrading levels of protection, and methods for instrument maintenance and calibration.

3.1 INSTRUMENTS AND USE

A direct reading carbon monoxide monitor will be used monitor the level of carbon monoxide in the vicinity of the drill rig. The monitor will be selective to carbon monoxide and will be capable of measuring concentrations between 0.0 ppm and 100 ppm. It will be equipped with an alarm that will sound at 25 ppm and will either be worn by the driller or positioned in the work area to represent worst case exposures. Use of this monitor is only required while the drill rig is in operation. No other monitoring equipment is required providing particulate emissions are adequately suppressed with water spray. If water spray is not used, a particulate monitor must be used as described in section 3.2 below.

3.2 MODIFICATION OF AIR MONITORING REQUIREMENTS

If water spray is not used to control particulate emissions during drilling, the work area will be monitored with an direct-reading particulate monitor (MIE PDM-3 Miniram, or equivalent). This instrument will provide a real-time, as well as an 8-hour average, measurement of total airborne particulate and, therefore, it will be useful in estimating the concentration of airborne lead. If it is conservatively assumed that the average concentration of lead within the soils is 10,000 mg/kg (1.0% lead), an average reading of 3.0 mg/m³ on the particulate monitor would represent an average exposure to lead at the OSHA Action Level of 30 µg/m³ (i.e. 0.01 X 3.0 mg/m³ x 1,000 µg/mg = 30 µg/m³). Therefore, by maintaining total dust exposures below 3.0 mg/m³, lead exposures will be maintained below the OSHA action level. If exposures exceed this action level, water spray will be used to reduce the emission or the work will cease until further direction has been given by the CLEAN Health and Safety Manager. If respiratory protection must be used to control lead exposures, all work must conform to the requirements of OSHA 29 CFR 1910.134 and 29 CFR 1910.1025.

3.3 ACTION LEVELS

The following action levels will apply to this project:

Carbon Monoxide Monitor	0.0 ppm to 12.4 ppm	Continue Work and Monitoring
	12.5 ppm to 25 ppm	Continue Work and observe workers for symptoms of overexposure. Ventilate area to the extent feasible.
	Greater than 25 ppm	Cease work until mechanical ventilation adequately reduces carbon monoxide levels
Observation	Symptoms of CO poisoning	Cease work and obtain further direction from the PM and CLEAN HSM.
Particulate Monitor	0.0 mg/ ³ to 3.0 mg/ ³	Continue work
	Greater than 3.0 mg/ ³	Wet down area or obtain further direction from the PM and the CLEAN HSM.

These action levels are based upon the assumption that lead and carbon monoxide will be the only air contaminants which pose a reasonable health risk to site workers. In the event that this assumption is found to be invalid, the action levels will be modified as appropriate.

3.4 INSTRUMENT MAINTENANCE AND CALIBRATION

Air monitoring instruments will be maintained and pre-field calibrated by the equipment supplier. Field calibration will not be necessary. Field maintenance will consist of daily cleaning of the instruments using a damp towel or rag to wipe off the instrument's outer casing and overnight battery recharging.

3.5 RECORDKEEPING

Carbon monoxide readings above 12.5 ppm must be recorded in the field book. This should indicate the date, reading(s) observed, workers potentially affected, and actions taken to reduce exposures. If particulate monitors are used, the time-weighted average reading for each day will be recorded in the field log book. In addition, if the particulate action level is exceeded, the log book will indicate what action was taken to reduce exposures.

4.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

This section presents requirements for the use of personal protective equipment for each of the activities being conducted as defined in Section 1.3 of this HASP. This section includes anticipated levels of protection for each of the activities, the criteria used for selecting various levels of protection, and criteria for modifying levels of protection based on monitoring instrument readings and personal observations.

4.1 ANTICIPATED LEVELS OF PROTECTION

All work is anticipated to be performed in a Level D Protection, as defined in Appendix B of OSHA Standard 29 CFR 1910.120 - "Hazardous Waste Operations and Emergency Response: Final Rule." Many activities will require the use of chemical resistant coveralls, gloves, and boot covers as presented in the task breakdown which follows. Where activities overlap, the more protective requirements will be applied. Additionally, it is possible that work will be upgraded to Level C protection (air-purifying respirators equipped with HEPA filters) depending on the results of air monitoring as discussed in Section 3.0 of this HASP.

4.1.1 Mobilization/Demobilization

Minimum requirements include steel-toe hard sole work boots. Leather or cotton work gloves will be worn, as needed, to prevent cuts and abrasions when handling drilling equipment.

4.1.2 Drilling Operations

Minimum requirements include hard hat, safety glasses, steel-toe hard sole work boots, Tyvek coveralls, disposable boot covers, and nitrile or neoprene gloves over latex inner gloves. All ankle and wrist seams will be taped and all loose clothing will be secured. If Tyvek becomes saturated, PVC coveralls will be substituted.

4.1.3 Soil Sampling

Minimum requirements include steel-toe hard sole work boots and nitrile or neoprene gloves over latex inner gloves. In addition, hard hat and safety glasses will be worn when working in close proximity to the drill rig and disposable boot covers will be worn when walking/working on potentially contaminated debris or soils.

4.1.4 Groundwater Sampling

Minimum requirements include steel-toe hard sole work boots, Tyvek coveralls, disposable boot covers, and nitrile or neoprene gloves over latex inner gloves. All ankle and wrist seams will be taped. If Tyvek becomes saturated, PVC coveralls will be substituted.

4.2 PPE SELECTION CRITERIA

Respiratory protection was not selected for use during initial stages of work as it is unlikely that lead exposures will exceed the current exposure limit of $50 \mu\text{g}/\text{m}^3$, providing water spray is used during drilling operations to suppress dust emissions. Nitrile and/or neoprene gloves were selected to provide protection against the potentially corrosive battery waste that could be encountered and to help reduce the amount of lead ingested as a result of incidental hand to mouth contact. Hard hats, safety glasses, and work boots

were selected to provide protection against some of the physical hazards associated with drilling operations and disposable boot covers were selected to help minimize the spread of contamination. Tyvek coveralls were selected to minimize the potential for contamination of street clothes and PVC coveralls were selected for use to in the event that drilling and/or sampling operations have the potential to result in the saturation of work clothes.

4.3 PPE MODIFICATION CRITERIA

This section presents criteria for upgrading and downgrading chemical protective clothing and/or respiratory protection. Where uncertainties arise, the more protective requirement will apply.

4.3.1 CPC Modification Criteria

Tyvek coveralls and boot covers must be worn anytime there is a reasonable potential for contamination of street clothes. Polyvinyl chloride (PVC) coveralls must be worn anytime there is a reasonable potential for saturation of work clothes.

Nitrile or neoprene gloves must be worn anytime there is a reasonable potential for contact with site contaminants. Samples found to have a pH > 2 and < 12 can be handled with surgical latex gloves.

4.3.2 Respiratory Protection Modification Criteria

Half-face or full-face air-purifying respirators equipped with high-efficiency particulate air (HEPA) filters must be worn anytime dusty conditions are observed and these emissions cannot be suppressed with water spray. However, before the use of respiratory protection is prescribed, the CLEAN Health and Safety Manager must be notified.

5.0 STANDARD WORK PRACTICES

The following standard work practices will apply to all HALLIBURTON NUS and subcontractor personnel as applicable to the work being performed at this site.

5.1 GENERAL REQUIREMENTS (ALL TASKS)

- Drilling areas inside of Building 31 shall be physically cordoned off (using items such as caution tape, hazard cones, etc.) to clearly identify the work area, and to aid in restricting access of unauthorized persons.
- Walking and/or working over the debris (pieces of concrete slab) within the building shall be avoided to the extent possible. When avoidance is not possible, objects must be handled in a manner that does not restrict the workers ability to move safely within the area.
- Objects that cannot be manually handled comfortably shall either be handled by more than one person or with mechanical lifting devices.
- Eating, drinking, chewing gum or tobacco, taking medication, and smoking are prohibited in the exclusion or decontamination zones, or any location where there is a possibility for contact with site contaminants exists.
- Upon leaving the exclusion zone, hands and face must be thoroughly washed with soap and potable water. Any protective outer clothing is to be decontaminated and removed as specified in this HASP, and left at a designated area prior to entering the clean area.
- Contact with potentially-contaminated substances must be avoided. Contact with the ground or with contaminated equipment must also be avoided. Monitoring equipment must not be placed on potentially contaminated surfaces.
- No facial hair, which interferes with a satisfactory fit of the mask-to-face seal, is permitted on personnel required to wear respiratory protective equipment.
- All personnel must procure a site-specific Health and Safety Plan from the project Health and Safety Officer prior to commencing work on site. All site personnel must read and understand all components of this HASP.
- All personnel must satisfy medical monitoring procedures.
- Any new analytical data must be promptly conveyed via telephone to the CLEAN Health and Safety Manager.
- All work areas must be kept free of ground clutter.
- Areas must be designated for chemical storage. Acids, bases and flammable shall all be stored separately. Storage areas must be labeled as to the contents within the storage area.

- All compressed gas cylinders must be stored and used in an upright position, properly secured and protected from damage, segregated, and labelled as empty or full.
- All site personnel including subcontractors must be complete a medical datasheet, to be maintained on site.
- Site personnel must immediately notify HALLIBURTON NUS Health Sciences of all incidents for OSHA recordkeeping purposes.
- If personnel note any warning properties of chemicals (irritation, odors, symptoms, etc.) or even remotely suspect the occurrence of exposure, they must immediately notify the CLEAN Health and Safety Manager for further direction.
- Site personnel are not to undertake any activity which would be considered a confined-space entry without first being trained in the proper procedures as required by the CLEAN Health and Safety Manager, and without first obtaining a Confined Space/Limited Egress Permit.

5.2 DRILLING OPERATIONS

- The location of all underground and overhead utilities must be confirmed and visibly identified prior to mobilizing the drill rig to each new location. The mast of the drill rig shall be positioned so as not to contact live conductors, raceways, conduit, or piping. Bore holes must be located no less than 2 feet from in-service underground utilities.
- All drill rigs must be equipped with an operational emergency stop device. Drillers and geologists must be aware of the location of this device. This device must be tested prior to job initiation, and periodically thereafter. No one shall handle rotating augers unless absolutely necessary and unless there is a standby person in the ready position to activate the emergency stop.
- The driller must never leave the controls while the tools are rotating unless all personnel are clear of the rotating equipment.
- A long-handled shovel or equivalent must be used to clear drill cuttings away from the hole and from rotating tools. Hands and/or feet are not to be used for this purpose.
- A remote sampling device must be used to sample drill cuttings if the tools are rotating. Samplers must not reach into or near the rotating equipment. If personnel must work near any tools which could rotate, the driller must shut down the rig prior to initiating such work.
- Drillers, helpers, and samplers must secure all loose clothing when in the vicinity of the drilling operations.
- Only equipment which has been approved by the manufacturer may be used in conjunction with site equipment and specifically to attach sections of drilling tools together. Pins that excessively protrude from augers shall not be allowed.
- No persons shall climb the drill mast while tools are rotating.

- No person shall climb the drill mast without the use of ANSI approved fall protection (i.e. approved belts, lanyards, and a fall protection slide rail) or portable ladder which meets the requirements of OSHA standards.
- Hearing protection shall be worn while the drill rig is in operation unless it can be demonstrated that noise exposures will not exceed 85 dBA as an 8-hour time-weighted average.

6.0 DECONTAMINATION

This section describes the steps site personnel will follow to prevent the spread of site contaminants into areas that may affect unprotected, unsuspecting site personnel or the public. It includes requirements for decontamination of personnel, sampling equipment, and drilling equipment.

6.1 PERSONNEL DECONTAMINATION

The decontamination of personnel and their protective clothing will be performed in three stages.

- Stage 1 includes removing contamination from reusable protective clothing and/or clothing that will be disposed of at sanitary landfills. These efforts will involve washing and rinsing these items in a sequence that begins at the highest level to the lowest level (i.e.: from the head down towards the feet).
- Stage 2 will include removal of protective clothing, discarding disposable clothing into a drum conspicuously marked "Contaminated Clothing" and/or storing reusable protective clothing in the contamination reduction zone. Stage 2 efforts involve a structured, segregated process carefully removing PPE items beginning with the outermost item and progressing inward.
- Stage 3 will consist of workers washing their hands and face with potable water and soap each time they leave the exclusion zone, before performing any type of hand-to-mouth activity.

All decontamination fluids generated will be contained as described in the field sampling plan. The decontamination area will be physically identified with rope or flagging and well equipped to be conducive for completion of proper decontamination activities.

6.2 SAMPLING EQUIPMENT DECONTAMINATION

Decontamination of sampling tools may involve the use of deionized water, detergents (Alconox), methanol, and/or nitric acid. Requirements for decontaminating sampling equipment are presented in the Field Sampling Plan. Methanol and nitric acid will only be used in well ventilated areas and personnel will avoid breathing vapor and/or mist. Material Safety Data Sheets for the decontamination solutions will be presented during site specific training and maintained on site for reference upon request.

6.3 HEAVY EQUIPMENT DECONTAMINATION

Decontamination of drilling tools and other heavy equipment will be accomplished through the use of a high pressure steam system. The HALLIBURTON NUS Field Team Leader (FTL) will inspect all heavy equipment prior to being released from the site. All decontamination fluids generated will be contained and disposed of as described in the Field Sampling Plan.

7.0 TRAINING

7.1 INTRODUCTORY AND REFRESHER TRAINING

7.1.1 Requirements for HALLIBURTON NUS Personnel

All HALLIBURTON NUS personnel must complete 40 hours of introductory hazardous waste site training prior to performing work at the Naval Submarine Base - New London. Additionally, HALLIBURTON NUS personnel who have had introductory training more than 12 months prior to site work must have completed 8 hours of refresher training within the past 12 months before being cleared for site work.

Documentation of HALLIBURTON NUS introductory and refresher training can be obtained through the CLEAN Health and Safety Manager. Copies of certificates or other official documentation will be used to fulfill this requirement.

7.1.2 Requirements for Subcontractors

All HALLIBURTON NUS subcontractor personnel must have completed introductory hazardous waste site training or equivalent work experience as defined in OSHA Standard 29 CFR 1910.120(e) and 8 hours of refresher training meeting the requirements of 29 CFR 1910.120(e)(8) prior to performing work at Naval Submarine Base - New London. HALLIBURTON NUS subcontractors must certify that each employee has had such training by sending HALLIBURTON NUS a letter, on company letterhead, containing the information in the example letter provided as Figure 7-1. Copies of training certificates will not be accepted as a substitute for the official letter but may be provided as supporting documentation.

7.2 SITE-SPECIFIC TRAINING

HALLIBURTON NUS will provide site-specific training to all HALLIBURTON NUS employees and subcontractor personnel who will perform work at this project. This training will only be provided once and personnel who do not attend will not be permitted to perform work at the Naval Submarine Base - New London. Site-specific training will include:

- Names of personnel and alternates responsible for site safety and health
- Safety, health and other hazards present on site
- Use of personal protective equipment
- Work practices to minimize risks from hazards
- Safe use of engineering controls and equipment
- Medical surveillance requirements
- Signs and symptoms of overexposure
- The contents of the health and safety plan and addendum
- Review of relevant MSDSs

7.2.1 Site-Specific Training Documentation

HALLIBURTON NUS and subcontractor personnel will be required to sign a statement indicating receipt of site-specific training and understanding of site hazards and control measures. Figure 7-2 will be used to document site-specific training.

**FIGURE 7-1
OSHA TRAINING CERTIFICATION**

The following statements must be typed on company letterhead and signed by an officer of the company:

LOGO
XYZ CORPORATION
555 E. 5th Street
Nowheresville, Kansas 55555

Month, day, year

Mr. Willis C. Isner
Project Manager
HALLIBURTON NUS Corporation
661 Andersen Drive; Foster Plaza 7
Pittsburgh, Pennsylvania 15220

Subject: Hazardous Waste Site Training - Naval Submarine Base - New London

Dear Mr Isner:

The employees listed below have had introductory hazardous waste site training or equivalent work experience as required by 29 CFR 1910.120(e). In addition, those employees listed below who have received their introductory training more than 12 months ago have also received 8 hours of refresher training in accordance with 29 CFR 1910.120 (e)(8).

LIST FULL NAMES OF EMPLOYEES AND THEIR SOCIAL SECURITY NUMBERS HERE

Should you have any questions, please contact me at (555) 555-5555.

Sincerely,

(Name of Company Officer)

8.0 MEDICAL SURVEILLANCE

8.1 REQUIREMENTS FOR HALLIBURTON NUS PERSONNEL

All HALLIBURTON NUS personnel participating in project field activities will have had a physical examination meeting the requirements of HALLIBURTON NUS' medical surveillance program and will be medically qualified to perform hazardous waste site work using respiratory protection.

Documentation for medical clearances can be obtained from the CLEAN Health and Safety Manager.

8.2 REQUIREMENTS FOR SUBCONTRACTORS

Subcontractors are required to obtain a certificate of their ability to perform hazardous waste site work and to wear respiratory protection. The "Subcontractor Medical Approval Form" (Figure 8-1) must be used to satisfy this requirement providing it is properly completed and signed by a licensed physician.

**FIGURE 8-1
SUBCONTRACTOR MEDICAL APPROVAL FORM**

For employees of _____
Company Name

Participant Name: _____ Date of Exam: _____

Part A

The above-named individual has:

1. Undergone a physical examination in accordance with OSHA Standard 29 CFR 1910.120, paragraph (f) and found to be medically -

- qualified to perform work at the **Naval Submarine Base - New London** work site
- not qualified to perform work at the **Naval Submarine Base - New London** work site

and,

2. Undergone a physical examination as per OSHA 29 CFR 1910.134(b)(10) and found to be medically -

- qualified to wear respiratory protection
- not qualified to wear respiratory protection

My evaluation has been based on the following information, as provided to me by the employer.

- A copy of OSHA Standard 29 CFR 1910.120 and appendices.
- A description of the employee's duties as they relate to the employee's exposures.
- A list of known/suspected contaminants and their concentrations (if known).
- A description of any personal protective equipment used or to be used.
- Information from previous medical examinations of the employee which is not readily available to the examining physician.

Part B

I, _____, have examined _____
Physician's Name (print) Participant's Name (print)
and have determined the following information:

1. Results of the medical examination and tests (excluding finding or diagnoses unrelated to occupational exposure):

**FIGURE 8-1
SUBCONTRACTOR MEDICAL APPROVAL FORM
PAGE TWO**

2. Any detected medical conditions which would place the employee at increased risk of material impairment of the employee's health:

3. Recommended limitations upon the employee's assigned work:

I have informed this participant of the results of this medical examination and any medical conditions which require further examination or treatment.

Based on the information provided to me, and in view of the activities and hazard potentials involved at the _____ work site, this participant

- may
- may not

perform his/her assigned task.

Physician's Signature _____

Address _____

Phone Number _____

NOTE: Copies of test results are maintained and available at:

_____ Address

9.0 SITE CONTROL

This section outlines the means by which HALLIBURTON NUS will delineate work zones and use these work zones in conjunction with decontamination procedures to prevent the spread of contaminants into previously unaffected areas of the site. In general, a three zone approach will be used during work at this site; exclusion zone, contamination reduction zone, and support zone.

9.1 EXCLUSION ZONE

The exclusion zone will be considered those areas of the site of known or suspected contamination. In many cases, however, significant amounts of surface contamination will not be encountered in the proposed work areas of this site until/unless contaminants are brought to the surface by drilling activities. Furthermore, once such activities have been completed and surface contamination has been removed, the potential for exposure is again diminished and the area can then be reclassified as part of the contamination reduction zone. Therefore, the exclusion zones for this project will be limited to those areas of the site where active work is being performed and/or anywhere there is believed to be the potential for inhalation exposure to site contaminants.

9.2 CONTAMINATION REDUCTION ZONE

The contamination reduction zone (CRZ) will be a buffer area between the exclusion zone and any area of the site where contamination is not suspected. For purposes of this project, the CRZ will be considered the area within Building 31 excluding any areas classified as an exclusion zone. In addition, the equipment decontamination area established for this project will be considered as a separate CRZ.

9.3 SUPPORT ZONE

The support zone for this project will be located outside Building 31 and will include a staging area where site vehicles will be parked, equipment will be unloaded, and where food and drink containers will be maintained. In all cases, the support zones will be established at areas of the site where exposure to site contaminants would not be expected during normal working conditions or foreseeable emergencies.

10.0 OTHER MISCELLANEOUS REQUIREMENTS

10.1 CONFINED SPACE ENTRY

No personnel, under any circumstances, are to enter confined spaces. Therefore, it is not applicable to specify procedures for such operations in this Health and Safety Plan.

10.2 SPILL CONTAINMENT PROGRAM

It is not anticipated that bulk hazardous materials will be handled as part of this scope of work such that spillage would constitute a danger to human health or the environment. Therefore, a spill containment program has not been developed as part of this HASP.

10.3 MATERIALS AND DOCUMENTS

The HALLIBURTON NUS Field Team Leader shall ensure the following materials/documents are taken to the project site and utilized as required.

- Incident Reports
- Medical Data Sheets
- Material Safety Data Sheets for decon solutions and other substances brought to the site
- Follow-Up Reports (to be completed by the Field Team Leader)
- OSHA Job Safety and Health Poster (posted in site trailer)
- Training Documentation Form (Blank)
- First Aid Supply Usage Form
- Emergency Reference Form (Figure 11-1, extra copy for posting)
- User manuals for CO Monitor and Particulate Monitor

11.0 EMERGENCY RESPONSE PLAN

11.1 INTRODUCTION

This Emergency Response Plan (ERP) is applicable to emergency situations that could arise as a result of activities associated with HALLIBURTON NUS work at Building 31, Naval Submarine Base - New London and has been prepared to comply with the requirements of OSHA Standard 29 CFR 1910.120 (l) (2) and (3).

11.2 PRE-EMERGENCY PLANNING

Pre-emergency planning activities associated with this project include the following:

- Coordinating with Naval Submarine Base - New London personnel to ensure that HALLIBURTON NUS emergency response activities are compatible with existing facility emergency response procedures. Specifically, Deborah Stockdale will be provided with a copy of this ERP for review and comment by the appropriate Naval Submarine Base - New London personnel.
- Establishing and maintaining information at the project staging area (support zone) for easy access in the event of an emergency. This information will include the following and it will be the responsibility of the HALLIBURTON NUS Field Team Leader to ensure the information is available.
 - An inventory of chemical substances used on site, with corresponding Material Safety Data Sheets.
 - Site personnel records regarding medical treatment concerns (medical data sheets).
 - A log book identifying personnel present on site each day.
- Identifying a chain of command for emergency response. In this regard, Naval Submarine Base - New London will assume control of any situation to which they respond and HALLIBURTON NUS personnel will be subject to the orders of the official in charge of the response.

11.3 TYPES OF EMERGENCIES

Personal injuries and accidental overexposure to carbon monoxide are the only type of emergencies that can reasonably be anticipated to occur in the performance of HALLIBURTON NUS' work at Naval Submarine Base - New London. Therefore, these potential emergencies will be the focus of this ERP. Injuries and illnesses requiring first-aid will not be considered emergencies in the context of this plan.

11.4 PERSONNEL ROLES, LINES OF AUTHORITY, AND COMMUNICATION

The coordination of project-related emergency response activities will be the primary responsibility of the HALLIBURTON NUS Field Team Leader (FTL), with assistance from the Site Safety Officer (SSO). Specific responsibilities of the HALLIBURTON NUS FTL include

- Ensuring that base medical resources are contacted immediately upon being informed of an emergency
- Ensuring that Building 31 is not entered by unprotected personnel if carbon monoxide levels are in excess of 100 ppm and ensuring that anyone who enters the building when levels exceed 25 ppm are kept within line of site and evacuated within 15 minutes.

The specific responsibilities of the HALLIBURTON NUS SSO will include:

- Providing assistance to the HALLIBURTON NUS FTL
- Accounting for site personnel if the building has been evacuated
- Air monitoring (as needed) for carbon monoxide

All other site personnel will be responsible for following the directions of the HALLIBURTON NUS FTL. If response from the NSB-NLON Fire Department has been requested, HALLIBURTON NUS personnel will be subject to the orders of their official in charge of the response. This individual should make their identity known to HALLIBURTON NUS at the time of their arrival at the incident scene.

11.5 EMERGENCY RECOGNITION AND PREVENTION

11.5.1 Recognition

As stated in Section 11.3, personal injury/illness are the only emergency situations reasonably anticipated. These situations will generally be recognizable by visual observation. An injury or illness will be considered an emergency if it requires treatment other than first-aid (i.e. requires treatment by a medical professional).

11.5.2 Prevention

HALLIBURTON NUS will prevent emergencies by ensuring compliance with the site-specific health and safety plan.

11.6 SAFE DISTANCES AND PLACES OF REFUGE

In the event that Building 31 must be evacuated, all personnel will immediately stop activities and report to the support zone outside the building. Upon reporting to the refuge location, personnel will remain there until directed otherwise by the HALLIBURTON NUS FTL. The Site Safety officer will take roll at this location, using the log book, to confirm the location of all site personnel.

11.7 SITE SECURITY AND CONTROL

If Building 31 is evacuated, the HALLIBURTON NUS FTL will deploy project personnel to strategic locations to secure the building and prevent entry by unauthorized personnel. Only essential personnel who are properly protected will be permitted to enter the building.

11.8 EVACUATION ROUTES AND PROCEDURES

Building 31 must be evacuated whenever carbon monoxide levels unexpectedly rise above 25 ppm or whenever personnel show signs or symptoms of carbon monoxide poisoning. If the event evacuation of Building 31 is necessary, the HALLIBURTON NUS FTL or the Site Safety Officer will give the verbal order to evacuate. In this event, personnel will proceed immediately out of the building to the support zone. Personnel will remain at this location until instructed otherwise by the HALLIBURTON NUS FTL.

11.9 DECONTAMINATION PROCEDURES/EMERGENCY MEDICAL TREATMENT

Due to the nature and extent of contamination at this site and the types of emergencies anticipated, personnel decontamination will be secondary to building evacuation. Therefore, once personnel exit the building, contaminated clothing will be removed. If medical treatment is needed, injured/ill persons will be transported to the base medical facility or, if necessary, base medical personnel will be requested at the scene of the incident.

11.10 EMERGENCY ALERTING AND RESPONSE PROCEDURES

Since HALLIBURTON NUS personnel and subcontractors will be working in close proximity to each other, hand signals and voice commands will be sufficient to alert site personnel of an emergency. In addition, HALLIBURTON NUS will utilize the telephone located in Building 20 to request emergency medical assistance from the NSB-NLON Fire Department. The procedure for response will be as follows:

Step 1 - The victim(s) will remove themselves (if possible) from the hazard or a coworker may attempt to rescue the victim(s) if rescue can be accomplished simply, timely, and without endangering life or health. Before a rescue is attempted, the rescuer must identify the cause of the injury or illness and ascertain that a rescue can be performed safely. If uncertainty exists, rescue at this time will not be initiated.

Step 2 - The victim(s) or witnesses will notify the HALLIBURTON NUS FTL of the nature of the injury/illness.

Step 3 - The HALLIBURTON NUS FTL will notify the SSO, and (2) notify the NSB-NLON Fire Department (via the telephone in Building 20) if the injury/illness will require medical attention.

Step 4 - The NSB-NLON Fire Department will deploy a Medical Team as needed and will notify the medical facility who will await the arrival of the injured/ill party at the facility.

Step 5 - The SSO and an assistant will (1) deploy to the scene appropriately equipped with first-aid supplies, (2) don any protective equipment needed to enter Building 31 if the victim must be rescued from a carbon monoxide atmosphere, (3) provide first-aid services within their capabilities and training, and (4) transport the victim to the support zone and/or to the medical facility (as appropriate) if transport can be accomplished without aggravating an injury.

Step 6 - The HALLIBURTON NUS FTL will ensure that all persons with chemically related injuries/illness are examined, by a licensed physician who is in contact with the HALLIBURTON NUS Medical Consultant, at the earliest possible time following the incident.

Step 7 - The HALLIBURTON NUS FTL will (1) perform a critique of the incident, (2) determine measures to prevent recurrence, (3) determine measures to improve response efforts, (4) complete an incident report.

11.11 PPE AND EMERGENCY EQUIPMENT

A first-aid kit will be maintained on site and immediately available for use in the event of an emergency.

11.12 PROCEDURES FOR INCIDENT REPORTING

In the event of an emergency situation, the HALLIBURTON NUS FTL will be responsible for determining the need for, and carrying out communications with the NSB-NLON Fire Department. All emergency situations are to be communicated (via the telephone in Building 20) directly to the NSB-NLON Fire Department. Personnel at that location are authorized to deploy emergency resources if needed. Figure 11-1 provides telephone numbers that may be necessary in the event of an emergency.

11.13 EMERGENCY CRITIQUE AND FOLLOW-UP

Emergencies will be critiqued by the HALLIBURTON NUS FTL with assistance from the SSO. The objective of these critiques will be to identify and improve weaknesses. Once weaknesses have been identified, the HALLIBURTON NUS FTL will follow-up by ensuring that necessary modifications are made to the ERP; the site-specific health and safety plan; and any applicable procedures. In addition, the HALLIBURTON NUS FTL will complete an incident report form.

11.14 EMERGENCY CONTACTS

The primary contact in an emergency situation is the NSB-NLON Fire Department. This department is manned on a 24-hour basis. This department will make the critical decisions regarding where and injured person will be transported. In case of immediate threat of life, the Naval Hospital on NSB-NLON will be used; otherwise persons will be transported to Lawrence and Memorial Hospital in New London.

11.15 EMERGENCY ROUTE TO HOSPITAL (See Map Figure 11-2)

From Building 31, go north on Capelin or Bullhead road and turn left onto Argonaut Road. Cross Railroad tracks and turn left onto Shark Blvd. Pass Building 338 and turn right onto Wahoo Avenue. Wahoo Avenue becomes Tautog Avenue and Hospital is on the right (Building 449).

FIGURE 11-1

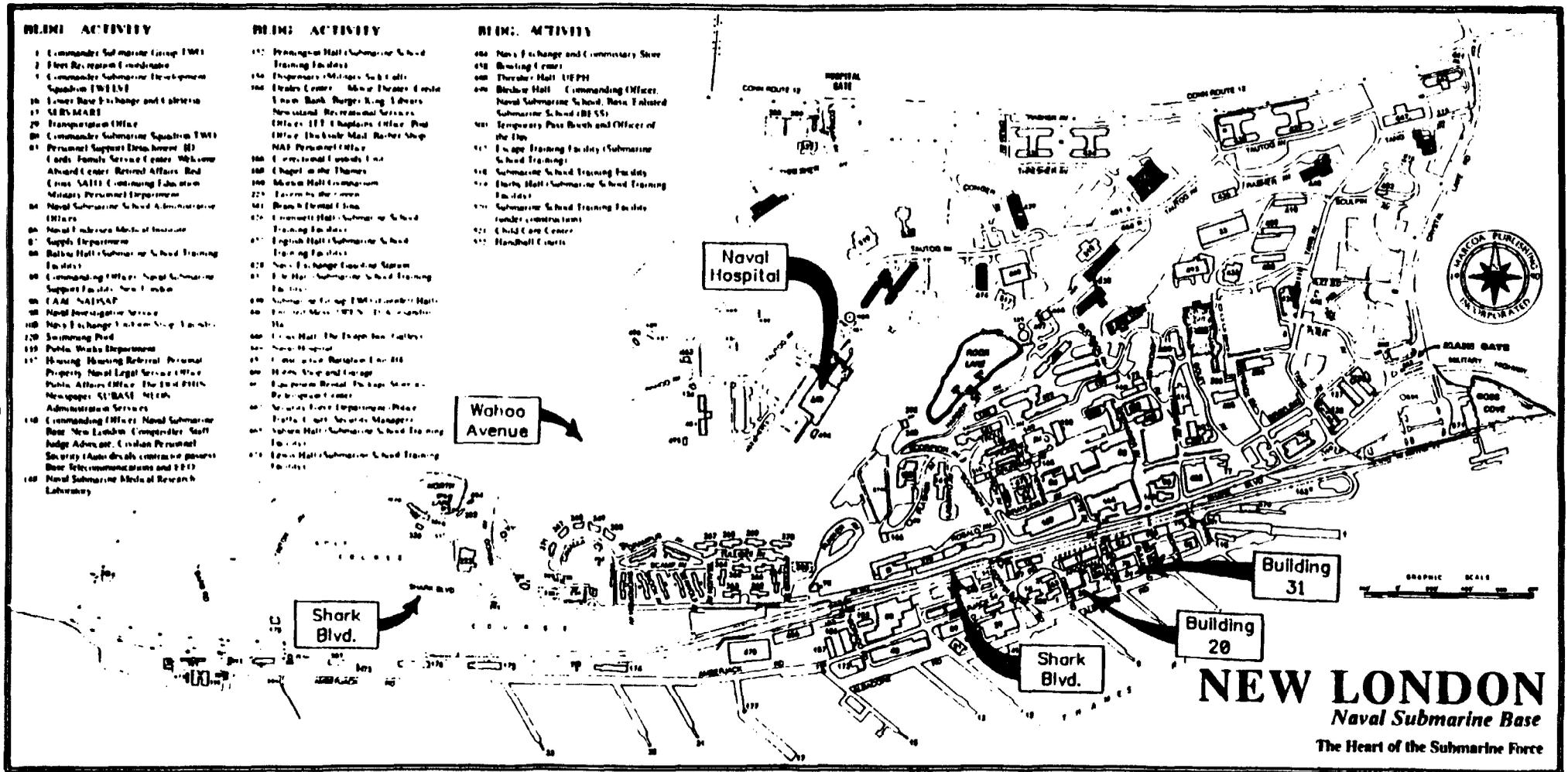
EMERGENCY REFERENCE
Naval Submarine Base - New London - Groton, Connecticut

Contact	Phone Number
Local emergency medical team located at NSB-NLON (ambulance/fire dispatcher):	Dial 449-3333 449-3666
Nearest emergency room (NSB-NLON Hospital): Emergency Room at Lawrence and Memorial Hospital (New London) Groton Police: Groton Fire Department:	911 or 442-0711 911 or 445-2451 991 or 445-2456
Utility Emergencies (electric, gas, water and sewer) NSB-NLON Public Works: Public Works: Authorized Navy Site Personnel:	449-4711
William Mansfield: Deborah Stockdale:	449-2276 (215) 595-0567
NSB-NLON Security: National Information Centers:	449-3444
Chemtrec: National Response Center:	(800) 424-9300 (800) 424-8802
Project Manager Wil Isner	(412) 921-8616
CLEAN Health and Safety Manager Matthew M. Soltis	(412) 921-8912
Medical Consultant Dr. Britton	(713) 797-3111

EMERGENCY ROUTE TO HOSPITAL (See Map Figure 11-2)

From Building 31, go north on Capelin or Bullhead road and turn onto Argonaut Road. Cross Railroad tracks and turn left onto Shark Boulevard. Pass Building 338 and turn right onto Wahoo Avenue. Wahoo Avenue becomes Tautog Avenue and Hospital is on the right (Building 449).

FIGURE 11-2
MAP TO NAVAL HOSPITAL



SOURCE: NSB-NLON

ATTACHMENT 1 HEALTH HAZARD INFORMATION FOR INORGANIC LEAD

Although the toxicity of lead has been known for 2,000 years, the knowledge of the complex relationship between lead exposure and human response is still being refined. Significant research into the toxic properties of lead continues throughout the world, and it should be anticipated that our understanding of thresholds of effects and margins of safety will be improved in future years. The provisions of the lead standard are found on two prime medical judgements: first, the prevention of adverse health effects from exposure to lead throughout a working lifetime requires that worker blood lead levels be maintained at or below 40 $\mu\text{g}/100\text{ g}$ and second, the blood lead levels of workers, male or female, who intend to parent in the near future should be maintained below 30 $\mu\text{g}/100\text{ g}$ to minimize adverse reproductive health effects to the parents and developing fetus. The adverse effects of lead on reproduction are being actively researched and OSHA encourages the physician to remain abreast of recent developments in the area to best advise pregnant workers or workers planning to conceive children.

The spectrum of health effects caused by lead exposure can be subdivided into five developmental stages: normal, physiological changes of uncertain significance, pathophysiological changes, overt symptoms (morbidity), and mortality. Within this process there are no sharp distinctions, but rather a continuum of effects. Boundaries between categories overlap due to the wide variation of individual responses and exposures in the working population. OSHA's development of the lead standard focused on pathophysiological changes, as well as later stages of the disease.

1. Heme Synthesis Inhibition. The earliest demonstrated effect of lead involves its ability to inhibit at least two enzymes of the heme synthesis pathway at very low blood levels. Inhibition of delta-aminolevulinic acid dehydrase (ALA-D) which catalyzes the conversion of delta-aminolevulinic acid (ALA) to protoporphyrin is observed at a blood level below 20 $\mu\text{g}/100\text{ g}$ whole blood. At a blood level of 40 $\mu\text{g}/100\text{ g}$, more than 20% of the population would have 70% inhibition of ALA-D. There is an exponential increase in ALA excretion at blood lead levels greater than 40 $\mu\text{g}/100\text{ g}$.

Another enzyme, ferrochelatase, is also inhibited at low blood levels. Inhibition of ferrochelatase leads to increased free erythrocyte protoporphyrin (FEP) in the blood which can then bind to zinc to yield zinc protoporphyrin. At a blood lead level of 40 $\mu\text{g}/100\text{ g}$ and the associated ZPP level, which has led to the development of the ZPP screening test for lead exposure.

While the significance of these effects is subject to debate, it is OSHA's position that these enzyme disturbances are early stages of a disease process which may eventually result in the clinical symptoms of lead poisoning. Whether or not the effects do progress to the later stages of clinical disease, disruption of these enzyme processes over a working lifetime is considered to be a material impairment of health.

One of the eventual results of lead-induced inhibition of enzymes in the heme synthesis pathway is anemia which can be asymptomatic if mild but associated with a wide array of symptoms including dizziness, fatigue, and tachycardia when more severe. Studies have indicated that lead levels as low as 50 $\mu\text{g}/100\text{ g}$ can be associated with a definite decreased hemoglobin, although most cases of lead-induced anemia as well as shortened red-cell survival times, occur at lead levels exceeding 80 $\mu\text{g}/100\text{ g}$. Inhibited hemoglobin synthesis is more common in chronic cases whereas shortened erythrocyte life span is more common in acute cases.

In lead-induced anemias, there is usually a reticulocytosis along with the presence of basophilic stippling, and ringed sideroblasts, although none of the above are pathognomonic for lead-induced anemia.

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2. Neurological Effects. Inorganic lead has been found to have toxic effects on both the central and peripheral nervous systems. The earliest stages of lead-induced central nervous system effects first manifest themselves in the form of behavioral disturbances and central nervous system symptoms including sleep disturbances, fatigue, vertigo, headache, poor memory, tremor, depression, and apathy. With more severe exposure symptoms can progress to drowsiness, stupor, hallucinations, delirium, convulsions, and coma.

The most severe and acute form of lead poisoning which usually follows ingestion or inhalation of large amounts of lead is acute encephalopathy which may arise precipitously with the onset of intractable seizures, coma, cardiorespiratory arrest, and death within 48 hours.

While there is disagreement about what exposure levels are needed to produce the earliest symptoms, most experts agree that symptoms definitely can occur at blood levels of 60 $\mu\text{g}/100$ g whole blood and therefore recommend a 40 $\mu\text{g}/100$ g maximum. The central nervous system effects frequently are not reversible following discontinued exposure or chelation therapy and when improvement does occur, it is almost always only partial.

The peripheral neuropathy resulting from lead exposure characteristically involves only motor function with minimal sensory damage and has a marked predilection for the extensor muscles of the most active extremity. The peripheral neuropathy can occur with varying degrees of severity. The earliest and mildest form which can be detected in workers with blood levels as low as 50 $\mu\text{g}/100$ g is manifested by slowing of motor nerve conduction velocity often without clinical symptoms. With progression of the neuropathy there is development of painless extensor muscle weakness usually involving the extensor muscles of the fingers and hand in the most active upper extremity, followed in severe cases by wrist drop or, much less commonly, foot drop.

In addition to slowing of nerve conduction, electromyographical studies in patients with blood lead levels greater than 50 $\mu\text{g}/100$ g have demonstrated a decrease in the number of acting motor unit potentials, an increase in the duration of motor unit potentials, and spontaneous pathological activity including fibrillations and fasciculations. Whether these effects occur at levels of 40 $\mu\text{g}/100$ g is undetermined.

While the peripheral neuropathies can occasionally be reversed with therapy, again such recovery is not assured particularly in the more severe neuropathies and often improvement is only partial. The lack of reversibility is felt to be due in part to segmental demyelination.

3. Gastrointestinal. Lead may also affect the gastrointestinal system producing abdominal colic or diffuse abdominal pain, constipation, obstipation, diarrhea, anorexia, nausea and vomiting. Lead colic rarely develops at blood lead levels below 80 $\mu\text{g}/100$ g.

4. Renal. Renal toxicity represents one of the most serious health effects of lead poisoning. In the early stages of disease nuclear inclusion bodies can frequently be identified in proximal renal tubular cells. Renal function remains normal and the changes in this stage are probably reversible. With more advanced disease there is progressive interstitial fibrosis and impaired renal function. Eventually extensive interstitial fibrosis ensues with sclerotic glomeruli and dilated and atrophied proximal tubules; all represent end stage kidney disease. Azotemia can be progressive, eventually resulting in frank uremia necessitating dialysis. There is occasionally associated hypertension and hyperuricemia with or without gout.

Early kidney disease is difficult to detect. The urinalysis is normal in lead nephropathy and the blood urea nitrogen and serum creatinine increase only when two-thirds of kidney function is lost. Measurement of creatinine clearance can often detect earlier disease as can other methods of measurement of glomerular filtration rate. An abnormal Ca-EDTA mobilization test has been used to differentiate between lead-induced and other nephropathies, but this procedure is not widely accepted. A form of Fanconi syndrome with

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aminoaciduria, glycosuria, and hyperphosphaturia indicating severe injury to the proximal renal tubules is occasionally seen in children.

5. Reproductive effects. Exposure to lead can have serious effects on reproductive function in both males and females. In male workers exposed to lead there can be a decrease in sexual drive, impotence, decreased ability to produce healthy sperm, and sterility. Malformed sperm (teratospermia) decreased number of sperm (hypospermia), and sperm with decreased motility (asthenospermia) can all occur. Teratospermia has been noted at mean blood lead levels of 53 $\mu\text{g}/100\text{ g}$ and hypospermia and asthenospermia at 41 $\mu\text{g}/100\text{ g}$. Furthermore, there appears to be a dose-response relationship for teratospermia in lead exposed workers.

Women exposed to lead may experience menstrual disturbances including dysmenorrhea, menorrhagia and amenorrhea. Following exposure to lead, women have a higher frequency of sterility, premature births, spontaneous miscarriages, and stillbirths.

Germ cells can be affected by lead and cause genetic damage in the egg or sperm cells before conception and result in failure to implant. Miscarriage, stillbirth, or birth defects may result.

Infants of mothers with lead poisoning have a higher mortality during the first year and suffer from lowered birth weights, slower growth, and nervous system disorders.

Lead can pass through the placental barrier and lead levels in the mother's blood are comparable to concentrations of lead in the umbilical cord to birth. Transplacental passage becomes detectable at 12-14 weeks of gestation and increases until birth.

There is little direct data on damage to the fetus from exposure to lead but it is generally assumed that the fetus and newborn would be at least as susceptible to neurological damage as young children. Blood lead level of 50-60 $\mu\text{g}/100\text{ g}$ in children can cause significant neurobehavioral impairments and there is evidence of hyperactivity at blood levels as low as 25 $\mu\text{g}/100\text{ g}$. Given the overall body of literature concerning the adverse health effects of lead in children, OSHA feels that blood lead level in children should be maintained below 30 $\mu\text{g}/100\text{ g}$ with a population mean of 15 $\mu\text{g}/100\text{ g}$. Blood lead levels in the fetus and newborn likewise should not exceed 30 $\mu\text{g}/100\text{ g}$.

Because of lead's ability to pass through the placental barrier and also because of the demonstrated adverse effects of lead on reproductive function in both the male and female as well as the risk of genetic damage of lead on both the ovum and sperm, OSHA recommends a 30 $\mu\text{g}/100\text{ g}$ maximum permissible blood lead level in both males and females who wish to bear children.

6. Other toxic effects. Debate and research continue on the effects of lead on the human body. Hypertension has frequently been noted in occupationally exposed individuals although it is difficult to assess whether this is due to lead's adverse effects on the kidney or if some other mechanism is involved. Vascular and electrocardiographic changes have been detected but have not been well characterized. Lead is thought to impair thyroid function and interfere with the pituitary-adrenal axis, but again these effects have not been well defined.

CARBON MONOXIDE

CAS: 630-08-0

CO

TLV-TWA, 50 ppm (\approx 55 mg/m³)TLV-STEL, 400 ppm (\approx 440 mg/m³)

Carbon monoxide is a flammable, colorless, practically odorless gas. Its physiochemical properties include:

Molecular weight: 28.01

Freezing point: -207°C Condensation point: -190°C

Lower explosive limit: 12.5% by volume in air

It has a density practically the same as that of nitrogen, slightly less than that of air. Sparingly soluble in water (3.3 ml/100 ml of H₂O at 0°C).

CO is an ingredient of gaseous fuels (producer gas, water gas) which have been largely replaced by natural gas. It is chiefly encountered as a product of incomplete combustion of almost any carbonaceous material, especially in the exhausts of internal combustion engines. High concentrations are frequently encountered in blast furnace operations in the steel industry. Space heaters, improperly adjusted oil or gas burners and fires in buildings are also important sources of carbon monoxide exposure.

Carbon monoxide is a chemical asphyxiant gas whose primary toxic action is a direct result of the hypoxia produced by a given exposure. It rapidly diffuses across the alveolar membrane and is reversibly bound to one of the heme proteins. Complexes of 80-90% with hemoglobin resulting in a reduction in the oxygen-carrying capacity of the blood. The remainder of the CO binds with myoglobin, cytochrome oxidase, cytochrome P-450, and the hydroperoxidases.

A small amount of CO is produced endogeneously, mainly from the catabolism of hemoglobin. In healthy male subjects at rest, the average rate of endogenous CO production is approximately 0.4 ml/hr resulting in a carboxyhemoglobin (COHb) saturation of 0.4-0.7%.⁽¹⁾ Hypermetabolism, certain drugs and hemolytic anemia can increase the endogenous production of COHb to 4-6%.⁽²⁾

Tobacco smokers are the most heavily exposed, non-industrial segment of the population.⁽³⁾ COHb saturations in this group range from 4-20% with a mean for one-pack-per-day consumers of 5-6%.⁽³⁾

Each molecule of CO combining with hemoglobin reduces the oxygen carrying capacity of the blood and exerts a finite stress on man. Thus, it may be reasoned that there is no dose of CO that is not without an effect on the body. Whether that effect is physiologic or harmful depends upon the dose of CO and the state of health of the exposed individual. The body compensates for this hypoxic stress by increasing cardiac output and blood flow to specific organs, such as the brain or the heart. When this ability to compensate is overpowered or is limited by disease, tissue injury results.

The absorption and elimination of CO is mathematically described by the equation of Coburn *et al.*, which takes into account such important variables as exposure duration, alveolar ventilation, partial pressure of CO in the inhaled air, blood volume, barometric pressure, diffusivity of the lung for CO, rate of endogenous CO production, average partial pressure of oxygen in the lung and capillaries, and the exact ratio of the affinity of blood for CO.^(4,5) Of these variable CO concentration, duration of exposure, and alveolar ventilation are the most influential in determining COHb saturation.

Exposure to CO sufficient to produce COHb saturations in the 3-5% range impairs cardiovascular function in patients with cardiovascular disease⁽⁶⁻¹²⁾ and in normal subjects.⁽¹³⁻¹⁵⁾ COHb saturations in the 4-6% range have been shown to significantly reduce the ventricular fibrillation threshold in both normal, anesthetized dogs, and those with acute myocardial injury.⁽¹⁶⁾ These levels also increase myocardial ischemia associated with acute myocardial infarction in dogs.⁽¹⁷⁾

The question of significant changes in mental function produced by COHb saturation between 2-5% was controversial and has been reviewed.⁽¹⁸⁾ It does appear that an abrupt elevation of COHb saturation to 5% will transiently alter the visual light threshold.^(19,20) In the industrial setting, the ability to perform complex tasks requiring both judgment and motor coordination is not affected adversely by saturations below 10%.⁽¹⁸⁾

A threshold limit value for carbon monoxide of 100 ppm has been extant for many years, but no substantial justification for its validity under ordinary circumstances of work can be found. The often quoted work of Henderson and Haggard,⁽²¹⁾ states that a three-hour exposure at 100 ppm produces no effect, but six hours' exposure produces a perceptible effect, and nine hours' exposure causes headache and nausea. Drinker⁽²²⁾ states that the safety constant must be reduced to one-third or less under exercise or work. The Committee believes that the apparent success of the 10 ppm value was due to inurement and accumulation of individuals of low degree of susceptibility. A great deal of confusion has resulted over the years from the summation of thousands of publications on the effects of carbon monoxide on man because of serious difficulty in the determination of low levels of the compound in air and blood. It now seems reasonably certain that an equilibrium exposure of man at 50 ppm of carbon monoxide will result in a COHb value of 8-10%, and that under usual conditions for work and rest periods an "end of work day" level of 5-6% would be expected. A crew of workers in the Holland Tunnel who worked two hours in and two hours out, for eight-hour "swing" shifts in an average tunnel CO concentration of 70 ppm showed an average of 5% COHb with no one above 10%. Under this average exposure of 25-50 ppm, no symptoms or health impairments were found,⁽²³⁾ or would be expected.

Men exposed continuously for many days in a submarine at 50 ppm CO complained of headache, but a 60-day exposure at 40 ppm CO was without effect.⁽²⁴⁾

Schulte⁽²⁵⁾ stated that exposure at 100 ppm of CO for over four hours is excessive and recommends a maximal exposure at 50 ppm CO for over four hours' duration.

Studies made upon a group of healthy young men exposed for a prolonged period at 44 ppm CO produced no adverse reactions on their general health.⁽²⁶⁾

The recommended time-weighted TLV of 50 ppm is a concentration that should not result in blood CO levels above 10%, which might cause signs and symptoms of borderline effects.⁽²⁷⁾

The primary effect of exposure to low concentrations of CO on workmen results from the hypoxic stress secondary to the reduction in the oxygen-carrying capacity of blood. Healthy workmen are exquisitely sensitive to such stresses and immediately compensate by increasing cardiac output and flow to critical organs. However, workmen with significant disease, both detected and undetected, may not be able to compensate adequately and are at risk of serious injury. For such workers a TLV of 25 ppm, an air concentration that should not result in blood COHb saturations above 4%, might be necessary. Even such a concentration might be detrimental to the health of some workers who might have far advanced cardiovascular disease.

ATTACHMENT 2
page 2

To protect workers with chronic heart disease NIOSH, in its criteria document for CO⁽²⁸⁾ recommends a work environment standard of 35 ppm as a TWA, with a ceiling of 200 ppm. Much of the evidence on which this recommendation is based is derived from studies of cigarette smokers.⁽²⁹⁾

It would appear to the Committee that the time-weighted TLV of 50 ppm for carbon monoxide might also be too high under conditions of heavy labor, high temperatures, or at high elevations (over 5000 feet above sea level). For the great majority of workers, however, exposure to carbon monoxide at concentrations below 50 ppm, under a wide range of working conditions, should not result in either mild temporary distress or permanent impairment of health. The Committee also suggests a STEL of 400 ppm.

Other recommendations: Australia, Finland, West Germany, Belgium, Holland, Switzerland and Yugoslavia have adopted the 50 ppm TLV; Sweden, 35 ppm; East Germany, 30 ppm; Czechoslovakia, Hungary, Poland, Romania, 26 ppm; Bulgaria, USSR, 17 ppm.

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APPENDIX D

QUALITY ASSURANCE PROJECT PLAN

R-49-1-93-7

**Quality Assurance Project Plan
Naval Submarine Base - New London
Groton, Connecticut**

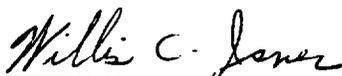
**Submitted to:
Northern Division
Environmental Branch, Code 1823
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
Lester, Pennsylvania 19113-2090**

**Submitted by:
Halliburton NUS Corporation
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Wayne, Pennsylvania 19087-1710**

**Contract Number N62472-90-D-1298
Contract Task Order 0112**

FEBRUARY 1993

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1.0 PROJECT DESCRIPTION

As requested by the U.S. Navy, HALLIBURTON NUS has prepared this Quality Assurance Project Plan (QAPP) for environmental sampling and analysis work at Building 31 of the Naval Submarine Base - New London (NSB-NLON) located in Groton, Connecticut.

HALLIBURTON NUS has established quality assurance/quality control (QA/QC) measures and a program to ensure that these measures are applied to the collection and interpretation of all environmental quality data at the facility. The QAPP is designed to assure that the precision, accuracy, representativeness, comparability, and completeness (the PARCC parameters) of the data are known, documented, and adequate to satisfy the data quality objectives of the study.

This plan represents the policies, organization, objectives, data-collection activities, and QA/QC activities that will be utilized to ensure that all data collected during, and reported by, this study are representative of existing conditions. Chemical analyses will be conducted by a laboratory subcontractor. The laboratory will possess current Contract Laboratory Program (CLP) certification and will have site-specific Naval Energy and Environmental Support Activity (NEESA) approval. QA/QC procedures for the chemical analyses will satisfy NEESA requirements for Level D QC, which is equivalent to EPA CLP DQO Level IV QC Criteria.

2.0 PROJECT SCOPE OF WORK

Environmental sampling and analysis will be performed to determine the extent of lead and related battery contamination in the soils and groundwater at Building No. 31. Details of the sampling, such as the approach, selection of drilling locations, and sample collection activities, are found in Sections 2.0 and 3.0 of the Abbreviated Field Sampling Plan (AFSP). A brief history of the site is contained in Section 1.0 of the AFSP.

A summary of previous investigations at Building No. 31 and existing analytical data are briefly summarized in Section 1.1 of the AFSP.

3.0 SAMPLE MATRICES, PARAMETERS, AND FREQUENCY COLLECTION

As part of the field work, environmental quality samples will be collected from soil and groundwater matrices. A listing of the sample matrices, parameters, and frequency of collection is found in Table 3-1. Sampling protocols to be used in this study are provided in Section 6.0 of this QAPP. As required by NEESA, a sampling rationale is included in Section 2.0 and Section 3.0 of the Abbreviated Field Sampling Plan. All samples submitted for laboratory analysis will be analyzed for lead. Additional parameters are summarized in Table 3-1. In addition, Table 3-2 presents the sample containers, preservatives, and allowable holding times for the required analyses.

TABLE 3-1

**ANALYTICAL PROGRAM SUMMARY
SOIL AND GROUNDWATER SAMPLES
NAVY SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT**

Parameter	Method	Sample Type	No. of Samples	Equipment Rinsate ²	Field Blanks ³	Trip Blanks ⁴	Duplicates ⁵	Total Samples
Lead	CLP Protocol (3/90)	Surface Soil	2	1	0	0	1	4
Lead	CLP Protocol (3/90)	Subsurface Soil	105	8	2	0	11	126
TCLP (lead) ¹	SW 1311 SW 6010	Subsurface Soil	28	0	0	0	0	28
pH	E 150.1	Subsurface Soil	84	0	0	0	9	93
Appendix 8 Metals	SW 6010 SW 7000	Subsurface Soil	4	1	0	0	0	5
TCL Volatiles	CLP Protocol (3/90)	Subsurface Soil	4	1	0	2	1	8
TCL Semivolatiles	CLP Protocol (3/90)	Subsurface Soil	4	1	0	0	1	6
TCL Pest/PCBs	CLP Protocol (3/90)	Subsurface Soil	4	1	0	0	1	6
TAL - Metals	CLP Protocol (3/90)	Subsurface Soil	4	1	0	0	1	6
TAL - Cyanide	CLP Protocol (3/90)	Subsurface Soil	4	1	0	0	1	6
TCL Volatiles (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	2	1	9
TCL Semivolatiles (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	2	1	7
TCL Pest/PCBs (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	0	1	7

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**TABLE 3-1
ANALYTICAL PROGRAM SUMMARY
SOIL AND GROUNDWATER SAMPLES
NAVY SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT
PAGE TWO**

Parameter	Method	Sample Type	No. of Samples	Equipment Rinsate ²	Field Blanks ³	Trip Blanks ⁴	Duplicates ⁵	Total Samples
TAL Metals ⁸ (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	0	1	7
TAL Cyanide (1-round only)	CLP Protocol (3/90)	Groundwater	3	1	2	0	1	7
Appendix-8 ⁸ Metals (total) ⁹ (2-rounds)	200 Series	Groundwater	7	1	0	0	1	9
Appendix-8 ⁸ Metals (Dissolved) ⁷ (2-rounds)	200 Series	Groundwater	7	1	2	0	1	11

¹ TCLP = Toxicity Characteristics Leaching Procedure, Lead.

² Equipment Blank - Samples obtained by pouring analyte-free water over sample collection equipment (bailer, etc.) after decontamination. Assesses the effectiveness of field decontamination procedure. Obtained at a frequency of 1/day/media/analysis but analyzed every other day unless positive detection are recorded. Number of samples reflects the number of actual laboratory analyses performed.

³ Field Blank - Samples consisting of the source water used in (1) steam cleaning and/or (2) decontamination. Obtained at a frequency of 1/event/media.

⁴ Trip Blank - Prepared at the laboratory using analyte-free deionized water, and accompanies samples for VOCs at all times until analysis at the laboratory.

⁵ Duplicates - A single sample split into two portions during a single act of sampling. Assess the overall precision of the sampling and analysis program. Obtained at a frequency of 10% of the number of samples.

⁸ Total Metals - For the determination of total metals the sample is not filtered before acidification.

⁷ Dissolved Metals - For the determination of dissolved metals the sample must be field filtered through a 0.45 micron filter before acidification.

⁹ Appendix-8 Metals shall only include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.

TABLE 3-2

**SUMMARY OF ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS,
AND HOLDING TIMES
NAVY SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT**

Media	Analysis	Number of Samples	No. of Containers Per Sample	Container Type	Preservation Requirements	Holding Times
Surface Soil	Lead (total recoverable)	4	1	4 oz. amber wide mouth glass jar	Cool to 4°C	6 months
Subsurface Soil	Lead (total recoverable)/pH TCLP (lead)/Appendix-8 Metals ^(a)	126	2	1-4 oz. amber wide month glass jar 1-32 oz. wide mouth glass jar	Cool to 4°C	6 months ^(b)
Subsurface Soil	TCL Volatiles	8	2	60 ml VOA vial	Cool to 4°C	14 days
Subsurface Soil	TCL Semivolatiles	6	1	4 oz. amber wide mouth glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Subsurface Soil	TCL Pest/PCBs	6	1	4 oz. amber wide mouth glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Subsurface Soil	TAL Metals and Cyanide	6	1	8 oz. wide mouth jar	Cool to 4°C	6 months ^{(b)(c)}
Groundwater	TCL Volatiles	9	2	40 ml VOA vial	HCL to pH<2, Cool to 4°C	14 days
Groundwater	TCL Semivolatiles	7	1	80 oz. amber glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Groundwater	TCL Pest/PCBs	7	1	80 oz. amber glass jar	Cool to 4°C	7 days to extract 40 days after extraction
Groundwater	TAL Metals (total)	7	1	1-liter polyethylene bottles	HNO ₃ to pH<2 Cool to 4°C	6 months ^(b)

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TABLE 3-2
SUMMARY OF ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS,
AND HOLDING TIMES
NAVY SUBMARINE BASE, NEW LONDON
GROTON, CONNECTICUT
PAGE TWO

Media	Analysis	Number of Samples	No. of Containers Per Sample	Container Type	Preservation Requirements	Holding Times
Groundwater	TAL Cyanide	7	1	1-liter polyethylene bottles	NAOH to pH>12 Cool to 4°C	14 days
Groundwater	Appendix 8 Metals (total)	9	1	1-liter polyethylene bottles	HNO ₃ to pH<2 Cool to 4°C	6 months ^(b)
Groundwater	Appendix 8 Metals (dissolved)	11	1	1-liter polyethylene bottles	HNO ₃ to pH<2 Cool to 4°C Field filtered to .45μ	6 months ^(b)

(a) All samples will be analyzed for total recoverable lead. Additionally only 31 of these samples will be analyzed for TCLP (lead) and 6 samples will be analyzed for Appendix 8 Metals. Also, pH analyses will be performed on 93 of these samples.

(b) The holding time for mercury analysis is 28 days.

(c) The holding time for cyanide is 14 days.

4.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

Halliburton NUS will be responsible for the overall management of the project, including the field sampling activities. Personnel from Navy will support Halliburton NUS in a number of areas during the project.

4.1 NAVY SUPPORT

Ms. Deborah Stockdale will be the Northern Division Remedial Project Manager (RPM). She will be the primary Navy point of contact for the project. All project activities, including reporting and field activities, will be coordinated through Ms. Stockdale. Any changes in scope will be approved through Ms. Stockdale prior to implementation. Ms. Stockdale may be contacted at the following address:

Ms. Deborah Stockdale
Northern Division Naval Facilities Engineering Command
10 Industrial Highway
Mail Stop 82
Lester, Pennsylvania 19113-2090
(215) 595-0567

Mr. William L. Mansfield will be the primary point of contact at NSB-NLON. All field work will be coordinated through Mr. Mansfield; he will notify appropriate personnel (security, etc.) and make arrangements for equipment (support facilities) that will be provided by the Navy. Mr. Mansfield may be contacted at the following address:

Mr. William L. Mansfield
Director, Environmental Division
Naval Submarine Base, New London
Code 803
Groton, Connecticut 06349-5100
(203) 449-2276

4.2 PROJECT ORGANIZATION

The project will be staffed with personnel from the Pittsburgh office. The address and main phone number for the Pittsburgh office is:

Halliburton NUS Corporation
Foster Plaza VII
661 Andersen Drive
Pittsburgh, Pennsylvania 15220
(412) 921-7090

Key management staff and project staff members for this project are as follows:

- John Trepanowski, P.E. - Program Manager (215) 971-0900
- Debra Wroblewski - Deputy Program Manager (412) 921-8968
- Patricia Patton - Contracting Officer (301) 258-8644
- Debra Scheib - Quality Assurance Manager (412) 921-8876
- Matt Soltis - Health and Safety Manager (412) 921-8912
- Willis Isner - Project Manager (412) 921-8616
- Stan Conti - Field Operation Leader (412) 921-8422

The Project Manager has the primary responsibility for project and technical management of this project. He is responsible for the coordination of all onsite personnel, and for providing technical assistance for all activities that are directly related to the project. If quality assurance problems or deficiencies requiring special action are identified, the Project Manager, Deputy Program Manager, and Quality Assurance Manager will identify the appropriate corrective action.

4.3 FIELD ORGANIZATION

The Halliburton NUS field investigation team will team will consist of a combination of the following personnel:

- Field Operations Leader (FOL)
- Field hydrogeologist/geologist

The FOL will be responsible for the coordination of all onsite personnel and for providing technical assistance when required. The FOL, or his or her designee will coordinate and be present during all sampling activities and will assure the availability and maintenance of all sampling materials/equipment. The FOL will be responsible for the completion of all sampling, well construction, and chain-of-custody documentation, and will assume custody of all samples and ensure the proper handling and shipping of samples.

The Quality Assurance Manager, although not formally part of the field team, will be responsible for the adherence of all QA/QC guidelines as defined in this QAPP. Strict adherence to these procedures is critical to the collection of acceptable and representative data.

A site health and safety officer will be designated prior to field activities and will be responsible for assuring that all team members adhere to the designated health and safety requirements.

5.0 QUALITY ASSURANCE OBJECTIVES

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide environmental monitoring data of known and acceptable quality. Specific procedures to be used for sampling, chain-of-custody, calibration of field instruments, laboratory analysis, reporting, internal quality control, audits, preventative maintenance, and corrective actions are described in later sections of this QAPP. The purpose of this section is to address the data quality objectives in terms of the (PARCC) parameters, quantitation and detection limits, field blanks, rinsate blanks, duplicates, and bottleware cleanliness.

5.1 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) are qualitative and/or quantitative statements regarding the quality of data needed to support the project activities. The sampling rationale provided in the Abbreviated Field Sampling Plan explains the choice of sample locations and media which will supply information needed for the project.

5.2 PARCC PARAMETERS

The quality of data set is measured by certain characteristics of the data, namely the PARCC parameters. Some of the parameters are expressed quantitatively, while others are expressed qualitatively. The objectives of the project and the intended use of the data define the PARCC goals.

5.2.1 Precision

Precision characterizes the amount of variability and bias inherent in a data set. Precision describes the reproducibility of measurements of the same parameter for a sample under the same or similar conditions. Precision is expressed as a range (the difference between two measurements of the same parameter) or as a relative percent difference (the range relative to the mean, expressed as a percent). Range and Relative Percent Difference (RPD) values are calculated as follows:

$$\text{Range} = \text{OR} - \text{DR}$$

$$\text{RPD} = \frac{[\text{OR} - \text{DR}]}{1/2 (\text{OR} + \text{DR})} \times 100\%$$

where: OR = original sample result

DR = duplicate sample result

The internal laboratory control limits for precision are three times the standard deviation of a series of RPD or range values. RPD values may be calculated for both laboratory and field duplicates, and can be compared to the control limits as a QA check. Laboratory duplicates will be analyzed at the rate required by NEESA. Field duplicates will be collected for 10 percent of all samples collected.

5.2.2 Accuracy

Accuracy is the comparison between experimental and known or calculated values expressed as a percent recovery (%R). Percent recoveries are derived from analysis of standards spiked into deionized water (standard recovery) or into actual samples (matrix spike or surrogate spike recovery). Recovery is calculated as follows:

$$\%R = \frac{E}{T} \times 100\%$$

where: E = experimental result

T = true value (theoretical result)

and

$$T = \frac{(\text{sample aliq.}) (\text{sample conc.}) + (\text{spike aliq.}) (\text{spike conc.})}{\text{sample aliq.} + \text{spike aliq.}}$$

Control limits for accuracy are set at the mean plus or minus three times the standard deviation of a series or %R values.

Accuracy for aqueous and solid samples will be evaluated by use of surrogate and matrix spikes. Out-of-criteria results will be reviewed for data applicability as a part of data validation.

5.2.3 Representativeness

All data obtained should be representative of actual conditions at the sampling location. The AFSP is designed so that the samples taken will present an accurate representation of actual site conditions. The rationales discussed in the AFSP and QAPP are designed to ensure this. All sampling activities will conform to the protocols given in Section 6.0 of this QAPP. The use of NEESA approved CLP analytical protocols and data deliverables will ensure that analytical results and deliverables are representative, and both consistently performed and reported.

5.2.4 Comparability

Comparability will be achieved by utilizing standardized sampling and analysis methods and data reporting format. Both analytical procedures and sample collection techniques will maximize the comparability of this new data to previous data. Additionally, consideration will be given to seasonal conditions and other environmental conditions that could influence analytical results.

5.2.5 Completeness

Completeness is a measure of the amount of valid data obtained from the measurement program, compared to the total amount collected. For relatively clean, homogeneous matrices, 100-percent completeness is expected. However, as matrix complexity and heterogeneity increase, completeness may decrease. Where analysis is precluded or where DQOs are compromised, effects on the overall investigation must be considered. Whether any particular sample is critical to the investigation will be evaluated in terms of the sample location, the parameter in question, the intended data use, and the risk associated with the error.

Critical data points may not be evaluated until all the analytical results are evaluated. If in the evaluation of results it becomes apparent that the data for a specific medium are of insufficient quality (95 percent), either with respect to the number of samples or an individual analysis, resampling of the deficient data points may be necessary.

5.3 FIELD BLANKS

Field blanks are obtained by sampling the water(s) used in decontamination during the field investigation. Samples consist of the source water used in (1) steam cleaning of large equipment and (2) analyte-free water used for decontamination of sampling equipment. Field blanks will be used to confirm the effectiveness of decontamination procedures, and to determine if the analyte-free water or the potable water (used for steam cleaning) may be contributing to sample contamination. Field blanks will be collected for each type of water used for decontamination and will be submitted at a frequency of one per sampling event per media.

5.4 RINSATE BLANKS

Equipment rinsate blanks are obtained under representative field conditions by running analyte-free water through sample collection equipment (bailer, split spoon, corer, etc.) after decontamination and placing it in the appropriate sample containers for analysis. Equipment blanks will be used to assess the effectiveness of decontamination procedures. Equipment blanks will be collected for each type of non-dedicated sampling equipment used and will be submitted at a frequency of one per day per media. Equipment blanks, however, only from every other day will be analyzed unless positive detections are recorded in the prior sample blank. It will be the responsibility of the FOL to communicate to the laboratory whether an equipment blank is, or is not, to be analyzed as stated above.

5.5 FIELD DUPLICATES

Field duplicates are two samples collected (1) independently at a sampling location in the case of groundwater or surface water, or (2) a single sample split into two portions in the case of soil or sediment. Duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. Ten percent of all samples for each media shall be field duplicates. Duplicates shall be analyzed for the same parameters in the laboratory.

5.6 TRIP BLANKS

Trip blanks are defined as samples which originate from analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with the volatile organic compound (VOC) samples. One trip

blank should accompany each cooler containing VOCs, should be stored at the laboratory with the samples, and analyzed by the laboratory. Trip blanks are only analyzed for VOCs.

5.7 BOTTLEWARE

NEESA requires specific bottleware cleaning procedures. Precleaned bottles will be used for the Project. Precleaned bottles will be provided by the subcontracted laboratory who will also be responsible for providing the required certification.

6.0 SAMPLING PROCEDURES

6.1 SITE BACKGROUND

The site background information is provided in Section 1.0 of the AFSP.

6.2 SAMPLING OBJECTIVES

The objective of the sampling will be to characterize the nature and extent of lead and related contamination at Building No. 31. The data collected will also be used to assess potential migration pathways. The specific objectives are to identify the location and concentration of potential soil and groundwater contamination at one site identified as Building No. 31 to prepare an Action Memorandum and other supporting documentation for a time critical removal action.

6.3 SAMPLE LOCATION AND FREQUENCY

Soil and groundwater samples will be collected during the field activities. These samples will be analyzed in accordance with NEESA and EPA-approved methodology for lead. In addition, several soil samples are to be analyzed for the TCLP (lead) and Appendix 8 Metals. Groundwater samples are to be analyzed for both total and dissolved lead. A list of the analytes, analytical method, contract required quantification limits, containers, preservatives, and holding times are provided in Table 3-2 of this QAPP.

The sampling program consists of four activities. These activities are as follows and are described in detail in Sections 2.0 and 3.0 of the AFSP.

- Installation of Temporary Monitoring Drive Points
- Drive Point Sampling (GW)
- Subsurface Soil Sampling
- Surface Soil Sampling

Two rounds of groundwater sampling are planned at this facility. All sampling will be performed during one phase. The initial groundwater sampling will be conducted after the temporary well points are developed

(during the first sampling week). The second round of groundwater sampling will be conducted during the second sampling week just prior to demobilization. The temporary monitoring drive points will be removed after receiving authorization from the RPM at a later date.

6.4 SAMPLE DESIGNATION

Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of a three-segment, alpha-numeric code that identifies the sample medium and location, sample depth (in the case of soil samples), and QA designation, if required. In addition, because groundwater will be sampled during two phases, an additional segment will be attached to the end of groundwater sample numbers. Groundwater sample numbers will include a "-1" or "-2" depending upon whether the sample was obtained during Phase I or Phase II.

Any other pertinent information regarding sample identification will be recorded in the field log books.

The alpha-numeric coding to be used in the sample system is explained in the diagram and the subsequent definitions:

(AANN)	-	(NNN)	-	(A)
(Medium & Location)		(Sample depth)		(QA designation)

Character Type:

A	=	Alpha
N	=	Numeric

Medium:

GW	=	Groundwater from well point or monitoring well
SB	=	Soil sample from one of 28 soil borings
SO	=	Surface and shallow subsurface soil samples

Sample Location:

Subsurface soil = soil boring number.
Surface soil = sample location number.
Groundwater sample = well number.

Sample Identifier:

For soil samples = End depth, in feet, of sample.
Not used for groundwater.

QA Sample Designation:

D = Duplicate (Soil/Groundwater)
B = Equipment Rinsate Blank
F = Field Blank

6.5 SAMPLE EQUIPMENT AND PROTOCOLS

The sampling equipment and protocols to be used are presented in Appendix B of the AFSP.

6.6 SAMPLE HANDLING AND ANALYSIS

Sample handling and analysis are presented in Sections 5.0, 6.0, and 7.0 of this QA/QC Plan.

6.7 EQUIPMENT DECONTAMINATION

The equipment involved in field sampling activities will be decontaminated prior to and during drilling and sampling activities. This equipment includes drilling rigs, downhole tools, augers, well casing and screens, and all sampling equipment.

Major Equipment

All downhole drilling equipment and sampling tools shall be steam cleaned prior to beginning work, between well borings, any time the drilling rig leaves the site prior to completing a boring, and at the completion of the drilling program. In addition, well casing and screens shall be steam cleaned prior to being installed into the borings.

These decontamination operations will consist of washing the equipment using a high-pressure steam wash. All decontamination activities will take place at a location determined during mobilization. Additional requirements for drilling equipment decontamination can be found in Halliburton NUS SOP GH-1.6: Section 5.

Sampling Equipment

All sampling equipment used for collecting samples will be decontaminated both prior to beginning field sampling and between samples. The following decontamination steps will be taken:

- Potable water rinse
- Alconox or Liquinox detergent wash
- Potable water rinse
- Nitric acid rinse^(a)
- Analyte-free water rinse^(b)
- Methanol rinse^(b)
- Distilled/deionized water rinse^(b)
- Analyte-free water rinse^(c)
- Air dry

^(a) Not required for stainless steel equipment.

^(b) Required only for volatiles, semivolatiles, or pest/PCBs samples.

^(c) Not required for volatiles, semivolatiles, or pest/PCBs.

Field analytical equipment such as pH, conductivity and temperature instrument probes will be rinsed first with analyte-free water, then with the sample liquid.

7.0 SAMPLE CUSTODY

Sample custody procedures are designed to provide documentation of preparation, handling, storage, and shipping of all samples collected. An example of the chain-of-custody form, which will be used during this investigation, is included in Appendix A of the AFSP. A copy of the procedure is included in Appendix B.

Samples collected during the site investigation will be the responsibility of identified persons from the time they are collected until they, or their derived data, are incorporated into the final report. Stringent chain-of-custody procedures will be followed to document sample possession.

7.1 FIELD CUSTODY

- The FOL, or his or her designee, is responsible for the care and custody of the samples collected until they are delivered to the analyzing laboratory or entrusted to a carrier.
- Sample logs or other records will always be signed and dated.
- Chain-of-custody sample forms will be completed to the fullest extent possible prior to sample shipment. They will include the following information: project name, sample number, time collected, source of sample and location, description of sample location, matrix, type of sample, grab or composite designation, preservative, and name of sampler (see attached form).

These forms will be filled out in a legible manner, using waterproof ink, and will be signed by the sampler. Similar information will be provided on the sample label which will be securely attached to the sample bottle. The label will also include the general analyses to be conducted. In addition, sampling forms will be used to document collection, filtration, and preparation procedures. Copies of all forms used during field activities are provided in Appendix B.

7.2

TRANSFER OF CUSTODY AND SHIPMENT

The following procedures will be used when transferring custody of samples:

- Samples will always be accompanied by a chain-of-custody record. When transferring samples, the individuals relinquishing and receiving them will sign, date, and note the time of the chain-of-custody record. This record documents the sample custody transfer from the sampler to the laboratory, often through another person or agency (common carrier). Upon arrival at the laboratory, internal sample custody procedures will be followed.
- Prior to shipment to the laboratory for analysis, samples will be properly packaged. Individual custody records will accompany each shipment. Shipping containers will then be sealed for shipment to the laboratory. The methods of shipment, courier name, and other pertinent information, will be entered in the remarks section of the custody record.
- All shipments will be accompanied by the chain-of-custody record identifying the contents. The original record will accompany the shipment; and a copy will be retained by the field sampler.
- Proper documentation will be maintained for shipments by common carrier.

7.3

SAMPLE SHIPMENT PROCEDURES

The following procedures will be followed when shipping samples for laboratory analysis:

- Samples requiring refrigeration will be promptly chilled with ice or Blue Ice to a temperature of 4°C and will be packaged in an insulated cooler for transport to the laboratory. Ice will be sealed in containers to prevent leakage of water. Samples will not be frozen.
- Only shipping containers that meet all applicable state and Federal standards for safe shipment will be used.

- Shipping containers will be sealed with nylon strapping tape, custody seals will be signed, dated, and affixed, in a manner that will allow the receiver to quickly identify any tampering that may have occurred during transport to the laboratory.
- The field chain-of-custody document will be placed inside the shipping container in a sealed plastic envelope after the courier has signed the document.
- Shipment will be made by a public courier. After samples have been taken, they will be sent to the laboratory within 48 hours.

7.4 FIELD DOCUMENTATION RESPONSIBILITIES

It will be the responsibility of the FOL to secure all documents produced in the field (geologist's daily logs, lithologic and sampling logs, calibration forms, communications) at the end of each work day. A copy of all forms used during field activities are included in Appendix A.

The possession of all records will be documented; however, only the project FOL or designee may remove field data from the site for reduction and evaluation.

8.0 CALIBRATION PROCEDURES

Field equipment such as the photoionization equipment (HNU), the pH and specific conductance meters, and any other equipment used during this project will be calibrated and operated in accordance with the manufacturer's instructions and manuals. A log will be kept documenting the calibration results for each field instrument. The log will include the date, standards, personnel, and results of the calibration. A copy of the calibration form used during the field investigation is included in Appendix A. The SOP for calibration procedures is included in Appendix B.

9.0 ANALYTICAL PROCEDURES

Environmental samples collected during the field investigation for chemical analyses will be analyzed using the appropriate analytical procedures as outlined in Section 3.0 and Table 3-1 of this QAPP.

10.0 DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction, validation, and reporting are basic steps in the control and processing of field and laboratory project-generated data. Data validation procedures are described below.

Data validation consists of a stringent review of an analytical chemical data package with respect to sample receipt and handling, analytical methods, data reporting and deliverables, and document control. The quality of data generated by a laboratory is extremely important; it is an integral part of the investigation and should be clearly tied to the project goals. Data used to develop qualitative trends, for example, will not have the same data validation requirements as data used for litigation purposes.

A qualified Halliburton NUS chemist will review the analytical data packages using EPA procedures. Approximately 15 percent of the total number of environmental samples will be validated. After the data is validated, a listing of non-conformities will be generated and used to determine whether the data can be utilized for its intended purpose. Non-conformities require data qualifiers, which are used to alert the data user to inaccurate or imprecise data. For example, if holding times are exceeded, the data reviewer must qualify all positive results as estimated and all sample quantitation limits as estimated. If holding times are grossly exceeded (i.e. exceeded by more than two times the maximum allowance), the data reviewer must qualify all positive results as estimated and must reject all sample quantitation limits. For situations in which there are several quality control criteria out of specification (with regard to the limits specified in the Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program, NEESA 20.2-047B, June 1988), the data validator may make professional judgments and/or comments on the validity of the overall data package. In situations where the validity of an entire data package is in question, it may be necessary for the sample(s) to be re-analyzed. The reviewer will then prepare a technical memorandum presenting changes in the data, if necessary, and the rationale for making such changes.

The net result is a data package that has been carefully reviewed for its adherence to prescribed requirements and is suitable for its intended use. Data validation thus plays a major role in determining the confidence with which key technical evaluations may be made.

The final Action Memorandum report will include a data summary. The summary of analytical data will exclude non-detected compounds. No subtraction of blanks will be allowed. Data will be flagged if blank contamination occurs. All data flags will follow the result in the summary.

The laboratory data for each sample will be reported in an appendix. These data will be presented in a spreadsheet format with all field, and laboratory blanks marked. The format recommended by NEESA will be used. Field logs and forms will be included in another appendix.

11.0 INTERNAL QUALITY CONTROL CHECKS

Quality control samples generated by Halliburton NUS will include the collection of field duplicates, the preparation of field blanks, and the preparation of equipment/rinsate blanks. An approximate 10 percent duplication (one per 10 samples or one per sample matrix if less than 10 samples) will be collected. See Table 3-1 for the required number of sample duplicates.

As there are limited VOCs analyses to be performed, trip blanks using distilled water will be prepared by the analytical laboratory for this investigation and accompany those samples at all times. Rinsates, prepared by running distilled water through the sampling equipment, will be analyzed to determine whether the sampling procedures may be biasing the data. Field blanks will be prepared at a rate of one per source per event. Procedures for collecting these samples are contained in the Section 6.0 of this QA/QC Plan.

There are two types of quality assurance mechanisms used to ensure the production of analytical data of known and documented quality. The internal quality control procedures for the analytical services are specified under NEESA guidelines and Table 3-1. These specifications include the types of control samples required (sample spikes, surrogate spikes, controls, and blanks), the frequency of each control, the compounds to be used for sample spikes and surrogate spikes, and the quality control acceptance criteria. It will be the laboratory's responsibility to document, in each package, that both initial and on-going instrument and analytical QC criteria are met. This documentation will be included in the data packages generated by contract laboratory.

Analytical results of field-collected quality control samples will also be compared to acceptance criteria, and documentation will be performed showing that criteria have been met. Any samples in nonconformance with the QC criteria will be identified and reanalyzed by the laboratory, if possible. The following procedures will be employed for the samples:

- Proper storage of samples.
- Use of qualified and/or certified technicians.
- Use of calibrated equipment.

- Formal independent confirmation of all computation and reduction of laboratory data and results.
- Use of standardized test procedures.
- Inclusion of replicate samples at a frequency of one replicate per 10 samples or one per sample matrix if less than 10 samples are collected.

12.0 PERFORMANCE AND SYSTEM AUDITS

System audits will be performed as appropriate, to assure that the work is being implemented in accordance with the approved project SOPs and in an overall satisfactory manner.

- The FOL will supervise and check on a daily basis that the monitoring wells are installed and developed correctly, field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and the field work is accurately and neatly documented.
- The data validator will review (on a timely basis) the data packages submitted by the laboratory. The data validator will check that the data was obtained through the approved methodology, that the appropriate level of QC effort and reporting was conducted, that holding times were met, and that the results are in conformance with the QC criteria. On the basis of these factors, the data validator will evaluate the data quality and limitations.
- The project manager will oversee the FOL and data validator, and check that management of the acquired data proceeds in an organized and expeditious manner.
- System audits for the laboratory are conducted by NEESA on a regular basis as required.
- A formal audit of the field sampling procedures may be conducted in addition to the auditing that is an inherent part of the daily project activities.
- The auditors will check that sample collection, sample handling, decontamination protocols, and instrument calibration and use are in accordance with the approved project SOPs. The auditors will also check that the field documentation logs and chain-of-custody forms are being filled out properly.

The subcontracted analytical laboratory must be either NEESA approved or have worked for the Navy on a recent project, be eligible to perform the required analysis under NEESA protocols, and must have site-specific approval prior to commencement of work.

13.0 PREVENTATIVE MAINTENANCE

Halliburton NUS has established a program for the maintenance of field equipment to ensure the availability of equipment in good working order when and where it is needed. This program consists of the following elements:

- The equipment manager keeps an inventory of the equipment in terms of items (model and serial number) quantity and condition. Each item of equipment is signed out when in use, and its operating condition and cleanliness checked upon return.
- The equipment manager conducts routine checks on the status of equipment and is responsible for the stocking of spare parts and equipment readiness.
- The equipment manager maintains the equipment manual library and trains field personnel in the proper use and care of equipment.
- The FOL is responsible for working with the equipment manager to make sure that the equipment is tested, cleaned, charged, and calibrated in accordance with the manufacturer's instructions and Halliburton NUS SOP's before being taken to the job site and during field activities.

14.0 DATA ASSESSMENT PROCEDURES

14.1 REPRESENTATIVENESS, ACCURACY, AND PRECISION

All data generated in the investigation will be assessed for its representativeness, accuracy, and precision. The completeness of the data will also be assessed by comparing the valid acquired data to the project objectives to see that these objectives are being addressed and met. The specific procedures used to determine data precision, accuracy, and completeness will be provided in the analytical reports. Accuracy will be determined using laboratory spiked samples and laboratory field blanks.

The representativeness of the data will be assessed by determining if the data are consistent with known or anticipated hydrogeologic or chemical conditions and accepted principles. Field measurements will be checked for completeness of procedures and documentation of procedures and results.

Precision and accuracy will be determined using replicate samples and blank and spiked samples, respectively. The specific procedures for determining PARCC parameters are outlined in Section 5.0.

14.2 VALIDATION

Fifteen percent of the analytical data packages for each media will be validated using EPA validation protocol. If problems are found during this partial validation, then additional or all the data packages may be validated.

14.3 DATA EVALUATION

The evaluation of the data collected during the field investigation will be a comparison of chemical concentrations in the hydraulically upgradient groundwater well versus the chemical concentration in the downgradient groundwater wells; chemical concentrations in groundwater versus ARARs (such as the Safe Drinking Water Act MCLs) and risk-based concentrations; and chemical concentrations in soils versus background and risk-based concentrations.

The total and dissolved lead concentrations in the hydraulically upgradient groundwater versus downgradient groundwater will be compared to each other.

The evaluation of the soil data collected during the field investigation will be a statistical comparison of: chemical concentrations in the background (natural) samples versus the chemical concentration in the onsite samples; and chemical concentrations in site soils versus MCLs and risk-based concentrations. Typically, a statistical approach can be used to determine if there is a significant increase in contaminant concentrations across a site. This increase would indicate that the site is a source of the contamination. The conclusions of the data collected is expected to either conclusively indicate that the site is, or is not, causing soil contamination; or the data may be inconclusive and indicate that additional data collection is required. Relatively conclusive data that the site is causing soil contamination would occur if there is a significant (one or more orders of magnitude) increase in contaminant concentrations from the background soils to the site soils. If the contaminant concentrations are nearly identical (+/- 25%) in the background soils and the site soils, then this would indicate that the site is not causing the soil contamination. Otherwise, the data is inclusive and additional rounds of soil sampling would be required to allow a statistical evaluation.

Four existing soil samples were collected during previous investigations and are considered to be representative of uncontaminated local background conditions. Samples 2WMW2S (0-2), 6MW5S (0-7), 6MW5S (8-10), and 13MW6 (14-16) are the existing samples proposed for the evaluation.

15.0 CORRECTIVE ACTION

The QA program will enable problems to be identified, controlled, and corrected. Potential problems may involve nonconformance with the SOPs and/or analytical procedures established for the project or other unforeseen difficulties. Any person identifying an unacceptable condition will notify the project manager. The project manager, with the assistance of the project QA/QC officer, will be responsible for developing and initiating appropriate corrective action and verifying that the correction action has been effective. Corrective actions may include the following: resampling and/or reanalysis of sample, amending or adjusting project procedures. If warranted by the severity of the problem (for example, if a change in the approved AFSP is required), the Navy will be notified in writing and their approval will be obtained prior to implementing any change. Additional work that is dependent on a nonconforming activity will not be performed until the problem has been eliminated.

The laboratory maintains an internal closed-loop corrective action system that operates under the direction of the laboratory QA coordinator.

16.0 QUALITY ASSURANCE REPORTS

The Quality Assurance Manager or her designee will review all aspects of the implementation of the QA/QC Plan on a regular basis and prepare a summary report. Reviews will be performed at the completion of each field activity and reports will be completed at this time. These reports will include an assessment of data quality and the results of system and/or performance audits. Any significant QA deficiencies will be reported and identified, and corrective action possibilities discussed. The laboratory will issue monthly progress reports.

Other QA/QC reports are listed in Section 8.0.

17.0 REFERENCES

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