N00129.AR.000556
NSB NEW LONDON
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Work Plan and Sampling and Analysis Plan for Lower Subase Remedial Investigation

Naval Submarine Base New London

Groton, Connecticut

Northern Division
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0260

September 1997

Brown & Root Environmental
A Division of Halliburton NUS Corporation

019707/P (WP)

WORK PLAN AND SAMPLING AND ANALYSIS PLAN
FOR
LOWER SUBASE REMEDIAL INVESTIGATION

NAVAL SUBMARINE BASE, NEW LONDON
GROTON, CONNECTICUT

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Northern Division
Environmental Branch Code 18
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
Lester, Pennsylvania 19113-2090

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CONTRACT NUMBER N62472-90-D-1298
CONTRACT TASK ORDER 0260

SEPTEMBER 1997

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LCS	Laboratory Control Sample
MCL	Maximum Contaminant Level
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAD	North American Datum
NACIP	Navy Assessments and Control of Installation Pollutants
NAVFAC	Naval Facilities Engineering Command
NCP	National Contingency Plan
NEESA	Naval Energy and Environmental Support Activity
NESO	Naval Environmental Support Office
NIST	National Institute of Standards & Technology
NLDS	New London Disposal Site
NSB-NLON	Naval Submarine Base - New London
OVA	Organic Vapor Analyzer
PAH	Polynuclear Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Comparability and Completeness
PCB	Polychlorinated Biphenyl
PID	Photo Ionization Detector
PPT	Parts Per Thousand
POC	Point of Contact
PQL	Practical Quantitation Limit
PVC	Polyvinyl Chloride
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
%R	Percent Recovery
RAB	Restoration Advisory Board
RCRA	Resource Conservation and Recovery Act
REDOX	Oxidation/Reduction
RME	Reasonable Maximum Exposure
RI	Remedial Investigation
RPD	Relative Percent Difference
RPM	Remediation Project Manager
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service

SOP	Standard Operating Procedure
SOW	Statement of Work
SSO	Site Safety Officer
SVOC	Semivolatile Organic Compounds
TAL	Target Analyte List
TCL	Target Compound List
TPH	Total Petroleum Hydrocarbons
TOC	Total Organic Carbon
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
WP	Work Plan

1.0 INTRODUCTION

Brown & Root Environmental (B&R Environmental) has prepared this Work Plan and Sampling and Analysis Plan (SAP) for the Lower Subase Remedial Investigation (RI) at the Naval Submarine Base New London (NSB-NLON), Groton, Connecticut. These planning documents were prepared by B&R Environmental, a Division of Halliburton NUS (HNUS) Corporation, for the U.S. Department of the Navy (Navy) Northern Division (NORTHDIV) under Contract Task Order (CTO) 0260, for the Comprehensive Long-Term Environmental Action Navy (CLEAN) contract number N62472-90-D-1298.

These planning documents are an outgrowth of the March 1997 Existing Data Summary Report completed for this project. The Work Plan is designed to define the technical and management approach for the project. The Work Plan includes a discussion of objectives, scope, background information, rationale, project management techniques, community relations planning, and project schedule. The SAP is designed to provide direction for field and laboratory staff to ensure that specific procedures are properly implemented in a safe and scientifically defensible manner. The Work Plan and SAP are designed to provide a logical rationale for the RI approach based upon known regional and site-specific background information.

The Work Plan is presented in a modified United States Environmental Protection Agency (USEPA) Remedial Investigations and Feasibility Studies (RI/FS) under Comprehensive Environmental Response and Liability Act (CERCLA) Work Plan format (USEPA, 1988). The Work Plan is also consistent with the Handbook to Support the Installation Restoration Program (IRP) Statement of Work, Volume I - Remedial Investigation Studies (RI/FS) (DOD, 1991). This Work Plan consists of ten subsections which include this Introduction; Background, Objectives and Scope; Site Description; Zone Description; Project Rationale and Data Quality Objectives; Risk Assessment, Project Management and Organization; Deliverables and Data Management; and, Project Schedule. The SAP, Section 2.0, consists of nine subsections; Section 3, Sample Handling Procedures, has five subsections. The appendices include the following: Field Forms (Appendix A); Standard Operating Procedures (Appendix B); Quality Assurance Project Plan (Appendix C); and Health & Safety Plan (Appendix D).

1.1 BACKGROUND, OBJECTIVES, AND SCOPE

On August 28, 1991, NSB-NLON was placed on the National Priorities List (NPL) by the USEPA pursuant to CERCLA and the Superfund Amendments and Reauthorization Act (SARA) of 1986. The NPL is a list of uncontrolled or abandoned hazardous waste sites identified by USEPA requiring priority remedial actions.

In January 1995, the Navy, USEPA, and the State of Connecticut signed the USEPA Federal Facilities Agreement (FFA) for NSB-NLON. The agreement will be used to ensure that environmental impacts associated with past and present activities at NSB-NLON are thoroughly investigated and that the appropriate remedial actions are pursued to protect health and the environment. In addition, the FFA establishes a procedural framework and timetable for developing, implementing, and monitoring appropriate responses at NSB-NLON, in accordance with CERCLA (and SARA amendment of 1986), the National Contingency Plan (NCP), Resource Conservation and Recovery Act (RCRA) and Hazardous and Solid Waste Amendment (HSWA) of 1984, Executive Order 12580, and applicable state laws.

Two RIs have been completed at NSB-NLON that have included data collection and analysis at the Lower Subase and other areas of NSB-NLON. A Phase I RI was performed at the Lower Subase by Atlantic Environmental in 1992 and a Phase II RI was completed for this site by B&R Environmental in 1997. The findings of these RIs and other investigations conducted at the Lower Subase are summarized in the Existing Data Summary Report that was prepared and submitted by B&R Environmental on behalf of the Navy in March 1997.

The Existing Data Summary Report summarizes the data collected from both previous and on-going investigations at the Lower Subase. It also includes a definition of the seven zones of the Lower Subase to be investigated and evaluated during this RI. Preparation of the Existing Data Summary Report was used as the basis for development of the scope of this RI. The purpose of project scoping is to analyze the existing data to establish the physical characteristics of the site, to determine the need for additional data, and to develop an approach to collect the data.

The objectives of this RI are based upon the summary and recommendations of the Existing Data Summary Report. These objectives are to characterize the subsurface conditions at the Lower Subase, further characterize the quality of the sediment in the Thames River adjacent to the site, and provide data pertinent to identifying site-specific remedial alternatives. The data collected during this RI and data collected from previous investigations will be used for the following purposes:

- To identify the sources of soil and groundwater contamination;
- Define the major contaminant pathways;
- Define the nature and extent of contamination within the groundwater and soils at seven previously defined zones within the Lower Subase;
- To define the nature and extent of contamination in the sediments at adjacent areas of the Thames River;

- Provide supplemental data to develop a revised human health risk assessment;
- Provide supplemental data to develop a revised ecological risk assessment for the Thames River;
- Identify remedial alternatives.

The scope of this project will include the installation of soil borings, temporary and permanent groundwater monitoring wells; the collection and analysis of soil, groundwater and sediment samples to fill existing data gaps in the understanding of the nature and extent of contamination; reporting; and data/project management. In addition, water quality parameters (i.e., pH, dissolved oxygen, specific conductance, salinity, turbidity, and temperature) will be measured in the surface water at each sediment sampling location to provide correlation with sediment sample information. The results of this RI will be used to identify remedial alternatives that are pertinent to each zone within the Lower Subase. Both historical data and data collected during this RI are critical for the identification and development of remedial alternatives.

This RI will also include collection of data that will provide pertinent background information to evaluate the potential for natural attenuation or bioremediation as possible remedial actions. The groundwater data that will be collected to evaluate these potential remedial alternatives include total organic carbon (TOC), dissolved oxygen, salinity, oxidation-reduction (REDOX) potential, pH, alkalinity, hardness, divalent iron, chloride, nitrate, sulfate, phosphate, ammonia, and methane.

In addition to the sampling effort for the RI, sampling will also be conducted in the Thames River adjacent to the DRMO at the outfall of Stream 5 to support the Remedial Design for the Area A Downstream. The sampling will be completed at the same time as the Thames River sampling program for the RI. However, this supplemental sampling effort is discussed only in Appendix E because it is not related to the Lower Subase RI.

1.2 DESCRIPTION OF SITE CONDITIONS

NSB-NLON is located in southeastern Connecticut in the Towns of Ledyard and Groton. Figure 1-1 illustrates the location of NSB-NLON. NSB-NLON is situated on the east bank of the Thames River, approximately 6 miles north of Long Island Sound. It is bounded to the east by Connecticut Route 12, to the south by Crystal Lake Road, and to the west by the Thames River. The northern border is a low ridge that trends approximately east-southeast from the Thames River to Baldwin Hill.

Lower Subase is a subsection of NSB-NLON that includes piers and berths for submarine docking, as well as facilities for the submarine maintenance, repair, and overhaul. The site is a secure, access restricted portion of NSB-NLON. The Lower Subase is bounded on the west by the Thames River and on the east

by the Providence and Worcester Railroad tracks. A quay wall runs along the Thames River for a majority of the site.

For the purposes of this RI, the site extends to and includes Pier 2 to the south and Pier 33 to the north as shown on Figure 1-1. Building 175, located just north of Pier 33, is included within the investigation area of the RI.

As shown in Figure 1-2, the study area has been divided into seven zones. A detailed discussion of site conditions within each of the seven zones is presented in the Existing Data Summary Report (B&R Environmental, 1997). The following subsections of the Work Plan present a brief summary and overview of the site conditions at each of the seven zones and the Thames River.

The Lower Subase contains buildings, buried utilities, fuel distribution pipelines and roadways. The buried utilities present include water, sanitary sewer, storm sewer, electric, and steam and condensate ducts. The fuel distribution system is present in the southern areas of the Lower Subase (Zones 1, 2, 3 and 4) (Figure 1-2). The fuel distribution system is contained within concrete tunnels and often parallels the concrete-lined utility trenches. The fuel distribution system is suspected to be one of the major sources of total petroleum hydrocarbon (TPH) contamination within the Lower Subase.

Areas of the Lower Subase near the quay wall are constructed on a wooden pile and joist network (Halliburton NUS, 1995). The wooden piles and joists support horizontally placed wooden planks that are present six to seven feet below the ground surface. Voids are present beneath the wooden planks and the natural deposits that the piles are driven into. Above the wooden planks is sand and gravel fill that is present from six feet below surface to one foot below surface. The surface is covered with a concrete pad and asphalt.

1.2.1 Topography and Surface Features

Ground surface across the Lower Subase slopes gradually to the west toward the piers and the Thames River. The ground elevation ranges from approximately 22 feet above mean sea level (msl) along the eastern edge of the Lower Subase to 8 feet above msl along the piers. There is a high density of buildings at the Lower Subase. Except for a few isolated grassy areas, the Lower Subase is completely paved or covered with buildings, which promotes surface water runoff. Numerous catch basins and storm sewers collect runoff from around the buildings and convey it to the Thames River. Based on the topography of the site, runoff not collected by the storm sewers will also ultimately reach the Thames River.

1.2.2 Soil Characteristics

The Soil Conservation Service (SCS) soils map classifies the soil at the Lower Subase as Udorthents-Urban Land (in the northern portion of the Lower Subase) or as Urban Land. Udorthents-Urban Land consists of excessively drained to moderately well drained soils that have been disturbed by cutting and filling along with areas that are covered by buildings or pavement. About 60 percent of the complex is Udorthents, 25 percent is Urban Land, and 15 percent is other soils. Urban Land is defined by areas where more than 85 percent of the surface is covered by streets, parking lots, and buildings. Most of the underlying soils have been altered by excavating or have been covered with fill material (Atlantic, 1995).

1.2.3 Geology

In general, the Lower Subase is underlain by fill material that ranges in thickness from 5 feet on the east edge of the Lower Subase to at least 20 feet in the western portion of the Lower Subase. The fill material primarily consists of sand and gravel; however, wood, flyash, brick fragments, and concrete fragments have been detected in several locations. A silty layer underlies the sand and gravel fill along the western portion of the Lower Subase near the Thames River. In some cases, this silty layer contains sand and in other cases it contains clay. This layer also contains shell and wood fragments and is mapped as stratified drift of former glacial meltwater stream deposits. A medium, coarse sand layer underlies the sand and gravel fill in the central and eastern portions of the Lower Subase. Underneath Building 31, there was a very significant quantity (up to 30 percent by volume) of cobbles (up to 3-inch in diameter) mixed in with the sand and silt.

Most of the soil borings completed in the Lower Subase did not exceed 30 feet and many were 20 feet in depth or less. Therefore, the bottom of the silt and sand layer was not always encountered. However, borings at Zone 5 extended to deeper depths. According to geologic information obtained during investigations at Zone 5, the sand and silt layers are underlain by approximately 10 feet of gravel which overlies bedrock (Atlantic, 1995).

Boring log information confirms information provided on United States Geological Survey (USGS) surficial geology maps. According to the maps, most of the Lower Subase is artificial fill, with stratified drift shown as a terrace deposit of the Thames River mapped in the northern and eastern part of the Lower Subase. USGS bedrock geology maps indicate that bedrock at the Lower Subase is the Mamacoke Formation south of Berth 16. North of Berth 16, the maps indicate bedrock is Alaskite gneiss or Granite gneiss. Bedrock is mapped as Pre-Pennsylvania age rock which consists of igneous intrusives that have been metamorphosed to granitic gneisses.

1.2.4 Hydrogeology

At the Lower Subase, the groundwater table is within the unconsolidated overburden (fill material and underlying glacial drift deposits) at approximate depths of between 4 and 10 feet below the ground surface. The shallowest depths to groundwater occur near the Thames River. Fluctuations in the groundwater table closely correspond to the measured tidal variations in the Thames River of 2.2 feet.

During low tide conditions, shallow groundwater flow is towards the west to the river throughout the Lower Subase. During high tide, localized flow gradient reversals occur, with surface water from the river recharging groundwater. Tidal studies performed as part of Action Memorandum for Building 31 (HNUS, 1993) within the Lower Subase indicate that the reversal of flow gradient does not extend more than about 300 feet inland from the river. Overall, the daily groundwater discharge rate into the Thames River exceeds the recharge rate from the river to the aquifer.

An average hydraulic conductivity of 59 feet per day was calculated for the aquifer located within the shallow fill materials of the Lower Subase, with measured hydraulic conductivities (by slug test) ranging from 1.7 feet per day to 576 feet per day (B&R Environmental, 1996). An average hydraulic gradient of 0.0053 was calculated using groundwater and surface water measurements. No data exists for the hydraulic characteristics of the stratified drift deposits underlying the fill material. However, based on lithology from boring logs the glacial drift deposits are likely to be hydraulically connected to the fill material.

The bedrock at the Lower Subase consists of fractured metamorphic rock. In the bedrock aquifer, groundwater movement is along joint planes rather than through intergranular openings. Well records indicate that bedrock wells in the vicinity yield from between 1 to 65 gallons per minute (gpm). Potential well yields in bedrock wells are dependent on the degree of fracturing, topography and type and thickness of overburden. In general, the greatest well yields occur in valleys where bedrock is highly fractured and overlain by over 50 feet of stratified drift (Atlantic, 1995).

1.2.5 Climatology

NSB-NLON is located in an area that has a variable climate which is influenced by both continental and maritime air masses and by the region's proximity to the Atlantic Ocean. The region lies in the path of prevailing westerly winds and cyclonic disturbances that cross the country from the west or southwest toward the east and northeast. In the summer, prevailing winds are southwesterly while in the winter are northwesterly. The average wind speed is around ten miles per hour. The region is exposed to

occasional storms that travel up the Atlantic coast. Storms in the region are laden with moisture from the ocean; in addition, some storms are tropical and occasional storms are of hurricane intensity.

The average annual temperature for New London, Connecticut is approximately 50°F. Average monthly temperatures vary from 58 to 72°F in July and August, and from 23 to 30°F in January and February.

Precipitation averages approximately 44 inches per year, as measured at New London over an 81-year interval. Precipitation amounts range from 32 to 65 inches per year. Typically, the greatest amount of precipitation occurs in the months of March and August; the least amount occurs in June and September. Evaporation averages approximately 23 inches per year (NSB-NLON Master Plan, 1988).

1.2.6 Ecological Habitat

The Lower Subase is located in a highly industrialized portion of NSB-NLON and is characterized by large industrial buildings, a substantial amount of paved area, and very little maintained lawn. The area is characterized by heavy human activity and does not provide suitable habitat for wildlife. The only potential ecological habitat near the Lower Subase is the Thames River (described in Section 1.3.8) which represents the Lower Subase's western border. This portion of the Thames River is dominated by piers and serves as a docking and repair facility for submarines. Based on previous investigations, activities at the Lower Subase may have potentially impacted the Thames River sediments.

1.3 DESCRIPTION OF ZONES OF INVESTIGATION

1.3.1 Zone 1

Zone 1 extends from Darter Road (just south of Building 89) to the south side of Corvina Road. Environmental investigations have been performed at two sites with this zone and one site adjacent to this zone (Figure 1-2). Site 10 - Fuel Storage Tanks and Tank 54-H, and Site 11 - Power Plant Oil Tanks are located within Zone 1. The Building 89 UST site is located directly adjacent to Zone 1 and is considered as a Zone 1 site for purposes of this planning document even though technically it falls outside of the zone boundary. Fuel oil distribution lines and steam, condensate, and electrical ducts are also located within Zone 1. Figure 1-3 shows the sites included in Zone 1 and the limits of the zone. A summary of existing data for Zone 1, including investigation history, hydrogeology, and geology information, is included in Table 1-1.

Zone 1 is primarily paved or covered with buildings and the terrain slopes gently toward the Thames River. The Providence and Worcester Railroad runs along the eastern boarder of the zone. Zone 1 is located

along the Thames River. No other significant surface water features are located within or adjacent to Zone 1 with the exception of local storm sewers.

The SCS soils map classifies the soil within Zone 1 as Urban Land. The USGS surficial geology map indicates that Zone 1 soil is artificial fill. Based on logs for borings installed during the Phase I and Phase II RIs, Zone 1 soil consists of 15 to 20 feet of sand and gravel with thin layers (up to 5 feet) of sand and silt. The sand and gravel is underlain by at least 1 to 10 feet of sand and silt. The thickness of this layer is not known as borings were not installed to the bottom of the layer. Bedrock in Zone 1 is mapped as the Mamacoke Formation on USGS bedrock maps. The depth to groundwater is approximately 10 feet. Groundwater generally flows west toward the Thames River and is tidally influenced with fluctuations of 2 to 3 feet.

1.3.2 Zone 2

Zone 2 extends from the southern boundary of Zone 1 to Capelin Road (just north of Building 31) (Figure 1-2). With the exception of portions of the fuel oil distribution line and the steam, condensate, and electrical ducts which run through this zone, no sites have been identified within Zone 2. The site map, which shows the limits of the zone, is provided as Figure 1-4. A summary of existing data for Zone 2, including investigation history, hydrogeology, and geology information, is included in Table 1-2.

Zone 2 is paved or covered with buildings and the terrain gently slopes toward the Thames River. The Providence and Worcester Railroad runs along the eastern border of the zone. Zone 2 is located along the Thames River. No other significant surface water features are located within or adjacent to Zone 2 with the exception of local storm sewers.

The SCS soils map classifies the soil at Zone 2 as Urban Land. USGS surficial geology maps indicate that Zone 2 soil is artificial fill. Based on boring logs for borings installed during the Phase I and Phase II RIs, the east side of Zone 2 consists of 10 to 15 feet of sand and gravel, underlain by 5 to 10 feet of fine to medium sand. The medium sand is underlain by 0 to 5 feet of sand and gravel. Along the west side (near the Thames River) the sand and gravel layer is approximately 15 to 20 feet and is underlain by 0 to 5 feet of sand and silt. The thickness of the bottom layer is not known as borings were not installed to the bottom of the layer.

Bedrock in Zone 2 is mapped as the Mamacoke Formation on USGS bedrock maps. The depth to groundwater ranges from 6 to almost 20 feet below ground surface and the elevation of groundwater ranges from 3 feet above mean sea level (msl) on the east side of Zone 2 to approximately 1 foot above

msl on the west side. Groundwater generally flows west toward the Thames River and is tidally influenced with fluctuations of 2 to 3 feet.

1.3.3 Zone 3

Zone 3 extends from the southern end of Zone 2 to the south side of Bullhead Road and includes Site 17 - Hazardous Materials/Solvent Storage Area (Building 31). Fuel oil distribution lines and steam, condensate, and electrical ducts are also located within Zone 3. Figure 1-5 shows the sites included in Zone 3 and the limits of the zone. A summary of existing data for Zone 3, including investigation history, hydrogeology, and geology information, is included in Table 1-3.

The ground surface in Zone 3 slopes gently to the west towards the Thames River. Zone 3 is primarily paved or covered with buildings. Zone 3 is located along the Thames River. No other significant surface water features are located within or adjacent to Zone 3 with the exception of local storm sewers.

The SCS soils map classifies the soil at Zone 3 as Urban Land. USGS surficial geology map indicates that Zone 3 soil is artificial fill. Based on boring logs for borings installed during the Phase I and Phase II RIs, along the east side, Zone 3 consists of 5 to 10 feet of sand and gravel, underlain by 3 to 7 feet of fine to medium sand and 0 to 5 feet of fine sand. The sand is underlain by approximately 8 feet of sand and gravel. Along the west side (near the Thames River) the sand and gravel layer is approximately 15 to 20 feet thick and is underlain by 3 to 10 feet of sand and silt. The thickness of the bottom layer is not known as borings were not installed to the bottom of the layer.

Bedrock in Zone 3 is mapped as Mamacoke Formation on USGS bedrock maps. This was not confirmed by soil borings. The depth to groundwater is approximately 6 to 10 feet below ground surface and the elevation of groundwater ranges from 3 feet msl on the east side of Zone 3 to approximately 1 foot msl on the west side. Groundwater generally flows west toward the Thames River and is tidally influenced with fluctuations of 2 to 3 feet.

1.3.4 Zone 4

Zone 4 extends from the south side of Bullhead Road to the southern boundary of the Lower Subase. Sites within this zone include Site 13 - Building 79 Waste Oil Pit, Site 19 - Solvent Storage Area (Building 316) and the quay wall. Utility trenches and fuel distribution lines run through this zone. The gate valve (Building 332) to the tank farms is also located in this zone. Figure 1-6 shows the sites included in Zone 4 and the limits of the zone. A summary of existing data for Zone 4, including investigation history, hydrogeology, and geology information, is included in Table 1-4.

Zone 4 is primarily paved or covered with buildings. The Providence and Worcester Railroad runs along the eastern border of the zone. The ground surface in Zone 4 slopes gently to the west toward the Thames River. Zone 4 is located along the Thames River. No other significant surface water features are located within or adjacent to Zone 4 with the exception of local storm sewers.

The SCS soils map classifies the soil at Zone 4 as Urban Land. The USGS surficial geology map indicates that Zone 4 soil is artificial fill. Based on boring logs for borings installed during the Phase I and Phase II RIs, on the east side, Zone 4 consists of 10 to 15 feet of sand and gravel (fill material) underlain by five to 10 feet of sand and silt (natural deposits). On the east side of the site the sand and silt layer was not encountered; however, a thin layer of fine to medium sand (3 to 5 feet thick) underlain by fine sand (3 to 5 feet thick) was encountered within approximately 10 feet below ground surface. The sand was underlain by sand and gravel. The thicknesses of the bottom layers are not known as borings were not advanced to the bottom of these layers.

Bedrock in Zone 4 is mapped as Mamacoke Formation on USGS bedrock maps. The depth to groundwater is approximately 5 to 8 feet. The elevation ranged from 3 feet msl on the east side to less than 1 foot msl on the west side. Groundwater generally flows west toward the Thames River and is tidally influenced with fluctuations of 2 to 3 feet.

1.3.5 Zone 5

Zone 5 consists of Site 22 which includes Pier 33, Building 175 and approximately 800 feet of additional property adjacent to these two structures. The Zone is located north of Zone 6 and south of the DRMO. The Thames River lies to the west and Penn Central Railroad to the east of Zone 5. Building 175 was originally used to house several above-ground battery acid (sulfuric acid) storage tanks. These storage tanks and the associated transfer piping have been removed. The building is currently used for miscellaneous storage. Steam and condensate ducts and fuel oil distribution lines do not extend as far north in the Lower Subase as Zone 5. Figure 1-7 shows the site included in Zone 5 and the limits of the zone. A summary of existing data for Zone 5, including investigation history, hydrogeology, and geology information, is included in Table 1-5.

Zone 5 is generally level and covered by either buildings or pavement. Surface elevation ranges from 20 feet msl on the east side of the site to 5 feet msl on the west side. Zone 5 is located directly adjacent to the Thames River. Pier 33 is located southwest of Building 175. Surface water runoff from Zone 5 drains into the river via storm sewers. Surface drainage from areas east of Zone 5 discharge to the

Thames River via a box culvert conveying Stream 6 from the Area A Downstream Site, midway between Buildings 175 and 176.

According to SCS information, Zone 5 is mapped as Udorthents - Urban Land, 0 to 15 percent slope. This complex consists of excessively drained to moderately well drained soils that have been disturbed by cutting and filling, along with areas that are covered by buildings or pavement. About 60 percent of the complex is Udorthents, 25 percent Urban land, and 15 percent is other soils. Urban land consists mainly of areas of developed or disturbed land.

According to USGS surficial geology maps, the site is mapped as artificial fill, which was confirmed by geotechnical data collected at Zone 5 (Atlantic, 1995). Investigations indicate that Zone 5 is underlain by fill consisting of sand or sand and gravel. Fill extends to bedrock and ranges from 5 feet thick in the eastern portion of the site to 20 feet thick at the edge of the quay wall. USGS bedrock geology maps indicate bedrock at Zone 5 as Alaskite gneiss to the north and Granite gneiss to the south.

Groundwater is found in the overburden at a depth of approximately 4 feet below ground surface. The bedrock aquifer was not investigated at the site. The groundwater flow direction at the site was determined to be to the west, toward the Thames River.

1.3.6 Zone 6

Zone 6 consists of Building 174 which is identified as Site 24 - Central Paint Accumulation Area. The building was refitted in 1982 to house boat sandblasting and paint activities. The building has also been used as the primary paint storage facility for all paints used in boat maintenance. Steam and condensate ducts and fuel oil distribution lines do not extend into Zone 6. Figure 1-8 shows the site included in Zone 6 and the limits of the zone. As can be seen in Table 1-6, the Existing Data Summary table, very limited information is known about Zone 6 because there have been no previous soil or groundwater investigations at the zone. Therefore, the table generally summarizes the data gaps for Zone 6.

Zone 6 is primarily paved or covered with buildings. Zone 6 (i.e., Building 174) is located along the Thames River east of Pier 32. The Providence and Worcester Railroad runs along the eastern border of the zone. Surface water runoff at the site drains into the river via storm sewers.

According to SCS surface soil maps, Zone 6 is mapped as Udorthents - Urban Land, 0 to 15 percent slope. This complex consists of excessively drained to moderately well drained soils that have been disturbed by cutting and filling, along with areas that are covered by buildings and pavement. About 60

percent of the complex is Udorthents, 25 percent Urban land, and 15 percent is other soils. Urban land consists mainly of areas of developed or disturbed land.

According to USGS surficial geology maps, the site is mapped as stratified drift shown as terrace deposits of the Thames River. USGS bedrock geology maps indicate bedrock at Zone 6 is Granite gneiss to the north and Alaskite gneiss to the south.

1.3.7 Zone 7

Zone 7 extends from just north of Building 478 to the southern side of Dorado Road and includes Site 21 - Berth 16, Site 25 - Classified Materials Incinerator, and Transformers at Building 157 Vault 31. Fuel oil distribution lines and steam, condensate, and electrical ducts are also located within Zone 7. Berth 16 formerly included an underground, 250-gallon, diesel fuel storage tank that was located adjacent to the northern wall of Building 157. The storage tank was connected to the diesel-fuel transfer lines. Figure 1-9 shows the sites included in Zone 7 and the limits of the zone. A summary of existing data for Zone 7, including investigation history, hydrogeology and geology information, is included in Table 1-7.

The topography of Zone 1 is generally level with a gradual slope to the west. The zone is generally covered either by buildings or pavement. The zone is located adjacent to the Thames River on the west and the Providence and Worcester Railroad on the east. Surface water from the zone drains directly into the river via an extensive storm sewer system. The catch basins and storm sewers are shown on Figure 1-9.

According to SCS information, Zone 7 is mapped as Urban Land. This group consists of land where more than 85 percent of the surface is covered by streets, parking lots, buildings, and other structures. Most of the underlying soils have been altered by excavating or have been covered with fill material.

According to USGS surficial geology maps, the site is located along a contact between stratified drift and artificial fill. The stratified drift is shown as terrace deposits of the Thames River. USGS bedrock geology maps indicate bedrock at Zone 7 as Alaskite gneiss to the north and Mamacoke Formation to the south.

Geotechnical data collected at Zone 7 confirm the surficial geology and bedrock determinations of the USGS. Investigations indicate that the site is underlain by fill material consisting of sand and sand and gravel with pockets of debris overlying gravel. Bedrock is below the fill material at approximately 50 feet below ground surface. Groundwater at the site flows to the west toward the Thames River and is tidally influenced, with fluctuations of 2 to 3 feet.

1.3.8 Thames River

The Thames River is a tidal estuary formed at the confluence of the Shetucket and Yantic Rivers in Norwich, Connecticut. The river flows south approximately 16 miles to Long Island Sound. NSB-NLON and the town of Groton are on the east bank of the river approximately 6 miles north of Long Island Sound. The City of New London is located on the west bank of the river. Land development along the southern portion of the river is primarily industrial. Chemical companies, oil terminals, power plants, and waste water treatment plants occupy both banks of the river.

Petroleum compounds have been visible on the water surface along the shoreline of the Lower Subase on several occasions. Although no evidence of severe impacts to the river biota has been reported, the Thames River has likely been impacted by activities and contamination at the Lower Subase.

NSB-NLON borders the Thames River for approximately 1.5 miles (Figure 1-10). The NSB-NLON facility is highly developed along the Thames River in the vicinity of the Lower Subase. There are 15 piers at NSB-NLON. The ground elevation along these piers and at the facility boundary is less than 10 feet. The 100-year flood level for NSB-NLON is 11.2 feet above msl. This elevation is higher than most of the western portion of NSB-NLON; therefore, this area is susceptible to flooding.

Adjacent to the northern boundary of NSB-NLON, the land is relatively undeveloped with scattered residences. Further north, the land is residential, commercial, recreational, and open-space. To the immediate south of NSB-NLON along the Thames River, the land is primarily residential with open spaces. Along the Thames River, tributary streams and wetlands are prevalent. Other high profile industries along the Thames River include General Dynamics' Electric Boat Division (south of NSB-NLON on east shore), Pfizer Chemical Company (south of NSB-NLON on east shore) and Dow Chemical Company (north of NSB-NLON on east shore).

The Thames River and its tributaries drain approximately 1,500 square miles of eastern Connecticut, western Rhode Island, and south central Massachusetts. The Thames River originates at the City of Norwich Harbor, at the confluence of the Shetucket and Yantic Rivers, and discharges into Long Island Sound approximately 6 miles south of NSB-NLON and the town of Groton. The total length of the Thames River is 16 miles. The Yantic River has a drainage basin of 88 square miles. Average, minimum, and maximum flows in the Yantic have been reported at 170, 3.5, and 13,400 cubic feet per second (ft^3/s), respectively. The Shetucket, which has a 1,390-square-mile drainage basin, has reported average, minimum, and maximum flows of 2,000, 14, and 52,300 ft^3/s, respectively. Other sources of inflow to the

Thames River are reportedly minor in comparison to these flows and to the volume of tidal exchange. Other sources of inflow include wastewater treatment facilities in Norwich, Montville, New London, the City of Groton, and the Town of Groton, combined sewer overflows in Norwich, industrial discharges, and several small streams. Both surface water and groundwater from NSB-NLON discharge to the Thames River.

Widths of the river vary from 1.5 miles at New London Harbor to approximately 500 feet at Norwich Harbor. A dredged channel runs north to south in the river. Depths in the dredged channel are approximately 40 feet below msl. At NSB-NLON, the width of the river ranges from approximately 1,300 to 3,000 feet, while the width of the dredged channel ranges from 600 to 900 feet (see Figure 1-10). Outside of the channel (near the west shore of the river), river depths are relatively shallow (2 to 10 feet). Upstream of the NSB-NLON there are shallow coves that empty into the river. Most of the coves are at least partially cut off from the river by a rail bed.

The Thames River is a salt wedge estuary that is highly stratified with fresher water on the surface and denser saline water on the bottom. At the NSB-NLON, the measured tidal range is about 2.2 feet. Estimated freshwater flushing time is 0.5 to 2 days from Norwich to Long Island Sound. In comparison, estimated flushing time for bottom water is greater than 19 days. The average freshwater flow discharging to the Sound from the Thames River has been estimated at 222 million cubic feet per day. However, stream-flow in the river is small in comparison to intertidal volume and exchange. Very little vertical mixing occurs in the Thames River. The north-south alignment, steep banks, and narrow channel do not permit much wind induced mixing. Therefore, the freshwater outflows reach Long Island Sound in a well defined surface layer.

Studies of the Thames River indicate that net flow in the upper layer of water is downstream at velocities of 0.06 to 0.3 feet per second. The current velocities in this area vary according to tide and freshwater flow from upstream. Velocities of up to 1.6 feet per second have been measured in the river during periods of storm runoff during flood tide. The velocity of the lower layer is dominated by the tide and is reportedly relatively insensitive to stream flow rates. The lower layer of water has a net up-estuary flow at velocities of 0.03 to 0.2 feet per second during flood tide.

As stated above, the Thames River estuary is stratified with relatively fresh water on the surface and saline water on the bottom. Historical records show that the salinity in the water at the bottom of the river is relatively constant at 30 parts per thousand (ppt). Salinity measurements taken in the Thames River adjacent to NSB-NLON in May of 1995 for the Supplemental Ecological Investigation (B&R Environmental, 1996) confirmed the constant 30 ppt salinity level. Measurements taken near the bottom in the channel of

the Thames River ranged from 29.4 to 30 ppt. The salinity of the water at the surface of the river is more variable, with the salinity ranging from 28 ppt at the mouth of the river to 2 ppt at the upstream end of the estuary at Norwich.

1.4 PROJECT RATIONALE

In this section, the goals of the RI and a justification of the approach to the sampling program are presented. A systematic methodology for determining the data needs, including the number and location of environmental samples collected using the Data Quality Objectives (DQO) process is provided.

1.4.1 Data Quality Objectives

The Data Quality Objectives (DQO) process will be implemented for this investigation. DQOs are a systematic procedure, based on the Scientific Method, used to define the criteria by which data collection activities are performed (EPA, 1994). The goal of using the DQO process is to make best use of limited measures by collecting data of sufficient quality and quantity to support defensible decision making while eliminating unnecessary, duplicate or overly precise data. The most efficient way to accomplish these goals is to establish criteria for defensible decision making before the study begins and then develop a data collection design based on these criteria.

The DQO process should be used during the planning stages of all studies that require data collection, before the data are collected. The DQO process applies to all studies, however, the depth and detail of the process will vary with the complexity of the particular study. In addition, the DQO process is a flexible planning tool. For projects where the likelihood of making decision errors is small, where decision errors are not critical, or where prescriptive procedures/remedies are mandated, the DQO process can be used less intensively. For example, on many small projects involving presumptive procedures or remedies, it is often not necessary to determine quantitative limits on decision errors to optimize the investigative or remedial design. Also, the DQO process is naturally less stringent on those projects where little information is known about a site and the objective is to determine whether or not gross levels of contamination exist.

The complete DQO process consists of seven steps. A detailed description of the DQO process is beyond the scope of this document; however, the USEPA guidance previously cited (EPA, 1994) should be reviewed. A brief description of each step in the DQO process follows:

Step 1: State the Problem - Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.

Step 2: Identify the Decision - Identify what questions the study will attempt to resolve, and what actions may result.

Step 3: Identify the Inputs to the Decision - Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

Step 4: Define the Study Boundary - Specify the time periods and spatial area to which decisions will apply. Determine when and where data should be collected.

Step 5: Develop a Decision Rule - Define the statistical parameters of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.

Step 6: Specify Tolerable Limits on Decision Errors - Define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.

Step 7: Optimize the Design for Obtaining Data - Evaluate information from the previous steps and generate alternative data collection design. Choose the most resource-effective design that meets all DQOs.

The above steps are generally related in a downward decision flow, however, during development of the DQOs, the answers to subsequent questions may require a review of the previous step(s). In addition, the DQO steps must be reviewed during the data collection activities in order to allow for changes to the proposed plan that can better optimize the design. Therefore, the DQO process is an iterative procedure that requires dynamic work plans and input from the decision makers to qualify all decisions made before and during the design and implementation of the data collection activities.

Several operational processes have been identified to aid and assist in the DQO process. These processes are to be implemented during this investigation and are as follows:

1.4.1.1 General DQOs for the Site RI

The overall objective of this RI is to efficiently complete the characterization of the Lower Subase and adjacent Thames River by providing information as to the nature and extent of contamination in the soils and shallow groundwater table regime of the seven on-shore zones of investigation, and the sediments of

the adjacent Thames River. The information obtained during this investigation will be compiled with existing data to evaluate environmental risks to human health and the environment and to formulate an approach for reasonable remedial activities.

It is imperative that DQOs be established and used during this RI to determine the limits and extent of the investigation and data evaluation. This information will be provided in response to each of the seven steps in the DQO process in a general manner.

Statement of Problem - There are six general problems that have been identified during previous investigations for this RI to address and they are as follows:

- The Lower Subase contains widespread petroleum contamination in soils and groundwater and the source(s) and extent are locally insufficiently characterized.

- The Lower Subase contains metals contamination (primarily lead) in soils and groundwater and the extent is locally insufficiently characterized. In addition, the potential mobility of the metals (primarily lead) is not fully characterized.

- The Lower Subase potentially contains semi-volatile organic compound (SVOC) contamination in soils, groundwater, and sediments, which may be related to the petroleum contamination or fill material. The nature and extent of this contamination is insufficiently characterized.

- Insufficient data is presently available to evaluate the risk to human health within Zones 5, 6 and 7.

- Insufficient data is presently available to evaluate the risk to ecological receptors in the Thames River adjacent to all seven zones.

- There is insufficient historical data regarding the feasibility of natural attenuation or bioremediation as viable remedial alternatives.

Widespread petroleum contamination has been detected in the soils within the Lower Subase. Inorganic contamination, particularly lead, was also detected in soils within the Lower Subase. The soil contamination has had detectable impacts on groundwater quality. There is the potential that contamination, which may be due to historic or current operations, may have impacted the Thames River.

Data gaps in the historic site database regarding semi-volatile organic compound (SVOC) data in soils and groundwater has also been identified as a potential problem based upon historic site activities. Additional SVOC data from soil, groundwater, and sediment media are required to access the possible presence, nature and extent of these compounds and the related potential human health and ecological risks for the seven zones and adjacent areas of the Thames River.

Because of the industrial nature of the Lower Subase, the widespread petroleum contamination, and the results of the previous Phase II RI human health and ecological risk assessments, limited remedial actions in the Lower Subase may be necessary to ensure the protection of human health and the environment from contamination detected at the Lower Subase. For all zones, activities are necessary to determine sources of contamination and ensure that these sources are no longer present or that contamination from the sources cannot migrate or come into contact with potential receptors. In addition, highly contaminated soils, which may act as a secondary source of contamination, need to be identified and remediated.

Potential contaminant sources are located throughout the Lower Subase and include USTs, leaking fuel distribution pipelines (abandoned and active), a former incinerator, contaminated fill material and previous spills or releases of hazardous waste. Utility ducts, trenches and storm sewers located throughout the Lower Subase may also act as preferential flow pathways for subsurface contamination.

Identify the Decision - The purpose of this step in the DQO process is to determine what actions will resolve the problem. These actions are as follows:

- Determine the nature and extent of petroleum, SVOC, pesticides (one Thames River sediment sampling location only) and metals contamination at the Lower Subase and in the adjacent sediments of the Thames River.

  Yes: Document nature and extent of contamination in the Lower Subase RI Report and continue on with the IRP process.

  No: Conduct further investigations to fully define the nature and extent of contamination.

- Determine if any additional primary (leaking USTs, fuel distribution pipelines, etc.) or secondary sources (highly contaminated soils from previous releases) exist and are acting as on-going sources of contamination within the Lower Subase.

Yes: Identify the source areas with sufficient accuracy to support corrective action of any primary sources and development of appropriate remedial alternatives for primary or secondary sources. Document information in the Lower Subase RI Report. If warranted, conduct further investigations to address any data gaps that were identified.

No: Document findings in the Lower Subase RI Report and continue on with the IRP process.

- Determine if contamination is migrating along the major historic contaminant pathways to exposure points where it can come in contact with potential receptors.

Yes: Identify the migration pathways with sufficient accuracy to support development of appropriate remedial alternatives. Document information in the Lower Subase RI Report. If warranted, conduct further investigations to address any data gaps that were identified.

No: Document findings in the Lower Subase RI Report and continue on with the IRP process.

- Collect a sufficient amount of data to adequately define the risks to human and ecological receptors associated with the newly defined Lower Subase zones (i.e., Zones 5, 6 and 7) and the adjacent areas of the Thames River.

Yes: Document the results of the human health and ecological risk assessments in the Lower Subase RI Report and continue on with the IRP process.

No: Perform additional sampling to address identified data gaps and revise the risk assessment.

- Collect a sufficient amount of data to adequately define the risks to human and ecological receptors associated with the original Lower Subase zones (i.e., Zones 1 through 4) and the adjacent areas of the Thames River.

Yes: Document the results of the human health and ecological risk assessments in the Lower Subase RI Report and continue on with the IRP process.

No: Perform additional sampling to address identified data gaps and revise the risk assessment.

- Determine if natural attenuation or bioremediation are feasible remedial alternatives for the remediation of contaminated areas within the Lower Subase?

Yes: Document the results of the investigation in the Lower Subase RI Report and further evaluate the alternatives during the Feasibility Study (FS) for the Lower Subase.

No: Document the results of the investigation in the Lower Subase RI Report and determine other remedial alternatives which are appropriate for the Lower Subase.

Identify inputs to the Decision - The purpose of this step in the DQO process is to determine what measurements are required to resolve the problem. These measurements are as follows:

- Perform a geostatistical analysis of the historical data to focus the subsurface investigation to areas where additional samples are statistically justified.

- Collect additional shallow and deep soil samples within focused areas defined by the geostatistical analysis of the historical data. Utilize hollow stem augering and/or direct push technology for collecting soil samples for TPH, TAL metals, SPLP metals, TCL SVOC, and TCL VOC analysis.

- Install additional shallow groundwater table monitoring wells within focused areas defined by the geostatistical analysis of the historical data. Utilize hollow stem auger techniques to install permanent groundwater monitoring wells and/or direct push techniques to install temporary groundwater monitoring wells for the collection of shallow groundwater samples. The groundwater samples will be analyzed for a combination of the following parameters: TPH, TAL metals (filtered and unfiltered), TCL SVOCs and TCL VOCs.

- Sample selected existing groundwater monitoring wells to examine variations in TPH, TAL metals and SVOC concentrations relative to the historical data.

- Collect sediment samples in the Thames River in areas adjacent to potential contaminant sources or pathways. Analyze these samples for TAL metals, TCL SVOCs, TCL Pesticides (one location adjacent to Zone 5 only) and other parameters (i.e., TOC, grain size, pH, Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM), and ammonia) to assess ecological risks. Measure water quality parameters in surface water.

- Collect natural attenuation indicator data at select existing and new groundwater monitoring well locations to determine the feasibility of this process as a reasonable remedial alternative.

Define the Study Boundary - Specify temporal and spatial limits to which decisions will apply.

Spatially, the study boundaries are the seven defined zones as shown in Figure 1-2 and the adjacent areas of the Thames River. Temporally, data collection activities will be performed after approval of this Work Plan. The data collection activities will be performed in two phases;

- Phase 1: Perform a site characterization at Zone 6 to identify the possible presence of contamination. Collect shallow and deep soil sample data in Zones 1 through 5 and 7. The shallow and deep soil sample locations will be defined by the geostatistical analysis of the historical data or will be located based upon the suspected presence of primary or secondary contaminant source areas. Install temporary and/or permanent shallow groundwater monitoring wells in focused areas of each of the seven zones as defined by the geostatistical analysis and test boring results.

- Phase 2: Collect groundwater samples and free-product thickness and water level measurements from new and existing monitoring wells. Collect sediment samples and surface water quality parameter measurements in the Thames River adjacent to suspected contaminant source areas or downgradient of potential contaminant pathways. Collect natural attenuation/bioremediation indicator parameters at identified contaminated areas to demonstrate the feasibility of pursuing these remedial alternative for this site. Conduct additional investigation at Zone 6 if Phase 1 data warrants further investigation.

Develop a Decision Rule - The purpose of this step is to determine how the data will be summarized and used to make a decision, what action levels will be used to make the decision and what decisions will be made after the review of the data.

- Based on the historical data and screening criteria for potential contaminants of concern, TPH, metals (particularly lead), and SVOCs are the primary contaminants of concern that this RI will focus on.

- If areas of TPH, metals or SVOC contamination are observed at levels that exceed previously defined screening criteria, and the areas are inadequately defined then additional samples will be collected to adequately define the source area(s). Additional sampling will be conducted either during Phase 2 of the investigation, or during the Feasibility Study (FS) or the Remedial Design (RD). The appropriate regulators (i.e., USEPA Region I and CTDEP) will be included in the decision making team that decides when additional sampling is necessary.

- Based on calculations included in Appendix E, additional soil sampling and analysis may be needed for Zones 3, 4, 6, and 7 after the current sampling program is completed. The additional sampling and analysis will be needed if the resulting data set is not adequate to calculate a representative average concentration for lead. The additional sampling will be completed as part of the Phase 2 investigation or a data gap investigation.

- The chemistry results of Thames River sediment samples may indicate potential risks to benthic invertebrates from sediment contaminants. If the Lower Subase is shown to be the source of elevated chemical concentrations in the Thames River sediment near the Lower Subase, additional ecological investigations may be conducted to more fully characterize potential risks. Several factors will be taken into account when determining if potential risks are high enough to warrant additional studies. These include, but are not limited to, magnitude of exceedances of guideline values (e.g., ER-Ms), bioavailability (e.g., AVS/SEM ratios), frequency of detection, location of exceedances, and whether elevated contaminants are capable of bioaccumulating.

  The sediment chemistry represents the first tier in the ecological risk assessment for the Thames River. If the factors listed above indicate significant potential risks, an additional tier of study will be performed. The results of previous studies have indicated that potential risks from Thames River sediment contaminants may be confined to shellfish. If the concentrations of contaminants that have the ability to bioaccumulate (e.g., lead, mercury, pesticides, PCBs, some PAHs) are significantly elevated and other factors, such as high frequencies of detection, are relevant, caged shellfish studies may be performed to determine whether these contaminants are bioaccumulating in Thames River shellfish. Sampling of water overlying the sediments may also be conducted to augment the shellfish study.

  It is also possible that the results of the sediment chemistry may indicate potential risks to benthic invertebrates other than shellfish. For example, the amount of SEM may exceed the AVS measured in sediments at several locations. In this case, sediment toxicity testing and/or benthic macroinvertebrate community analysis may be necessary to determine whether sediments are actually toxic. Additional sediment samples may also be necessary to fully define the nature and extent of potential sediment contamination. However, it should be noted that additional studies will be focused in nature and conducted only if the need is expressly indicated by the results of the first tier data. As mentioned above, a strong link between contaminants in Thames River sediments and contaminant sources in the Lower Subase must be established before additional ecological investigations will be considered.

- Geostatistically analyze the chemistry data between the Phase 1 and 2 investigations to ensure that nature and extent are sufficiently characterized.

Specify Tolerable limits on Decision Errors - The purpose of this step is to determine the possible range of the results obtained during data collection, determine the types of decision errors that could occur based upon erroneous results, determine the resulting consequences and determine acceptable probabilities for the decision errors.

The existing historical data base will be used to determine past data range values for six of the seven zones. Historical data are not available for Zone 6. Erroneous results may occur in Zone 6 as previous data are non existent. To minimize the potential for erroneous results, ten soil and five groundwater samples will be collected in an effort to adequately define the presence or absence of contamination at this zone.

Optimize the Design - The purpose of this step in the DQO process is to identify a resource-effective data collection design for generating data that are expected to satisfy the DQOs. The following table presents the optimized data collection design for the Phase 1 and 2 investigations:

Activity	Objective	Action
Phase 1		
Perform soil (shallow and deep) and groundwater investigation at Zone 6	Focus subsurface investigation and determine if potential or substantial sources of TPH, SVOC, VOC, or metals contamination are present.	If substantial sources of contamination are detected, collect additional soil and groundwater data during Phase 2 to adequately define the source(s) and pathway(s) of the contamination. If no substantial sources of contamination are detected, present results in RI report
Collect shallow and deep soil samples at Zones 1 through 5 and 7. Install and develop additional monitoring wells in Zones 3, 4, and 7 in preparation for Phase 2.	Fill data gaps, define the extent and source areas of TPH, metals, and SVOC contamination; provide sufficient data for a human health risk assessment at Zones 1 through 5 and 7.	If contamination is present at levels that are above previously defined criteria and the source areas are inadequately defined, then additional sampling is required to define the extent and identify the source areas. Additional sampling will be completed during the FS or the RD. If contamination is well characterized, no additional sampling is required.

Activity	Objective	Action
Perform geostatistical analysis on new and existing chemistry data for soils from Zones 1 through 5 and 7. Perform geostatistical analysis on new soil and groundwater chemistry data from Zone 6.	Determine if an adequate amount of data has been collected to characterize all zones. Define data gaps that will be filled during Phase 2.	If data gaps are identified, develop sampling plan for additional sampling and analysis during Phase 2. If no data gaps are identified, no additional sampling, beyond the existing scope of work, is required during Phase 2.
Phase 2		
Collect groundwater, free-product thickness and water level data from newly installed and existing monitoring wells	Fill data gaps, define the extent and source areas of TPH, metals, and SVOC contamination. Determine viability of natural attenuation.	If contamination is present at levels that are above previously defined criteria and the source areas are inadequately defined, then additional sampling is required to define the extent and identify the source areas. If contamination is well characterized, no additional sampling is required.
Collect sediment samples and surface water quality parameters in the Thames River.	Fill data gaps, define the extent and source areas of TPH, metals, and SVOC contamination; provide sufficient data for the ecological risk assessment for the Thames River adjacent to Zones 1 through 7.	If contamination is present at levels that are above previously defined criteria and the source areas are inadequately defined, then additional sampling and analysis are required to define the extent and identify the source areas. Additional sediment and surface water sampling and analysis may be necessary as well as shellfish cage studies. If contamination is not present or is well characterized, no additional sampling is required.
Perform additional soil and groundwater investigation at Zone 6 and additional soil investigations at Zones 1 through 5 and 7 (if necessary).	Complete characterization of contamination detected during Phase 1. Focus investigation on specific contaminants that pose a potential risk.	If contamination is present at levels that are above previously defined criteria and the source areas are inadequately defined, then additional sampling is required to define the extent and identify the source areas. If contamination is well characterized, no additional sampling is required.

1.4.2 Geostatistical Analysis of Historical Data

A geostatistical (kriging) analysis was performed on selected historical chemicals of concern (COC) data for six of the seven zones during the generation of the Existing Data Summary Report (B&R

Environmental, 1997). The purpose of the geostatistical analysis in the Existing Data Summary Report was to spatially define the COCs based upon the existing historical data. The geostatistical analysis was performed on TPH and lead in near surface soils (less than four to five feet below surface) and deep soils (greater than four or five feet below surface); TPH in the shallow groundwater table regime; and filtered and unfiltered lead in the shallow groundwater regime (Figures 1-11 through 1-17).

The geostatistical analysis performed during the Existing Data Summary Report formed the basis for the generation of data confidence limit maps for this RI (Figures 1-11 through 1-17). The data confidence mapping techniques were used as a scientific tool to assist in the delineation of areas where additional soil or groundwater data collection should be considered for this RI. These data confidence maps are used to show the confidence of a computer-predicted value that is located between known sample location values. Three levels of confidence are presented on the attached figures for this Work Plan:

- Greater than 95% (high data confidence);
- 68 to 95% (moderate to high data confidence); and
- less than 68% (low data confidence).

Areas of high or moderate to high confidence limits are regions where additional data collection is statistically unnecessary. Areas of low data confidence are regions where data collection may be statistically justified but must be weighed with other factors such as historic site use, potential for severe contamination, etc.

1.4.3 Sample Locations and Zone Specific Discussion

The Table 1-8 presents the number of additional samples per matrix and zone to be collected for this RI. The selection of these locations and matrix analysis are based on the geostatistical analysis discussed in Section 1.4.2 and knowledge of past operations and activities within each of the seven zones. Summaries of the problems for each zone, as discussed in past reports and based upon historical data, are presented below.

1.4.3.1 Zone 1

Metals and petroleum hydrocarbons are the major soil COCs. SVOC data are not available for soils. Metals concentrations are likely the result of contaminated fill. Lead, the most prevalent metal detected in soils at Zone 1, was not detected at concentrations exceeding the OSWER residential soil screening level but was detected in TCLP leachate at levels exceeding the CTDEP's Pollutant Mobility Criteria for GB classified groundwater. TPH contamination is widespread in subsurface soils of Zone 1 with the highest

concentrations in the vicinity of the tanks at Sites 10 and 11. Fuel pipeline leaks or ducts acting as preferential flow pathways may be the source of the elevated TPH concentrations along Albacore Road, near Corvina Road.

Metals and petroleum hydrocarbons were also detected in groundwater. While concentrations of metals in groundwater (mostly unfiltered samples) exceeded several of the state groundwater standards, groundwater is not used or expected to be used in the future as a drinking water source because of brackish conditions. Several metals were detected in groundwater at maximum concentrations exceeding Connecticut remediation standards for surface water protection.

The human health risk assessment for Zone 1 for the potential receptor groups (i.e., construction worker and future resident) that were evaluated did not identify any noncarcinogenic HIs greater than unity or incremental cancer risks greater than 1×10^{-6} (i.e., the lower limit of the USEPA target risk range). The ecological risk assessment for the Thames River identified PAHs and metals as the primary COCs.

1.4.3.2 Zone 2

The major soil COCs are metals and petroleum hydrocarbons. Several metals were detected at maximum concentrations above background. Lead in particular was detected at a maximum concentration of 404 mg/kg which is greater than the residential soil screening level (OSWER 400 mg/kg). Lead was the only metal to have concentrations in TCLP leachates exceeding state pollutant mobility criteria for GB classified groundwater. A specific point source for the inorganic contamination is not apparent. The presence of these chemicals is most likely associated with fill material that has been placed throughout the Lower Subase.

A hot spot area of TPH soils was identified around the fuel line along Albacore Road between Corvina and Cisco Roads. TPH concentrations were as high as 8210 mg/kg. The petroleum hydrocarbon contamination may be a result of fuel line leaks or activities within Zone 1.

As with soils, the major COCs in groundwater are metals and petroleum hydrocarbons. However, the metals concentrations in groundwater are generally lower than those reported for Zone 1. Antimony was the only chemical detected (in the filtered samples only) at a maximum concentration exceeding the Connecticut MCL. While other metals exceeded Connecticut remediation standards for groundwater protection, groundwater is not used or expected to be used in the future as a drinking water source because of brackish conditions. Arsenic and lead were detected at maximum concentrations exceeding the surface water protection criteria.

TPH was detected in groundwater in the vicinity of Building 18 and the utility trench (13MW6) and south of Building 20 (13MW11). Organic compound concentrations in groundwater were low (less than 3 µg/L).

Human health risks for the 3 potential receptor groups (i.e., full time employees, construction workers, and future residents) that were evaluated did not exceed USEPA acceptable limits (i.e., HIs <1; $1x10^{-4}$ > ICRs > $1x10^{-6}$). The ecological risk assessment for the Thames River identified PAHs and metals as the primary COCs.

1.4.3.3 Zone 3

The major soil COCs are metals (lead) and petroleum hydrocarbons. High lead concentrations may be a result of lead contamination associated with Building 31. Concentrations of lead detected in TCLP leachate exceeded both state and Federal criteria. Although soils under and adjacent to Building 31 have been removed, some soils in the vicinity of Building 31 may have elevated levels of lead. TPH was also detected in soil, with higher concentrations in soils along Bullhead Road between Argonaut and Albacore Roads and along Albacore Road from Capelin Road to past Bullhead Road. Sources of the petroleum contamination are likely pipeline leaks within Zones 3 and 4 and tank leaks within Zone 4.

Limited groundwater data is available for Zone 3; however, based on the data, contaminants have not migrated to groundwater (i.e., no detections of volatiles and TPH and low concentrations of lead in groundwater).

The human health risk assessment for Zone 3 for the potential receptor groups (i.e., construction workers and future residents) that were evaluated did not identify any noncarcinogenic HIs greater than unity or incremental cancer risks greater than 1×10^{-4} (i.e., the upper limit of the USEPA target risk range). The ecological risk assessment for the Thames River identified PAHs and metals as the primary COCs.

1.4.3.4 Zone 4

The major COCs are metals and petroleum hydrocarbons. Concentrations of most metals detected in Zone 4 soils exceeded background. Lead in particular was detected in TCLP samples at concentrations exceeding the Federal Toxicity Characteristic regulatory level. TPH was detected at a maximum concentration of 11,800 mg/kg and was detected in all soil samples collected within Zone 4. Two hot spot areas within Zone 4 and one area along the boundary of Zones 3 and 4 are evident. The hot spot area located at Argonaut Road and Bluefish Road and the area along the boundary of Zones 3 and 4 are

apparently from pipeline leaks. The other hot spot area, located on Albacore Road west of Building 79, is likely from the pit at Building 79. High concentrations of lead were also detected in the vicinity of Building 79.

TPH and lead concentrations in groundwater indicate that groundwater has been impacted by soil contamination. TPH was detected in groundwater at levels up to 5,400 µg/L. Organic and inorganic concentrations exceeded the Connecticut MCLs, remediation standards for groundwater protection, and surface water protection criteria.

The human health risk assessment for Zone 4 for the potential receptor groups (i.e., construction workers and future residents) that were evaluated did not identify any noncarcinogenic HIs greater than unity or incremental cancer risks greater than 1×10^{-4} (i.e., the upper limit of the USEPA target risk range). Lead concentrations were at levels which would be unacceptable for exposure to children. The ecological risk assessment for the Thames River identified PAHs and metals as the primary COCs.

1.4.3.5 Zone 5

Contamination originating from the tank on the south side of Building 175 is evident at Zone 5. This contamination may be from a tank leak or from spillage during tank filling. TPH and SVOCs are the major COCs detected in this area. Concentrations of lead detected in TCLP leachate exceeded the CTDEP's Pollutant Mobility Criteria for GB classified groundwater. Contaminated sediments collected from the storm sewers in this zone generally contained the highest concentrations of contaminants. Lead in particular was detected at concentrations as high as 85,600 mg/kg. Contamination in the storm sewers may be related to recent activities at the site.

Groundwater results indicated that the soil contamination has only had minor impacts on groundwater quality. Analytical groundwater data for Zone 5 were compared to state standards and there were no exceedances of state MCLs or groundwater remediation standards for either unfiltered or filtered groundwater. Only maximum concentrations of phenanthrene in unfiltered groundwater and arsenic in filtered groundwater exceeded the state's surface water protection criteria.

A human health risk assessment was not conducted for this zone. The ecological risk assessment for the Thames River identified PAHs and metals as the primary contaminants of concern.

1.4.3.6 Zone 6

Sampling and analysis have not been conducted within Zone 6; therefore, the nature and extent of contamination cannot be evaluated. In addition, historical information on Site 24 was not reviewed for evaluation of this zone. A background review, collection of historical information, interviews, and other activities are recommended for this zone to provide a site description. Potential COCs and contaminated media of concern need to be identified and a sampling plan developed based on this information. It is recommended that an initial sampling program focus on identifying the presence of contamination, and if contamination is identified, further sampling should be conducted to characterize the contamination. The need for additional remedial activities would be determined based on an evaluation of the initial sampling.

1.4.3.7 Zone 7

Two general areas of petroleum hydrocarbon contamination in soils were identified in Zone 7; southwest of Building 478 and north of Building 157. Inorganic compounds, particularly lead (up to 189,000 mg/kg), were also detected above background in soils at Zone 7. Concentrations of lead detected in TCLP leachate exceeded both state and Federal criteria. Sediment samples collected from the storm drains also contained elevated concentrations of TPH, SVOCs, and inorganic compounds. The exact source of these contaminants is not known. With the exception of lead in groundwater (117 µg/L), soils containing fuel-oil residues have only had minor impacts on groundwater quality.

No contaminants were detected at concentrations which exceeded state MCLs. Lead concentrations in unfiltered and filtered groundwater samples exceeded CTDEP remediation standards for groundwater. Metals and SVOCs exceeded the state's surface water protection criteria.

A human health risk assessment was not conducted for this zone. The ecological risk assessment for the Thames River identified PAHs and metals as the primary COCs.

1.4.3.8 Thames River

The activities and contamination at the Lower Subase may have impacted the Thames River. The main COCs are PAHs. While PAHs were detected in sediments upstream and downstream of NSB-NLON, the concentrations of PAHs increased slightly in the vicinity of Zones 5 and 7, and increased substantially in the vicinity of Zones 1 through 4. PAHs were also detected in the biota samples (caged ribbed mussel) collected in the vicinity of the Lower Subase. Other contaminants detected in sediments of the Thames River (i.e., pesticides and metals) were not detected in the vicinity of the Lower Subase at concentrations that would suggest the Lower Subase as the source of contamination. Pesticide concentrations were

found at low concentrations throughout the Thames River, while concentrations of metals tended to be only slightly greater near the Lower Subase than concentrations in other areas sampled.

The only unacceptable risk identified in the human health risk assessment was from ingestion of shellfish and finfish from the Thames River. However, individuals are not permitted to harvest shellfish in the area and there are no licensed recreational shell fishing areas in the Thames River. There are also no commercial shellfish beds in close proximity to NSB-NLON. The risks from ingestion of finfish are marginally above the acceptable risk range and are likely overestimated because of the conservative assumptions made during the risk assessment. The results of the ecological risk assessment indicate that the Thames River near NSB-NLON represents a minimal potential risk to ecological receptors, mainly benthic macroinvertebrates. Further discussion on the Thames River is provided below in Section 1.5.2, Ecological Risk Assessment.

1.4.4 Natural Attenuation Parameters

Parameters indicative of biodegradation of petroleum hydrocarbons will be collected during this investigation to examine the viability of natural attenuation or bioremediation as feasible remedial alternatives for petroleum contamination within the groundwater at this site. The groundwater data that will be collected include total organic carbon (TOC), dissolved oxygen, salinity, REDOX potential, pH, alkalinity, hardness, divalent iron, chloride, nitrate, sulfate, phosphate, ammonia and methane. TOC data will be collected at locations within the contaminant plume, to monitor the extent of contaminant migration since the date of release and for modeling future contaminant movement. Dissolved oxygen data will be collected at both background locations and within the contaminant plume. These data are collected to identify an inverse correlation indicative of aerobic biodegradation. The remaining parameters, REDOX potential, pH, alkalinity, hardness, divalent iron, dissolved nitrate, sulfate, phosphate, ammonia and methane will be collected to determine if intrinsic remediation is in progress and to determine the levels of possible nutrients available for microorganisms. Divalent iron, dissolved nitrate, sulfate and methane are used to identify a correlation between electron acceptors and metabolic by-production indicative of anaerobic biodegradation. Other general groundwater field parameters such as chloride, conductivity and temperature data will be collected to verify that the site samples are obtained from the same groundwater system. Salinity measurements will be taken to determine the potential impact of salt water intrusion on the viability of natural attenuation. High levels of salinity have been shown to impede the natural degradation process.

1.5 RISK ASSESSMENT

An evaluation of the risks to human and ecological receptors will be performed for each zone for this RI. In general, the approach to the human health and ecological risk assessments will be similar to those conducted for the Phase II RI (B&R Environmental, 1997). The details of the approach to each risk assessment are provided below.

1.5.1 Human Health Risk Assessment

A human health risk assessment will be included in the Lower Subase RI to identify potential public health risks associated with exposure to chemicals detected in the environmental media at the Lower Subase. The results of the assessment will be used to identify the need for remedial actions and to develop potential remedial alternatives for the site, if warranted. This section of the RI Work Plan for the Lower Subase contains a brief discussion of the procedures which will be used to generate the human health risk assessment for the Lower Subase RI.

The human health risk assessment for the Lower Subase RI will be performed in accordance with current USEPA risk assessment guidance. Any newly published risk assessment or regulatory guidance will be incorporated into the risk assessment, as appropriate. Updated toxicological information will be used to assess potential human health risks.

In general, the risk assessment will follow the procedures identified in Section 3.3 of the Phase II multi-site RI for NSB-NLON (B&R Environmental, March 1997). The 5 major components of a baseline risk assessment will be addressed in the human health risk assessment for the Lower Subase RI. The 5 major components include the following:

- Data evaluation and identification of chemicals of concern
- Identification of significant exposure pathways
- Toxicity assessment
- Estimation of potential public health risks
- Characterization of uncertainty in the risk estimates

For the Phase II RI, the Lower Subase was divided into 4 zones, each selected because of suspected source areas. A human health risk assessment was performed for each zone. For the Lower Subase RI, the investigation area has expanded due to additional suspected source areas and a total of 7 zones (i.e., the 4 original zones and 3 additional zones) will be investigated. Specific details regarding the location and

identification of each zone are summarized in the Lower Subase Existing Data Summary Report (B&R Environmental, March 1997).

As identified in the Phase II multi-site RI for NSB-NLON, potential receptors under current and future land use conditions at the Lower Subase consist of full-time employees, construction workers, and future residents. The same potential receptor groups will be evaluated in the Lower Subase RI. Full-time employees will be assumed to be exposed to surface soil (0 to 2 feet). Exposure to surface and subsurface soil to an estimated maximum depth of 12 feet will be assumed for construction workers and future residents. Dermal contact with groundwater will also be assessed for construction workers. The baseline human health risk assessment for each zone will not include an evaluation of groundwater as a drinking water supply for future residents (i.e., direct ingestion, dermal contact while bathing, and inhalation of volatiles) because the brackish conditions at the Lower Subase would preclude the future use of groundwater for this purpose.

Human exposures to surface water and sediment of the Thames River in the vicinity of the Lower Subase will not be considered in the baseline human health risk assessment for the Lower Subase RI. Because of the depth to sediment, direct contact with this medium is not anticipated for potential human receptors. Although human exposure (i.e., recreational water skiers, etc.) to surface water in the vicinity of the Lower Subase may occur, anticipated exposure is expected to be minimal as exposure to site-related chemicals is not expected to occur over an extended period of time.

Potential human health risks will be estimated for each of the 7 zones. Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) scenarios will be evaluated. Estimated carcinogenic risks (incremental cancer risks) for the zones will be compared to the USEPA target risk range, 1×10^{-4} to 1×10^{-6}. Estimated noncarcinogenic risks (HIs) will be compared to unity, the point of departure at which (or below which) adverse toxic effects are not anticipated for potential human receptors.

The methodology, model, and default parameter values contained in the Recommendations of the Technical Review Workshop for Lead for an Interim Approach to assessing Risks Associated with Adult Exposures to Lead in Soil (December, 1996) will be used in the baseline human health risk assessment for the Lower Subase. An arithmetic average lead concentration will be calculated per zone and used to assess potential exposure, as per the cited guidance.

1.5.2 Ecological Risk Assessment

Ecological data has been collected from the Thames River along the Lower Subase during several previous studies. These studies include the original and supplemental investigations for the Phase II RI,

and investigations for the SEAWOLF Homeporting and the Pier 17 replacement projects. Sampling locations for each of the studies are shown on Figure 1-10. The data collected from the later two studies was not evaluated in the Phase II RI. However, this data and the Phase II RI data were both used to scope the additional sampling necessary for the Lower Subase RI and both will be evaluated in the ecological risk assessment to be performed for the Lower Subase RI.

All of the data from the three studies was thoroughly reviewed to determine which data are suitable for inclusion into the Lower Subase RI ecological risk assessment. A brief summary of these studies is provided below to develop the rationale for additional sampling in the Thames River adjacent to the Lower Subase.

Numerous ecological studies of the Thames River near NSB-NLON have been performed by Maguire Group, Inc. These studies were performed in support of the SEAWOLF Homeport dredging project and the data were included in the SEAWOLF Class Submarine Homeporting Environmental Impact Statement (EIS; Maguire Group, Inc., 1995). In 1990, sediment samples were collected in the reach of the Thames River from NSB-NLON to the mouth of the river. Several samples were collected near Piers 32 and 33 and in the river channel near the ends of several other piers. Sediment samples were analyzed for contaminants, and benthic macroinvertebrate community analysis was also performed. Several metals and organics, mainly PAHs, were detected in samples in and near the Lower Subase, but concentrations were relatively low. Only a few detections of some metals exceeded Effects Range-Low (ER-L) sediment screening values (Long et al., 1995). The ER-L is defined as the concentration below which adverse effects are rarely observed. The results of the benthic macroinvertebrate analysis showed that abundance generally decreased from the mouth of the river to NSB-NLON, but community composition was similar. The study suggested that these differences may be due to shallower depth, lower salinity, and increasing rivine influences in the up-river samples.

Sediment samples were also collected for the SEAWOLF Homeporting project in the Thames River in and near NSB-NLON in 1991. Several grab and core samples were collected; three of the grab samples were collected near Piers 32 and 33. In addition, toxicity testing of sediments was performed on an amphipod, *Ampelisca abdita*, a clam, *Macoma nasuta*, and a sandworm, *Nereis virens*. Bioaccumulation tests for metals and PAHs with *Macoma* and *Nereis* were also performed. Slightly elevated concentrations of some metals and PAHs were detected in Pier 32 and 33 sediment samples. Several exceedances of ER-Ls were observed, along with occasional exceedances of ER-Ms. Concentrations below the ER-M and above the ER-L are in the range in which adverse effects are occasionally observed. Mortality for Pier 32 and 33 sediments was not significantly greater than that for control and reference sediments for *Ampelisca* or *Nereis*. Mortality for *Macoma* was significantly greater than control and reference sediments only if an

outlier was removed from the data set. No significant bioaccumulation of metals or PAHs was detected in *Macoma* or *Nereis*.

Sediment samples were also collected in 1994 in the river channel from NSB-NLON to the I-95 bridge in support of the SEAWOLF EIS. Only a few elevated concentrations of some metals were detected, and PAH concentrations were relatively low. No exceedances of ER-L values for PAH compounds were observed. Due to refined displacement and trim estimates in 1994, it was determined that the SEAWOLF submarine could traverse the river in 39 feet of water. Hence, the Navy proposed berthing the SEAWOLF at Piers 8 and 10 instead of Piers 32 and 33. As a result, three sediment samples were collected in 1995 near Piers 8 and 10. Slightly elevated concentrations of several metals were detected. Several exceedances of ER-L values were observed, although no exceedances of ER-M values were observed. PAH concentrations were relatively low. Only a few exceedances of ER-L values were observed for PAHs.

In addition to the samples collected in support of the SEAWOLF EIS, sampling was conducted near Piers 15 and 17 in 1994 for the Pier 17 replacement Environmental Assessment (EA; Maguire Group, Inc., 1994). Several surface sediment samples were collected around Piers 15 and 17, benthic macroinvertebrate surveys were conducted, and sediment toxicity tests using *Ampelisca* were performed, as well as bioaccumulation studies with *Macoma* and *Nereis*. Several metals and PAHs in sediment samples exceeded ER-L values, and ER-M values were exceeded for some metals and PAHs in two samples collected near Pier 17. Benthic macroinvertebrate diversity and abundance was low in samples collected near Pier 17, but was relatively high in samples collected near Pier 15. However, no significant mortality was observed for *Ampelisca* relative to control and reference sediments. Some bioaccumulation of PAH compounds was observed for *Macoma* and *Nereis*, and some bioaccumulation of PCBs was observed in *Nereis* but not in *Macoma*. No significant bioaccumulation of metals was observed.

Also, an ecological risk assessment for the Thames River was performed in support of the NSB-NLON Phase II RI (B&R Environmental, 1997). Surface water and sediment sampling and benthic macroinvertebrate analysis was conducted. Native shellfish, including blue mussels, oysters, and hardshell clams, were collected, and a caged mussel deployment study was performed. Only a few COCs were identified in surface water. In sediments, some elevated concentrations of some metals and PAHs were detected. Several exceedances of ER-L values were observed; exceedances of ER-M values were sporadic. Some PAHs were detected in one blue mussel sample near the Lower Subase. A few PAHs were also detected in one caged mussel sample in the Lower Subase. Low levels of metals were detected in caged and native shellfish. The results of the benthic macroinvertebrate study indicated that,

in general, the benthic community near NSB-NLON was similar to that in the upstream and downstream samples.

Due to the potential for ecological risks displayed by some analyses in the risk assessment, a supplementary ecological risk assessment was performed as part of the Phase II RI, which focused on the Thames River closer to the base. The supplemental investigation consisted of surface water and sediment sampling, toxicity tests with *Ampelisca* and *Leptocheirus*, modeling of potential risks to the herring gull and double-crested cormorant, and acid volatile sulfide/simultaneously-extracted metals (AVS/SEM) analysis of sediments. Some exceedances of benchmark values were observed in surface water and sediments samples, but sediments from only one sampling location in the Lower Subase exhibited toxicity (to *Ampelisca*). AVS concentrations exceeded semi-extractable metals (e.g., copper, cadmium, nickel, lead, and zinc) concentrations at all locations, indicating decreased bioavailability of several metals. Moreover, although elevated HI values were calculated for the avian species investigated, potential risks to these receptors are most likely much lower due to the use of several conservative assumptions in the models. In particular, the receptors were assumed to forage 100% of the time in the river near the Lower Subase, while the Lower Subase comprises only a fraction of the home range of these receptors. The conservative nature of the ecological risk assessment for avian receptors is described in detail in the uncertainty of the Thames River ecological risk assessment. The Phase II RI ecological risk assessment concluded that, with the possible exception of the Lower Subase area, potential risks to ecological receptors from Thames River contaminants are relatively low, and that potential risks to benthic receptors, primarily shellfish near the Lower Subase, are the only risks that may require further characterization.

In summary, the results of the SEAWOLF EIS studies and the Phase II RI studies indicate that potential risks to ecological receptors from contaminants in the reach of the Thames River along NSB-NLON are relatively low. Elevated concentrations of contaminants were detected near the Lower Subase in samples collected for those studies, and in Pier 17 replacement study samples. However, little or no mortality was observed in toxicity tests that used sediment samples from the Thames River near the Lower Subase. Diversity and abundance of benthic macroinvertebrates in the Lower Subase area of the river were similar to those found elsewhere in the Thames River, with the exception of a few samples collected near Pier 17.

Some bioaccumulation of PAHs and PCBs was observed in Pier 17 benthic receptor studies. Some PAHs were also detected in one blue mussel sample and one caged mussel sample taken during the Phase II RI at the Lower Subase. Furthermore, the Navy has completed dredging activities associated with Pier 17 replacement and SEAWOLF homeporting projects. Thus, several of the sediment sampling locations from the studies summarized above have been altered, and hence, the data from those samples are unusable

and the conclusions drawn from those data may no longer be valid. Each of the studies discussed above was conducted for different purposes. In other words, although data exist from the unaltered sampling locations in the Lower Subase area, no comprehensive study to define the nature and extent of contamination in the Thames River next to the Lower Subase has been conducted. For this reason, additional sampling is needed in the river adjacent to the Lower Subase to more fully define the nature and extent of contamination, to determine if the Lower Subase is contributing contaminants to the river adjacent to the base, and to more fully characterize the related potential ecological risks to benthic receptors.

Additional sediment sampling is needed in the river adjacent to the Lower Subase. These data can be used to assess correlations between source areas in the Lower Subase and the elevated concentrations of contaminants in the adjacent reach of the Thames River, if present. Sediment samples will be collected in the river in areas close to potential source areas and at potential discharge points along preferential contaminant transport pathways (i.e., near storm sewer outfalls). The potential source areas of TPH and metals were previously defined in the Existing Data Summary Report (B&R Environmental, 1997). Zone-specific sediment sampling locations for the Lower Subase RI are depicted and discussed in Section 2, the Sampling and Analysis Plan.

For the most part, the analysis of sediment samples will focus on PAH compounds (SVOCs) and metals, since these compounds were found to exceed benchmarks in the studies discussed above. PAHs were also shown to bioaccumulate in the tissues of benthic organisms.

The bioavailability and, therefore, toxicity of certain metals has been linked to the amount of AVS in the sediment (USEPA, 1994b). Therefore, sediments will be analyzed for AVS/SEM. Since the AVS fraction of the sediment is labile and subject to oxidation, the utility of using AVS as a basis for investigating the bioavailability of certain metals has been questioned (Luoma and Carter, 1993), and sediments collected for AVS/SEM analysis are often stored in a nitrogen atmosphere to minimize oxidation. However, recent experiments have suggested that the transient nature of AVS may be overstated (Ankley et al, 1996), and observations made by Boothman and Helmstetter (1992) indicate that it is possible to process and then refrigerate or freeze sediments for up to 14 days with no loss of AVS. Procedures outlined in USEPA (1991), Draft Analytical Method for Determination of Acid Volatile Sulfide in Sediment and USEPA (1994b), Equilibrium Partitioning Approach to Predicting Metal Bioavailability in Sediments and the Derivation of Sediment Quality Criteria for Metals, will provide the basis for AVS/SEM sample collection, analysis and evaluation. The methods discussed in Leonard et. al. (1996) will also be reviewed and used to provide further value to the AVS/SEM evaluation if applicable.

Several factors influence the spatial and temporal distribution of AVS in sediments. It has frequently been observed that surficial sediments generally contain less AVS than deeper sediments. This presumably is due to oxidation of AVS at the sediment surface, which may be enhanced by bioturbation (Peterson et al., 1996). Hence, the surficial layer of Thames River sediment samples (i.e., the upper few inches) will be used for AVS/SEM analysis. Also, the amount of AVS in sediments can vary seasonally. In systems where the amount of oxygen overlying the sediments remains appreciable in the colder months of the year, AVS tends to decrease. This is thought to be linked to a constant rate of oxidation of the AVS in conjunction with a seasonal decrease in sulfate-reducing bacteria. However, in contrast, systems in which the water overlying the sediments becomes anaerobic during winter can maintain relatively high sediment AVS concentrations. This may be the case in Thames River sediments. As a result, seasonal factors and chemistry data from water overlying sediments will be taken into account when interpreting AVS concentrations and AVS/SEM ratios in Thames River sediments.

In addition, recent observations from the Duluth, Minnesota EPA laboratory suggest that the relative concentrations of certain cationic metals (cadmium, copper, nickel, lead, and zinc) may influence the amount of AVS in sediments. To illustrate, a recent zinc-spiked sediment study by Liber et al. (1996) demonstrated a strong positive correlation between the amount of zinc added to test sediments and the subsequent concentrations of AVS in their sediment samples. Surficial depletion and seasonal variation of AVS were unexpectedly low in that study. These observations indicated that zinc sulfide is more stable than the iron sulfide that was presumably the source of most of the AVS in the control sediments. That is, zinc sulfide does not undergo oxidation to the degree that iron sulfide does. Studies conducted by Di Toro et al. (1996) confirm that cadmium and zinc form more stable sulfide complexes than iron. Therefore, seasonal variability in AVS concentrations will be less pronounced when the sediment concentrations of these metals are elevated. For these reasons, the relative concentrations of cationic metals in relation to expected seasonal variations in AVS will be considered in the assessment.

The bioavailability and toxicity of certain organic contaminants, including PAHs, has been linked to the amount of total organic carbon (TOC) in sediment (USEPA, 1996). TOC may also provide nominal binding of certain metals. Hence, sediments will be analyzed for TOC. Sediment grain size, % moisture, and % solids will also be measured in the laboratory, as suggested by USEPA (1994c). Recent qualitative investigations of sediments in waters near the Lower Subase (Goss Cove and Mamacoke Cove) have indicated the presence of elevated hydrogen sulfide, as evidenced by a strong hydrogen sulfide smell (B&R Environmental, 1997). Sediments in marine systems often contain relatively high levels of sulfides (Bagarinao, 1992), and may be toxic to benthic organisms (Knezovich et al., 1996). As a result, although Thames River sediments are part of a more dynamic system than those found in nearby coves, the possibility of toxic concentrations of sulfides may exist. However, insufficient information is currently

available to thoroughly evaluate the effects of sulfides on benthic organisms, thus, sediments in the Lower Subase will not be analyzed for hydrogen sulfide.

Increased concentrations of ammonia in sediments, mainly in porewater, can potentially be toxic to benthic organisms. Hence, ammonia will be measured in sediment samples collected in the Thames River adjacent to the Lower Subase.

Surface water parameters, including temperature, salinity, dissolved oxygen, pH, conductivity, and turbidity will also be measured during field activities. The measurement of these parameters in water overlying sediments will be used to help interpret sediment physical conditions. The parameters will also be measured in the shallow surface water to determine the variability of these parameters in the water column.

The data generated as part of the Lower Subase RI will be used to assess potential ecological risks to only benthic receptors that use the Thames River adjacent to the Lower Subase. The basic ERA framework described in the Phase II RI for NSB-NLON (B&R Environmental, 1996) will be used for the assessment of potential risks to benthic receptors from Thames River sediment contaminants. Specifically, metals concentrations in sediments will be compared to ER-L and ER-M values (Long et al., 1995). The AVS/SEM analysis will also be used to assess the potential toxicity of certain metals in sediments (cadmium, copper, nickel, lead, and zinc). Site-specific screening levels for organics will be calculated, in part, from TOC measured in sediments using the Equilibrium Partitioning method (EqP; USEPA, 1996) and compared to concentrations of organics detected in sediments. Comparisons to screening levels, AVS/SEM results, and the results of other field and laboratory parameter measurements will be used in a "weight of evidence" approach to assessing potential risks. Assessments of potential risks will be performed for each Zone and for the Thames River near the Lower Subase as a whole.

Applicable data from the SEAWOLF homeporting project and Pier 17 replacement study will supplement the new data and Phase II RI data used in the Phase II RI ecological risk assessment. Only previous study data from samples collected in close proximity to the Lower Subase will be evaluated; extraneous data from samples collected in other areas of the river will not be used. Previous study data from recently dredged areas will also be eliminated from the data set. The status of current or future dredging in the river near the Lower Subase will also be evaluated to ensure that only applicable data from non-dredged areas are considered.

It is possible that the results of the Lower Subase ecological risk assessment may indicate that concentrations of contaminants in Thames River surface water and sediments in the river adjacent to the

NSB-NLON may pose significant potential ecological risks to benthic receptors. In this event, additional ecological investigations may be necessary and would be completed as part of a data gap investigation. The scope and approach for additional ecological investigations is described in Section 1.4.1.1 under "Develop a Decision Rule".

1.6 PROJECT MANAGEMENT AND ORGANIZATION

B&R Environmental is responsible for the overall management of the project, including all field sampling activities. Navy personnel will actively support the investigation and will coordinate with personnel from B&R Environmental during field activities. The responsible organizations and personnel involved in the project are as follows:

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Ms. Kymberlee Keckler
Remedial Project Manager

Figure 1-18 presents the project management organization chart for the RI at NSB-NLON, Groton Connecticut. Under the direction of the Navy Remedial Project Manager, B&R Environmental is responsible for the overall management, implementation, and inspection of the contract field activities. Personnel from the Navy will be actively involved and will coordinate with B&R Environmental personnel in a number of areas. The authorities and organizational relationship of key personnel are depicted in Figure 1-18. Responsibilities for program management, project management, field operations, and laboratory operations are discussed in the following sections.

1.6.1 Field Responsibilities

The B&R Environmental field investigation team will be organized according to the activities planned. Field team members will be selected based on the type and extent of effort required. All team members will be appropriately skilled and trained for the tasks they are assigned to perform. The team will consist of a combination of the following personnel:

- Field Operations Leader (FOL). (The FOL may also fill other roles.)
- Site QA/QC Advisor
- Site Safety Officer (SSO)
- Field hydrogeologist/geologist(s)

The proposed field activities will be performed by B&R Environmental personnel and subcontractors, and overseen by the B&R Environmental Field Operations Leader (FOL). A general discussion of the FOL's responsibilities follows.

The FOL is responsible for coordinating all onsite personnel and for providing technical assistance when required. The FOL or designee will coordinate and be present during all sampling activities and will ensure the availability and maintenance of all sampling materials/equipment. The FOL is responsible for the completion of all sampling, boring, well construction, field, and chain-of-custody documentation and will assume custody of all samples and ensure the proper handling and shipping of samples. The FOL is responsible for providing oversight and technical supervision of the drilling and direct-push subcontractor. Other duties of the FOL include the following:

- Functions as communications link between field crew members, the Site QA/QC Advisor, Site Safety Officer, and the Project Manager.
- Oversees the mobilization and demobilization of all field equipment and subcontractors.
- Resolves logistical, weather, personnel, and equipment problems.
- Responsible for maintenance of the site logbook.
- Initiates field change requests when necessary.

The FOL will act as the Site QA/QC Advisor, who is responsible for ensuring adherence to all QA/QC guidelines as defined in the FSP and QAPP. Strict adherence to these procedures is critical to the collection of acceptable and representative data. The following is a summary of the Site QA/QC Advisor's responsibilities:

- Ensures that field duplicates and field quality control blanks are collected with the proper frequency.

- Ensures that additional volumes of sample are supplied to the analytical laboratory with the proper frequency to accommodate laboratory QA/QC analyses.

- Ensures that measuring and test equipment are calibrated, used, and maintained in accordance with applicable procedures.

- Acts as liaison between site personnel, laboratory personnel, and the QAM.

- Manages bottleware shipments; oversees field preservation and in-field filtration activities.

The yet to be determined FOL (or his assistant) will also serve as the Site Safety Officer (SSO). The duties of the SSO are detailed in the Site Security and Health and Safety Plan (Appendix D). The SSO has stop-work authority which can be executed upon the determination of an imminent safety hazard.

1.6.2 Laboratory Responsibilities

The subcontracted analytical laboratory shall have the responsibility for analyzing all RI samples in accordance with the specified analytical methods and for reporting data in accordance with the requirements outlined under the Contract Laboratory Program and the Quality Assurance Project Plan (Appendix C). Katahdin Laboratories of Westbrook, Maine has been selected as the analytical laboratory for this RI. It shall be the responsibility of the analytical laboratory to properly dispose of unused sample and to report the receipt of any broken sample bottles or other problems relative to samples (e.g., head-space in volatile organic vials) to the Project Manager.

1.7 COMMUNITY RELATIONS

A Community Relations Plan for NSB-NLON, Groton, Connecticut was developed and issued in February 1994 (Atlantic, 1994). The plan identified issues of community interest and concern regarding NSB-NLON. It also described the program of community relations activities that the Navy will conduct during the IRP. The Community Relations Plan covers all of the IRP sites being investigated at NSB-NLON including the Lower Subase. The applicable community relations programs will be followed during the RI to be conducted at the Lower Subase.

A Restoration Advisory Board (RAB) has been established by the Navy for the purpose of allowing individuals the opportunity to give advice to the Navy on their IRP at NSB-NLON and to act as a focal point for the exchange of information between the Navy and the local community. The NSB-NLON RAB includes representatives from regulatory agencies, such as the U.S. Environmental Protection Agency - Region I and the Connecticut Department of Environmental Protection, as well as community representatives. The RAB meets on a quarterly basis. The scope and findings of the Lower Subase RI will be discussed and explained at a future RAB meeting. In addition, the findings of the Lower Subase FS and Proposed Plan, which will be developed after the RI, will also be discussed at future RAB meetings.

1.8 DATA DELIVERABLES AND MANAGEMENT

A draft RI Report will be issued approximately six months after the completion of the field sampling effort. The report will contain a discussion of methodologies used by the field personnel, observations and

sampling methodologies, a detailed discussion of the sampling results, and tables summarizing sampling results generated from this investigation.

The data generated from this investigation shall be validated in accordance with the EPA's National Functional Guidelines as amended by Region I. Further details on the data validation process and data quality issues are outlined in the QAPP in Appendix C.

Historical analytical data from previous investigations at the Lower Subase are maintained in an electronic database. This database will be updated with the newly collected data and will be used to identify data trends, anomalous data results and will be used to compare the results to applicable standards. The database will also be used to identify anomalous results that are statistically significant relative to background values. The approach that will be used to manage the analytical database for the Lower Subase RI is discussed below.

1.8.1 Data Management Plan

The purpose of the Data Management Plan is to track investigation data and provide adequate levels of quality assurance. The following subsections summarize the components of the Data Management Plan.

Software

Microsoft Visual FoxPro 3.0 will be the primary software for all data management and data manipulation activities.

Responsibilities

All analytical and field data will be managed by The Information Management Solutions Group of B&R Environmental, who will be responsible for compiling and maintaining project files that will contain hard copies of the chains-of-custody, sample log forms, boring logs, sample location maps, and documentation of quality assurance of data manipulation. Removal of any files will require the initials of the requestor and date.

All electronic data will be managed on the B&R Environmental Network system under the CTO 260 directory. The security of the database will be maintained by the network backup system that occurs on a daily basis.

Sample Tracking

A "Cradle-to-Grave" sample tracking system will be employed beginning prior to the field effort. All sample numbers, requested laboratory analyses, and field duplicate information will be entered into a database from the approved Work Plan. The sample tracking database will then be used to generate both sample jar labels and sample log forms to be completed in the field. Chain-of-Custody forms will be faxed to B&R Environmental Pittsburgh office at the end of each sampling day to be compared against the sample tracking database. This will allow for early detection of errors made in the field so that any necessary adjustments can be made while the crew is mobilized. An electronic copy of the sample tracking database will be sent to the laboratory to avoid manual entry of sample numbers into the Laboratory Information Management System (LIMS). After successful completion of all requested analyses, the laboratory will submit an electronic deliverable to B&R Environmental for every Sample Delivery Group (SDG). The format specified for electronic deliverables from the laboratory is shown in Appendix B. Once all electronic deliverables have been received from the laboratory, queries will be run versus the pre-field effort database to ensure that the laboratory performed all of the requested analyses. The Project Manager will be notified as to any discrepancies. Ideally, discrepancies can be noted early enough so that resampling does not have to take place.

Sample Information

Before electronic files are received from the laboratory, all sample-specific information will be entered into the data management system. This information will include the depth at which the sample was collected, the area of concern that the sample is associated with, the aquifer in which the well was screened, etc. The sample information file will allow for the analytical results to be grouped together properly for statistical purposes in the RI Report.

Survey Data

All survey data will be delivered in Excel spreadsheet format. The files will contain a minimum of northing, easting, ground surface elevation, elevation of top of casing, elevation of top of riser. All coordinates will be submitted as state plane 1987 datum. Survey data will then be imported into the data management system.

Data Validation

Once all samples and analyses have been accounted for, the electronic data files are printed for each SDG and analytical fraction and submitted for data validation. Validators will incorporate data qualifiers into the electronic database and resubmit the data to the Information Management Solutions Group.

Project Data Compilation

The new data generated under this RI will be incorporated with all previous data generated at NSB-NLON. All data such as units of measure and chemical nomenclature will be manipulated to maintain consistency with the project database. The project database is a relational database that ensures data structure integrity and data quality for all NSB-NLON data.

Data Summary Output

The project database will be used to generate all statistical tables for the various sections of the RI Report such as Nature and Extent of Contamination, Human Health Risk Assessment, Ecological Risk Assessment and Data Evaluation. Programs have been written to pull data directly from the database for statistics in order to preserve data integrity and consistency. Report formats have been written in Visual FoxPro to present analytical results in Excel Spreadsheet style format that are typically included as appendices.

Field duplicates will be averaged for statistical purposes for all aqueous data (i.e. groundwater and surface water). The maximum concentration will be used to represent field duplicate concentrations in solid media (i.e. soil and sediment). The normal, duplicate and average/maximum concentrations will all be presented in the analytical results appendix.

Geographic Information Systems (GIS)

Upon compilation of all sample, chemical and positional data, the data will be incorporated into an ArcView GIS project. The basis of the ArcView project will be existing basemaps for NSB New London. The GIS system can be used to generate site location maps, sample location maps, contaminant iso-contour maps, potentiometric surface maps, and contaminant tag maps upon request. The data can be delivered to the Navy in Tri-Service Standard format upon request.

1.9 PROJECT SCHEDULE

The field activities for the project are presently scheduled to begin in September 1997 and should be completed in November 1997. The draft RI Report is scheduled to be completed within six months after the completion of the field work and the final RI Report is scheduled to be submitted within six months after the completion of the draft RI Report.

TABLE 1-1

ZONE 1 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING WELLS	16
DESTROYED OR NOT LOCATED WELLS	4
PREVIOUS INVESTIGATIONS	• Oil Contamination of Groundwater at Subase (NESO, 1979) • Final Initial Assessment Study (Envirodyne, 1983) • Final Site Investigation of Subsurface Oil Contamination (Wehran, 1987) • Hydrogeologic Investigation UST OT-4, OT-7, OT-8, OT-9, and Tank 54-H (Fuss & O'Neill, 1989) • Phase I Remedial Investigation (Atlantic, 1992) • Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995) • Site Characterization Report for OT-10, Building 325, and Building B-89 (HNUS, 1995) • Site Investigation Report for Tank Farm Investigation (B&R Environmental, 1996) • Phase II Remedial Investigation (B&R Environmental, 1996)

HYDROGEOLOGY

DEPTH TO WATER	4-10 feet (East to West)
AVERAGE HYDRAULIC CONDUCTIVITY	158 feet/day
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Sand and gravel
Depth > 5 feet	Sand with gravel or silt to 20' Sand and silt below 20'
FILL THICKNESS	15-20 feet
DEPTH TO BEDROCK	Not encountered

TABLE 1-2

ZONE 2 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING NUMBER OF WELLS	5
DESTROYED OR NOT LOCATED WELLS	2
PREVIOUS INVESTIGATIONS	• Oil Contamination of Groundwater at Subase (NESO, 1979) • Phase I Remedial Investigation (Atlantic, 1992) • Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995) • Site Investigation Report for Tank Farm Investigation (B&R Environmental, 1996) • Phase II Remedial Investigation (B&R Environmental, 1996)

HYDROGEOLOGY

DEPTH TO WATER	6-20 feet (East to West)
AVERAGE HYDRAULIC CONDUCTIVITY	75 feet/day
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Sand and gravel
Depth > 5 feet	Sand and gravel to 10-20' East - Sand below sand and gravel West - Silt below sand and gravel
FILL THICKNESS	6-14 feet
DEPTH TO BEDROCK	Not encountered

TABLE 1-3

ZONE 3 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING NUMBER OF WELLS	1
DESTROYED OR NOT LOCATED WELLS	5
PREVIOUS INVESTIGATIONS	• Final Site Investigation Subsurface Oil Contamination (Wehran, 1987) • Phase I Remedial Investigation (Atlantic, 1992) • Action Memorandum for Building 31 (HNUS, 1993) • Post Removal Action Report for Building 31 Lead Remediation (HNUS, 1995) • Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995) • Site Investigation Report for Tank Farm Investigation (B&R Environmental, 1996) • Phase II Remedial Investigation (B&R Environmental, 1996)

HYDROGEOLOGY

DEPTH TO WATER	6-10 feet (East to West)
AVERAGE HYDRAULIC CONDUCTIVITY	Unknown
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Silty sand with some gravel
Depth > 5 feet	Sand[1] (5-20 feet) Sand and gravel (>20 feet) or sand and silt
FILL THICKNESS	9-20 feet
DEPTH TO BEDROCK	Not encountered

(1) In the western portion of Zone 3, a wooden pier is encountered at a depth of approximately 7 feet. A void space extends to 13 feet. Fine-grained sand exists below the void space.

TABLE 1-4

ZONE 4 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING NUMBER OF WELLS	15
DESTROYED OR NOT LOCATED WELLS	2
PREVIOUS INVESTIGATIONS	• Oil Contamination of Groundwater at Subase (NESO, 1979) • Final Initial Assessment Study (Envirodyne, 1983) • Final Site Investigation of Subsurface Oil Contamination (Wehran, 1987) • Phase I Remedial Investigation (Atlantic, 1992) • Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995) • Quay Wall Removal Site Evaluation (HNUS, 1995) • Site Investigation Report for Tank Farm Investigation (B&R Environmental, 1996) • Phase II Remedial Investigation (B&R Environmental, 1996)

HYDROGEOLOGY

DEPTH TO WATER	5-8 feet
AVERAGE HYDRAULIC CONDUCTIVITY	Unknown
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Sand and gravel
Depth > 5 feet	West - Sand and gravel to 7 feet Wooden pier at 7 feet Void space to 10 feet Sand and silt at 10 to 15 feet (Natural) East - Sand and gravel to 10-15 feet Sand Sand and gravel
FILL THICKNESS	8-10 feet
DEPTH TO BEDROCK	Not encountered

TABLE 1-5

ZONE 5 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING NUMBER OF WELLS	3
PREVIOUS INVESTIGATIONS	• Pier 33 and Berth 16/Former Incinerator Site Investigation (SI) (Atlantic, 1995) • Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995)

HYDROGEOLOGY

DEPTH TO WATER	4 feet
AVERAGE HYDRAULIC CONDUCTIVITY	Unknown
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Sand or Sand and gravel
Depth > 5 feet	Sand or Sand and gravel
FILL THICKNESS	5-20 feet
DEPTH TO BEDROCK	4-20 feet

TABLE 1-6

ZONE 6 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING NUMBER OF WELLS	None
PREVIOUS INVESTIGATIONS	• Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995)

HYDROGEOLOGY

DEPTH TO WATER	Unknown
AVERAGE HYDRAULIC CONDUCTIVITY	Unknown
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Unknown
Depth > 5 feet	Unknown
FILL THICKNESS	Unknown
DEPTH TO BEDROCK	Unknown

TABLE 1-7

ZONE 7 EXISTING DATA SUMMARY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

INVESTIGATION HISTORY

EXISTING NUMBER OF WELLS	6
PREVIOUS INVESTIGATIONS	• Environmental Assessment for Pier 17 Replacement (Maguire Group, Inc., 1994) • Pier 33 and Berth 16/Former Incinerator Site Investigation (Atlantic, 1995) • Final Environmental Impact Statement for Seawolf Class Submarine Homeporting on the East Coast of the United States (Maguire, 1995)

HYDROGEOLOGY

DEPTH TO WATER	4-6 feet (East to West)
AVERAGE HYDRAULIC CONDUCTIVITY	Unknown
FREE PRODUCT THICKNESS	Unknown

GEOLOGY

SOIL TEXTURE	
Depth < 5 feet	Fill debris and/or Sand and gravel
Depth > 5 feet	Fill debris and/or Sand and gravel to Sand
FILL THICKNESS	16
DEPTH TO BEDROCK	50 feet

TABLE 1-8

SAMPLE SUMMARY
NSB-NLON, GROTON, CONNECTICUT
PAGE 1 OF 2

Matrix	Parameters	Number of samples							
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Total
SHALLOW SOILS[1]	TPH	3	3	3	3	6	5	11	**34**
	TAL METALS	3	0	3	3	2	5	4	**20**
	SPLP METALS[7]	0	0	0	0	0	3	0	**3**
	SPLP LEAD[8]	2	0	2	3	2	0	2	**11**
	TCL VOC	0	0	0	0	0	5	0	**5**
	TCL SVOC	9	7	5	5	6	5	11	**48**
	Subtotal	**17**	**10**	**13**	**14**	**16**	**23**	**28**	
DEEP SOILS[2]	TPH	0	0	0	0	0	5	0	**5**
	TAL METALS	0	3	3	3	2	5	4	**20**
	SPLP METALS[7]	0	0	0	0	0	3	0	**3**
	SPLP LEAD[8]	0	2	2	3	2	0	2	**11**
	TCL VOC	0	0	0	0	0	5	0	**5**
	TCL SVOC	9	7	5	5	6	5	11	**48**
	Subtotal	**9**	**12**	**10**	**11**	**10**	**23**	**17**	
GROUNDWATER	TPH	16	5	3	13	3	5	11	**56**
	TAL METALS[3]	16	5	3	13	3	5	11	**56**
	TCL SVOC	16	5	3	13	3	5	11	**56**
	TCL VOC[9]	0	0	0	0	0	5	0	**5**
	NATURAL ATTEN.[4]	16	5	3	13	3	5	11	**56**
	Subtotal	**64**	**20**	**12**	**52**	**12**	**25**	**44**	
SURFACE WATER	WATER QUALITY PARAMETERS[5]	8	4	4	6	8	4	6	**40**
	Subtotal	**8**	**4**	**4**	**6**	**8**	**4**	**6**	

TABLE 1-8

SAMPLE SUMMARY
NSB-NLON, GROTON, CONNECTICUT
PAGE 2 OF 2

Matrix	Parameters	Number of samples							
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Total
SEDIMENT	TCL SVOC	4	2	2	3	4	2	3	**20**
	TCL PESTICIDES	0	0	0	0	1	0	0	**1**
	TAL METALS	4	2	2	3	4	2	3	**20**
	AVS/SEM[6]	4	2	2	3	4	2	3	**20**
	AMMONIA	4	2	2	3	4	2	3	**20**
	pH	4	2	2	3	4	2	3	**20**
	TOC	4	2	2	3	4	2	3	**20**
	GRAIN SIZE ANALYSIS	4	2	2	3	4	2	3	**20**
	Subtotal	**28**	**14**	**14**	**21**	**29**	**14**	**21**	
TOTAL		**126**	**60**	**53**	**104**	**75**	**89**	**116**	**623**

1 Shallow soils are defined as samples collected from depths less than five feet below ground surface
2 Deep soils are defined as samples collected from depths greater than five feet below ground surface
3 TAL metals analysis does not include cyanide, but it does include total and dissolved analyses for groundwater samples
4 Natural attenuation parameters include total organic carbon (TOC), dissolved oxygen, salinity, oxidation-reduction (REDOX) potential, pH, alkalinity, hardness, divalent iron, chloride, nitrate, sulfate, phosphate, ammonia, and methane.
5 Field water quality parameters include pH, temperature, specific conductivity, dissolved oxygen, oxidation-reduction (REDOX) potential, turbidity, and salinity.
6 Acid Volatile Sulfide (AVS)/Simultaneously Extracted Metals (SEM).
7 Synthetic Precipitation Leaching Procedure followed by TAL metals analysis.
8 Synthetic Precipitation Leading Procedure followed by lead analysis.
9 Low-concentration TCL volatile analysis will be performed for groundwater samples.

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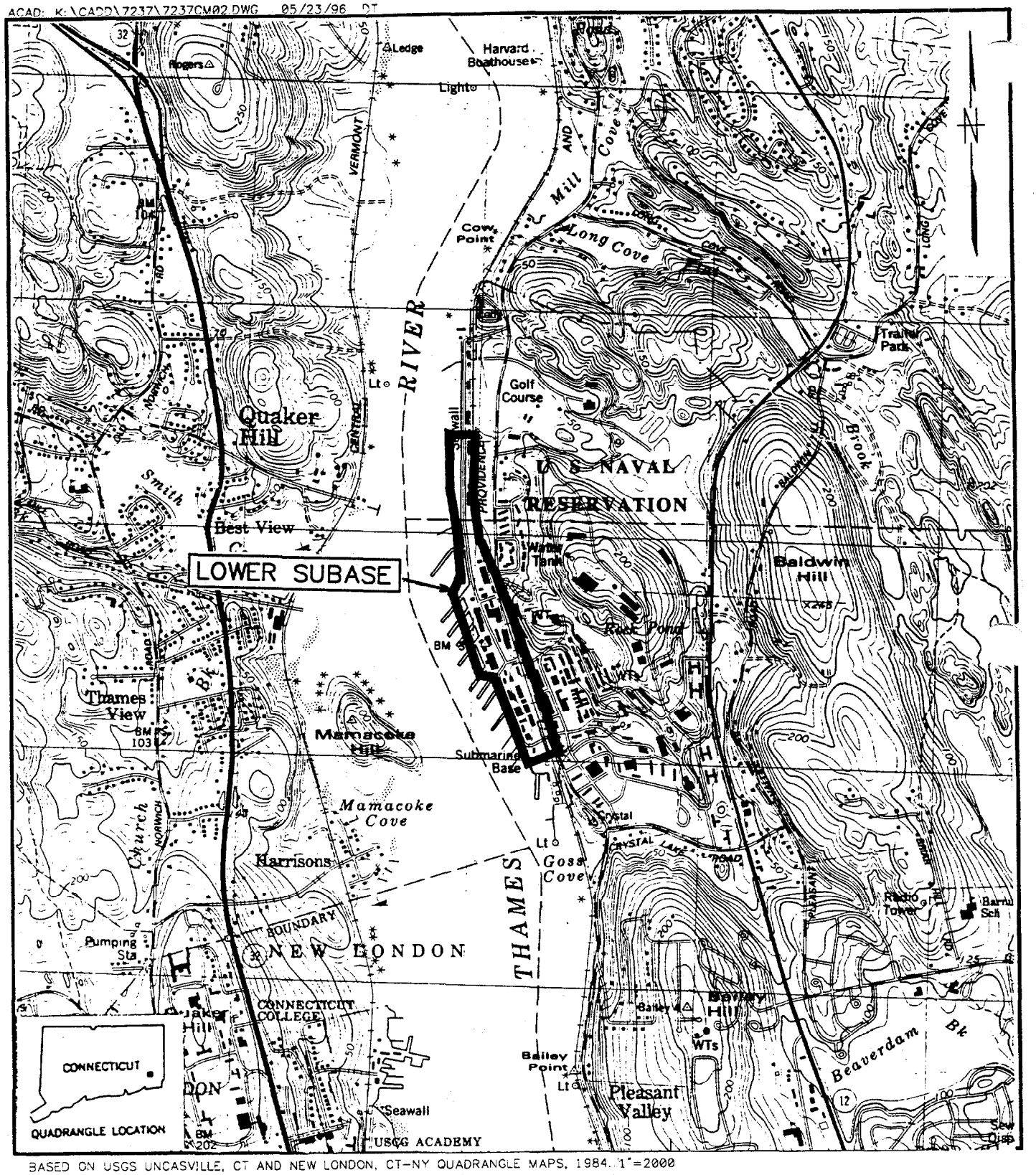

BASED ON USGS UNCASVILLE, CT AND NEW LONDON, CT-NY QUADRANGLE MAPS, 1984. 1"=2000

FIGURE 1

SITE LOCATION MAP

NSB-NLON, GROTON, CONNECTICUT

0 2000 4000

SCALE IN FEET

Brown & Root Environmental

0132801Z

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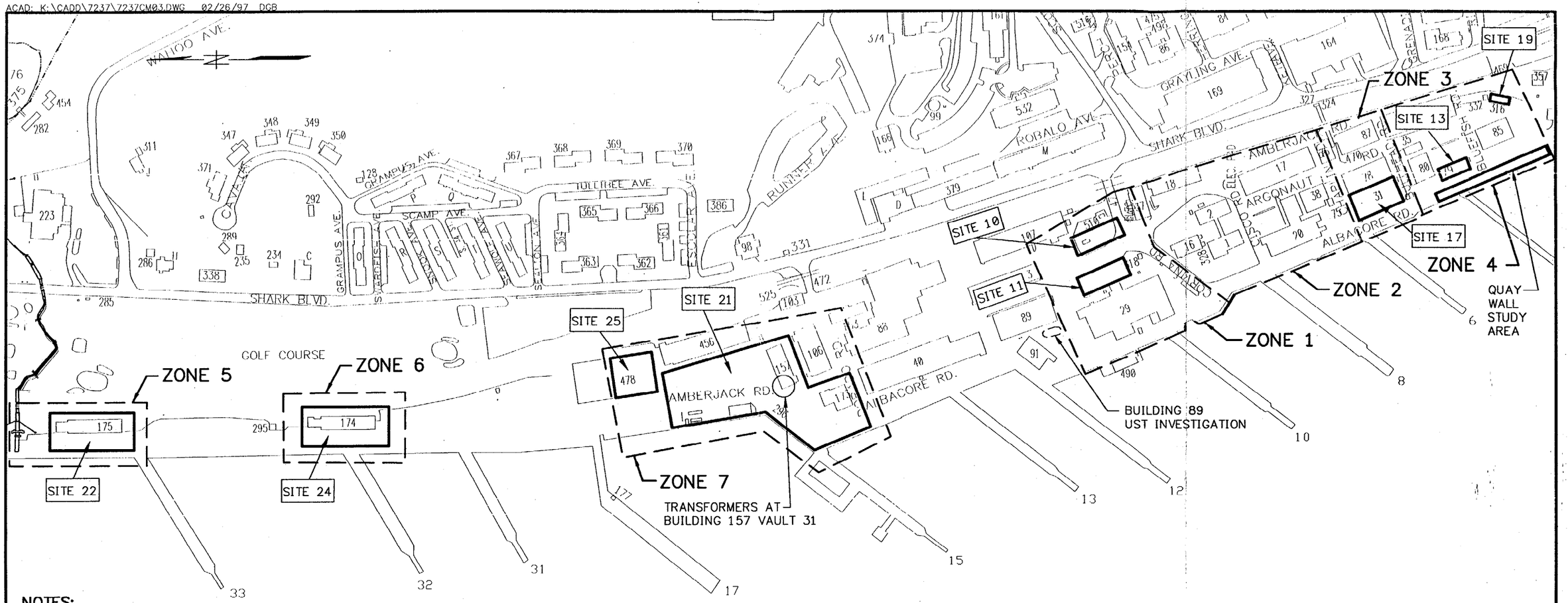

NOTES:

1. SITE AND STUDY AREA LOCATIONS WERE TAKEN FROM DRAWING 1, DRAFT FINAL PHASE II REMEDIAL INVESTIGATION REPORT, BROWN AND ROOT ENVIRONMENTAL, MARCH 1996.
2. SITE AND STUDY AREA BOUNDRIES ARE APPROXIMATE.
   - SITE 10 – FUEL STORAGE TANKS AND TANK 54–H
   - SITE 11 – POWER PLANT OIL TANKS
   - SITE 13 – BUILDING 79 WASTE OIL PIT
   - SITE 17 – HAZARDOUS MATERIALS/SOLVENT STORAGE AREA (BUILDING 31)
   - SITE 19 – SOLVENT STORAGE AREA (BUILDING 316)
   - SITE 21 – BERTH 16
   - SITE 22 – PIER 33
   - SITE 24 – CENTRAL PAINT ACCUMULATION AREA (BUILDING 174)
   - SITE 25 – CLASSIFIED MATERIALS INCINERATOR

LEGEND:

- — — — LOWER SUBASE REMEDIAL INVESTIGATION ZONE BOUNDARY
- ——— LOWER SUBASE REMEDIAL INVESTIGATION SITE OR STUDY AREA BOUNDARY

FIGURE 1–2

LOWER SUBASE
ZONE AND SITE LOCATION MAP
NSB–NLON, GROTON, CONNECTICUT

0 300 600
SCALE IN FEET

Brown & Root Environmental

0132802Z

ACAD: K:\CADD\7237\7237GM04.DWG 01/09/97 DT

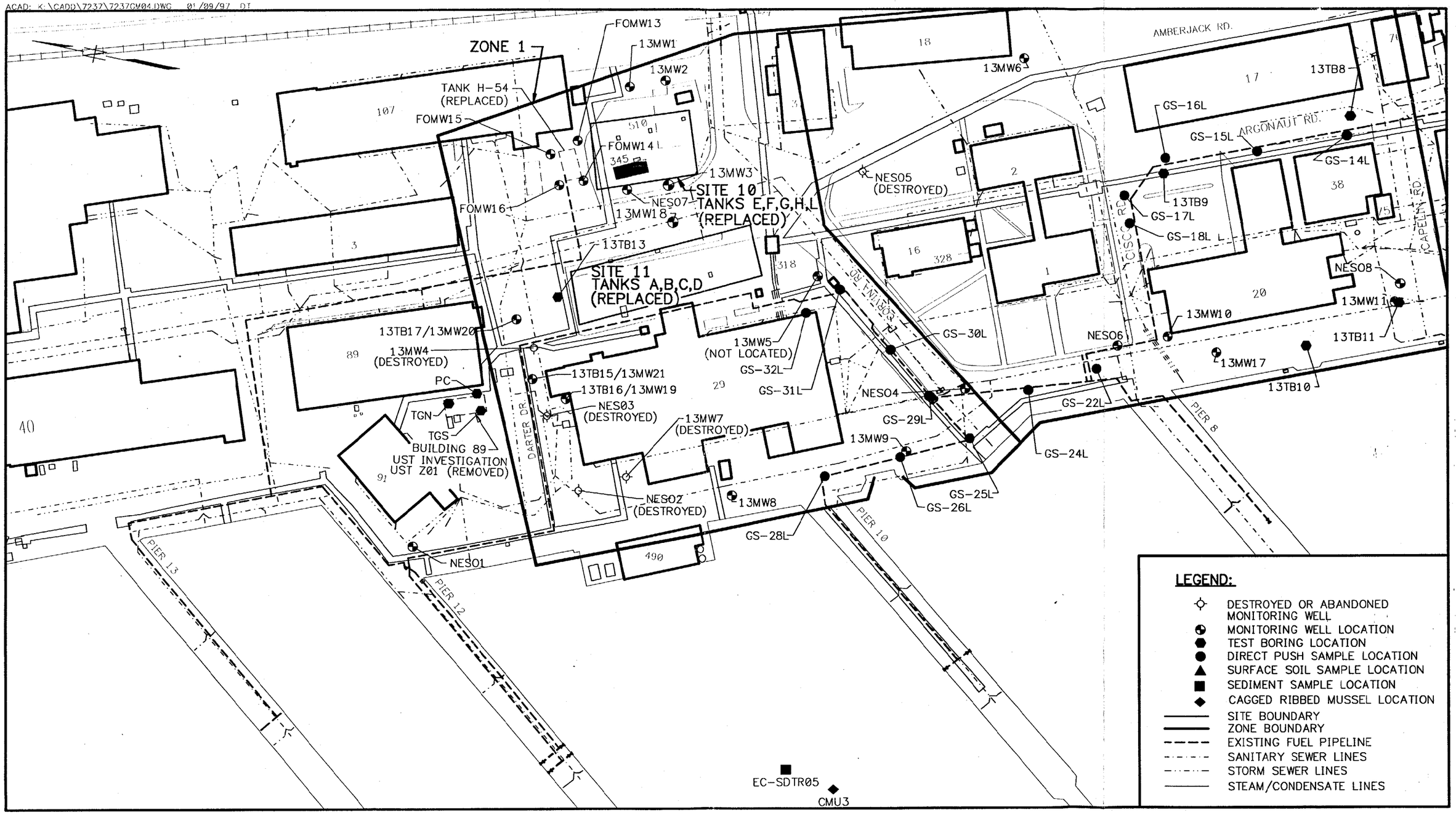

FIGURE 1-3

SITE LOCATION MAP
ZONE 1
NSB-NLON, GROTON, CONNECTICUT

0 90 180
SCALE IN FEET

019707/P (WP)

Brown & Root Environmental

CTO 0260

01328032

ACAD: K:\CADD\7237\7237GM05.DWG 01/09/97 DT

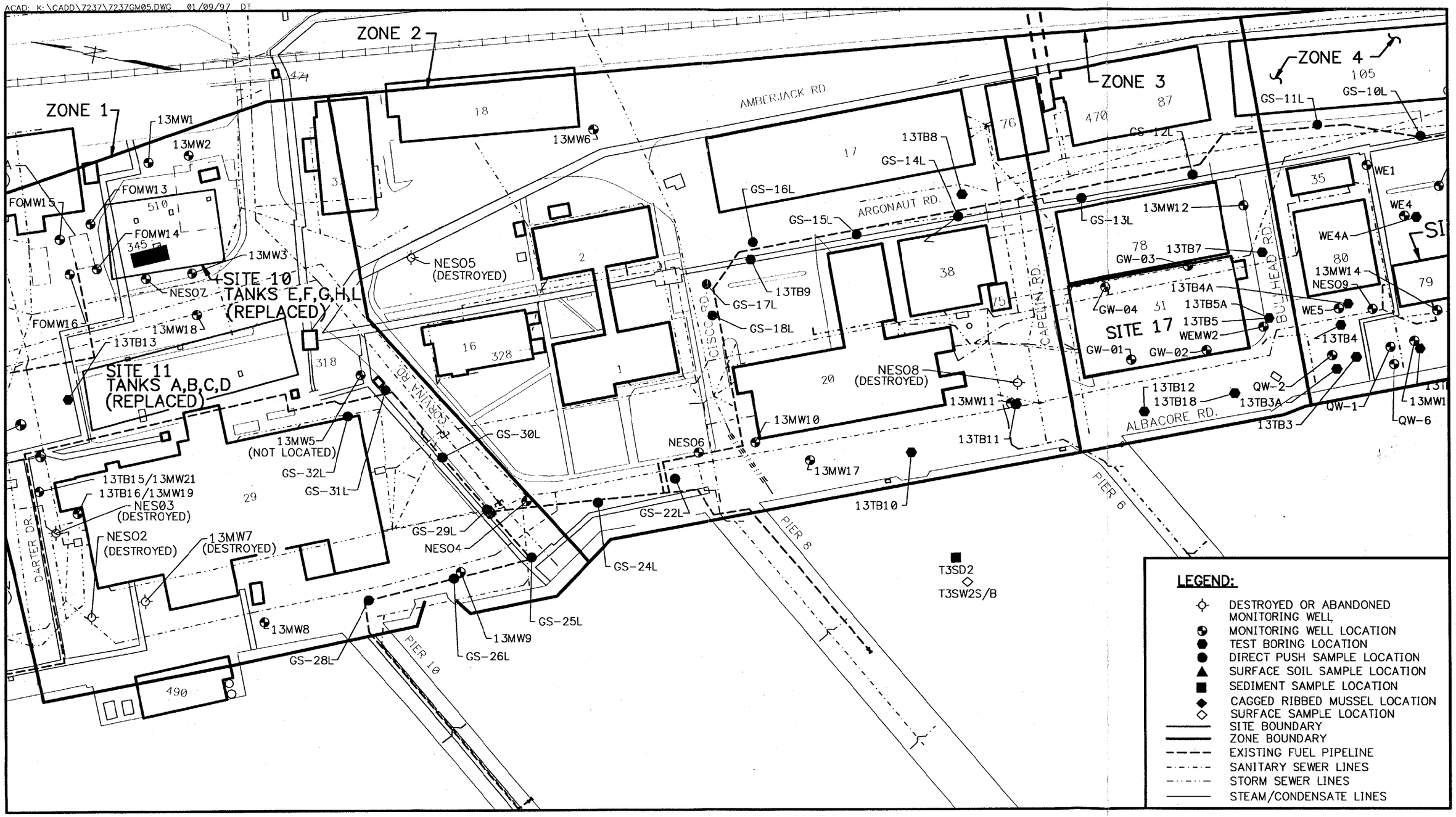

FIGURE 1-4

SITE LOCATION MAP
ZONE 2
NSB-NLON, GROTON, CONNECTICUT

0 90 180
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

ACAD: K:\CADD\7237\7237CM06.DWG 01/09/97 DT

0132 8042

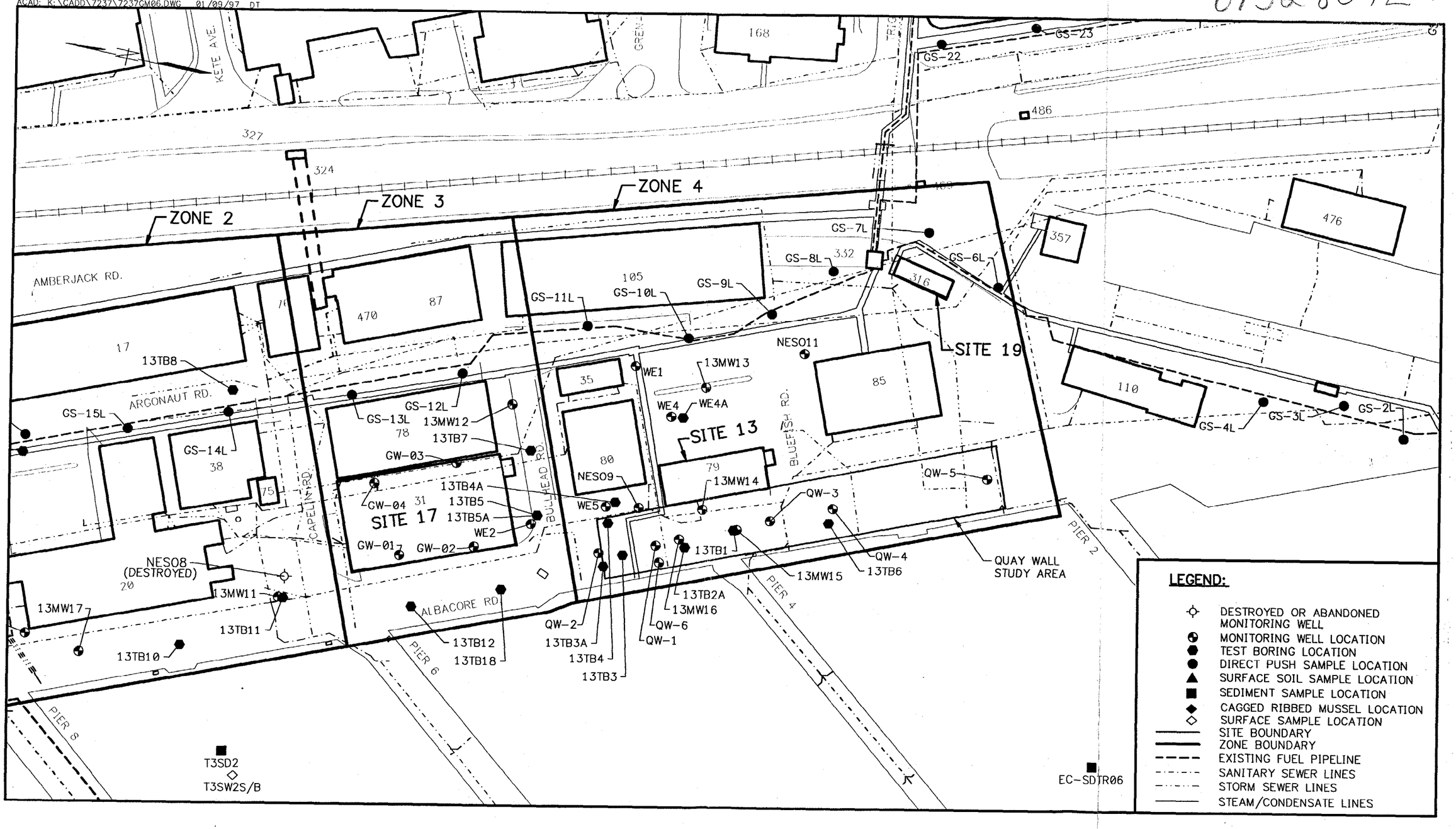

FIGURE 1-5

SITE LOCATION MAP
ZONE 3
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

019707/P (WP)

Brown & Root Environmental

CTO 0260

01328052

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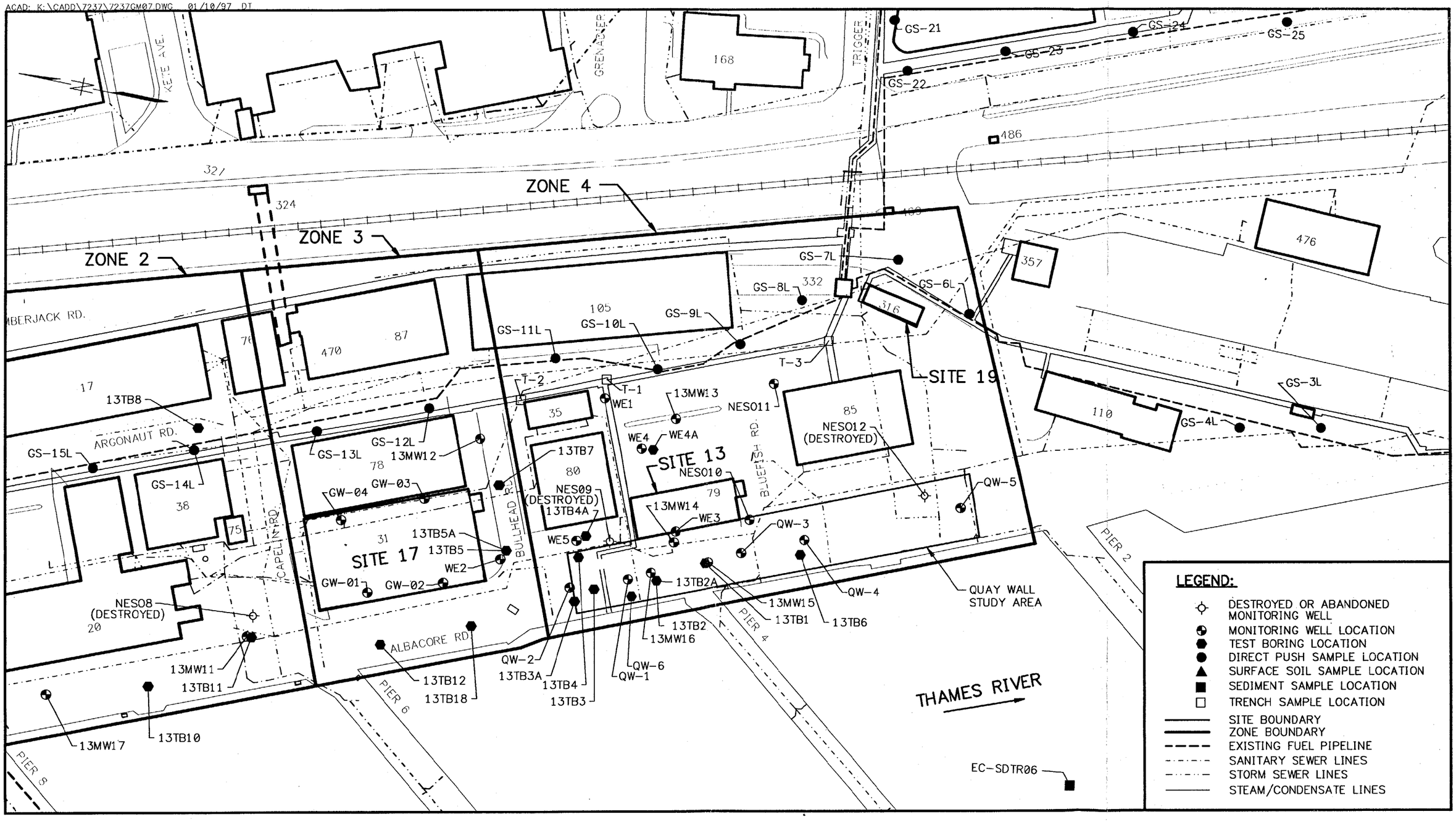


FIGURE 1-6

SITE LOCATION MAP
ZONE 4
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

01328062

ACAD: K:\CADD\7237\7237CM08.DWG 06/20/97 DT

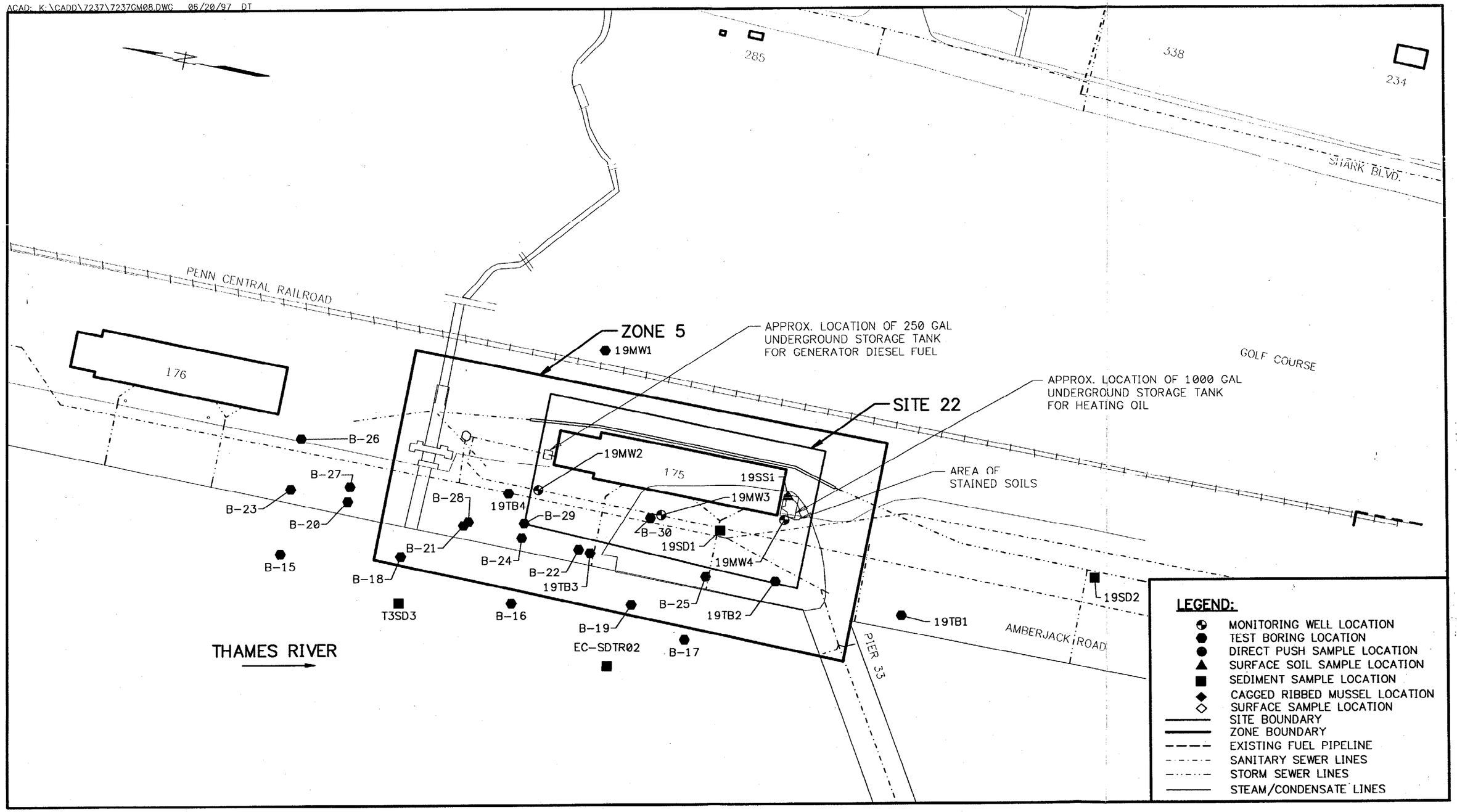


FIGURE 1-7

SITE LOCATION MAP
ZONE 5
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

Brown & Root Environmental

0132807Z

ACAD: K:\CADD\7237\7237GM09.DWG 12/20/96 DT

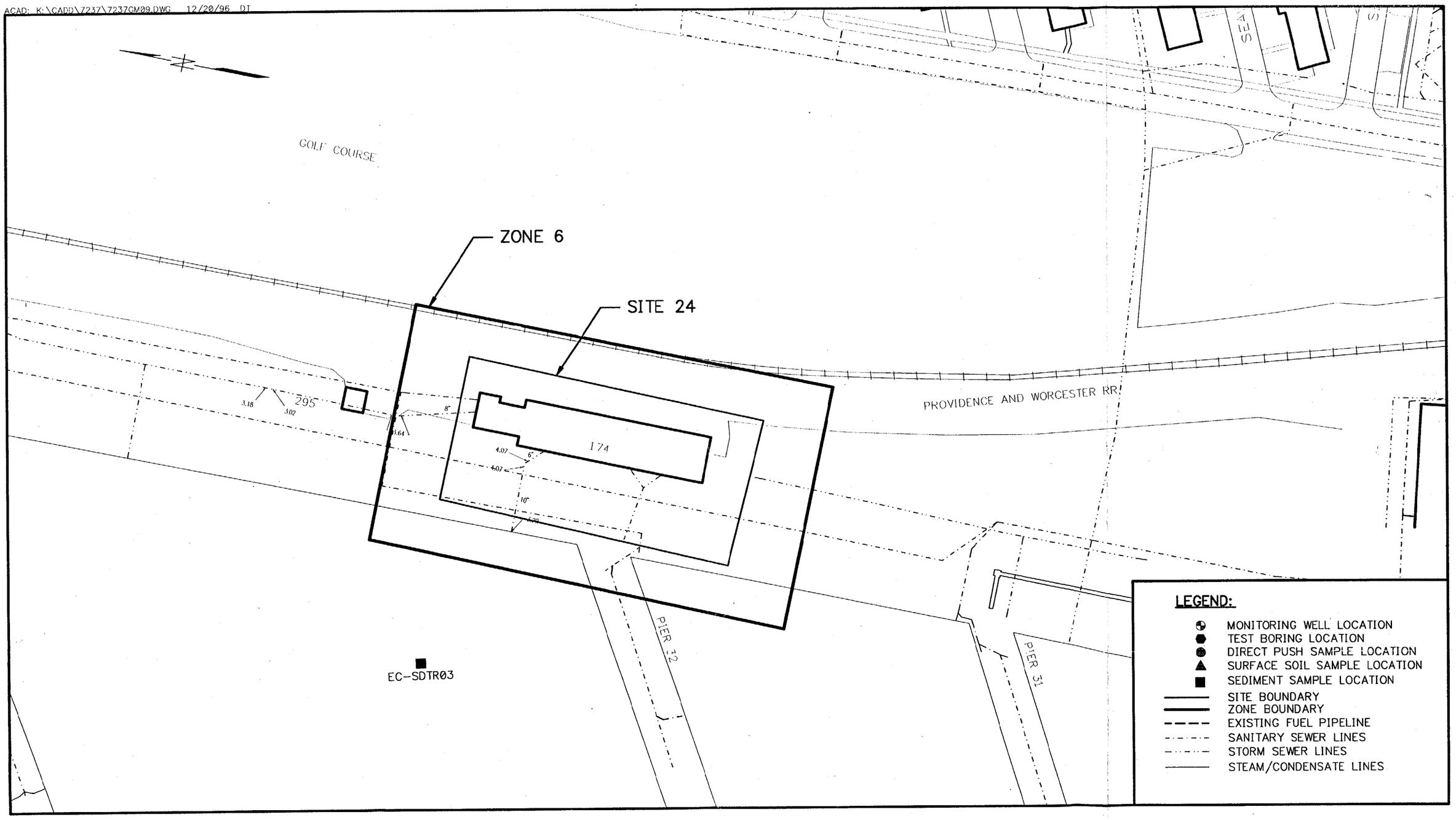


FIGURE 1-8

SITE LOCATION MAP
ZONE 6
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

ACAD: K:\CADD\7237\7237GM10.DWG 06/20/97 DT

01328082

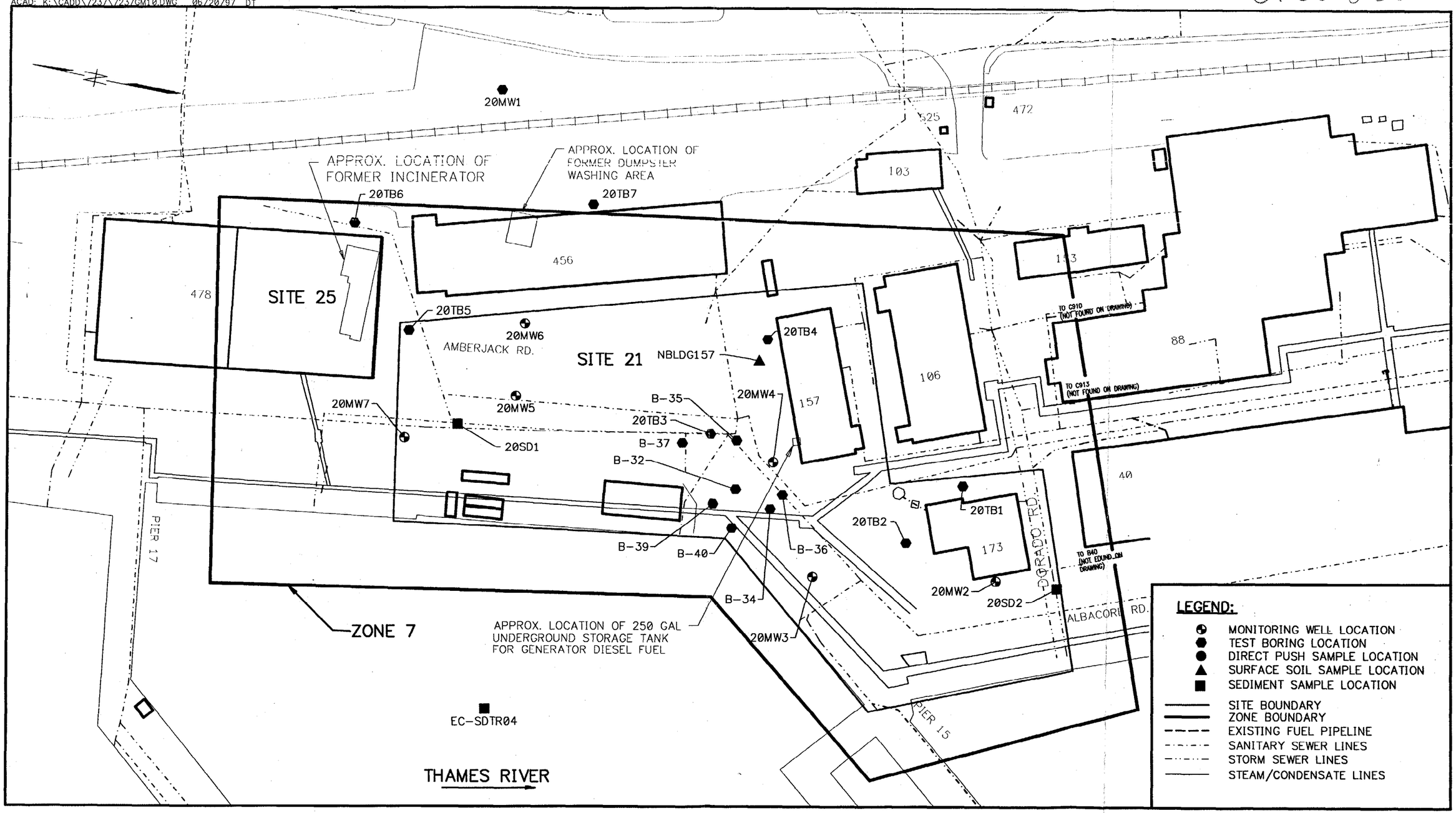


FIGURE 1-9

SITE LOCATION MAP
ZONE 7
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

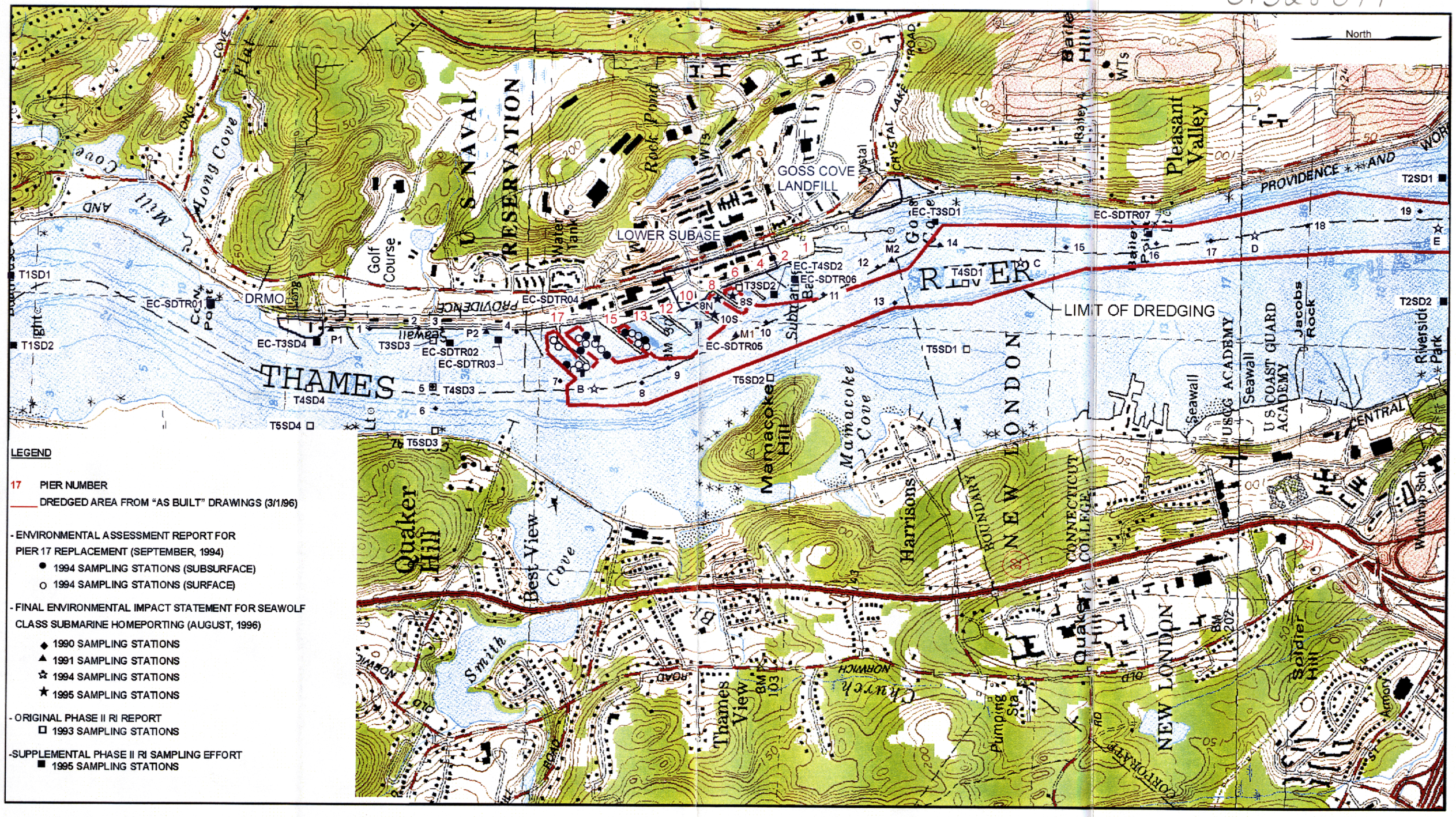
Brown & Root Environmental

019707/P (WP)

CTO 0260

K:\GIS\CD\9594\95940004.PSD 27-FEB-97 MJJ

0132809Y



LEGEND

17 PIER NUMBER

DREDGED AREA FROM "AS BUILT" DRAWINGS (3/1/96)

- ENVIRONMENTAL ASSESSMENT REPORT FOR PIER 17 REPLACEMENT (SEPTEMBER, 1994)
  - ● 1994 SAMPLING STATIONS (SUBSURFACE)
  - ○ 1994 SAMPLING STATIONS (SURFACE)
- FINAL ENVIRONMENTAL IMPACT STATEMENT FOR SEAWOLF CLASS SUBMARINE HOMEPORTING (AUGUST, 1996)
  - ◆ 1990 SAMPLING STATIONS
  - ▲ 1991 SAMPLING STATIONS
  - ☆ 1994 SAMPLING STATIONS
  - ★ 1995 SAMPLING STATIONS
- ORIGINAL PHASE II RI REPORT
  - □ 1993 SAMPLING STATIONS
- SUPPLEMENTAL PHASE II RI SAMPLING EFFORT
  - ■ 1995 SAMPLING STATIONS

FIGURE 1-10

0 1200 2400
SCALE IN FEET

THAMES RIVER SEDIMENT SAMPLING LOCATIONS AND LIMIT OF DREDGING
NSB-NLON, GROTON, CONNECTICUT

Brown & Root Environmental

019707/P (WP)

CTO 0260

01328102

ACAD: K:\CADD\7237\7237GM18.DWG 06/25/97 DT

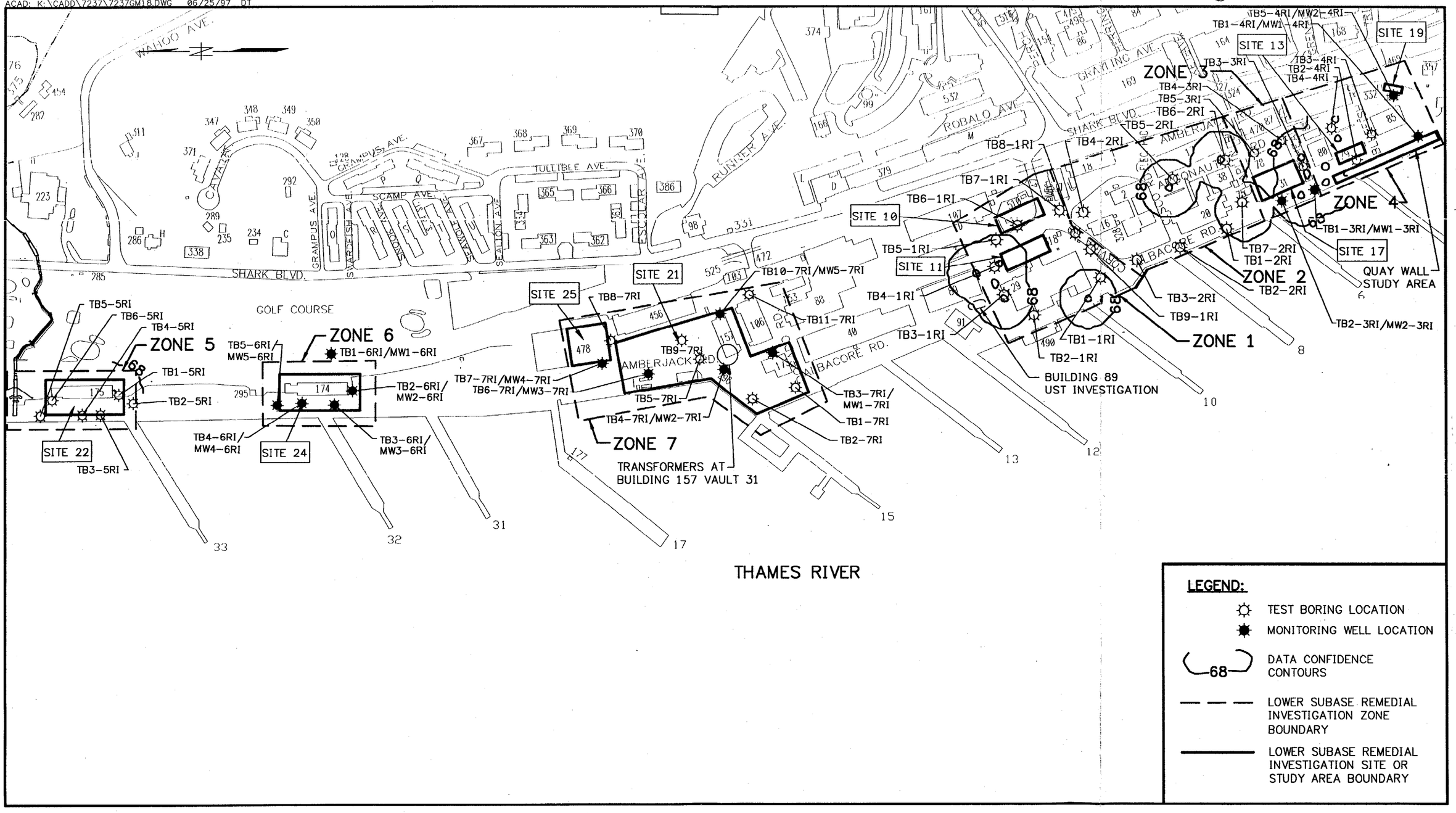


FIGURE 1-11

DATA CONFIDENCE LIMITS
FOR SHALLOW SOIL SAMPLES (TPH)
NSB-NLON, GROTON, CONNECTICUT

0 300 600
SCALE IN FEET

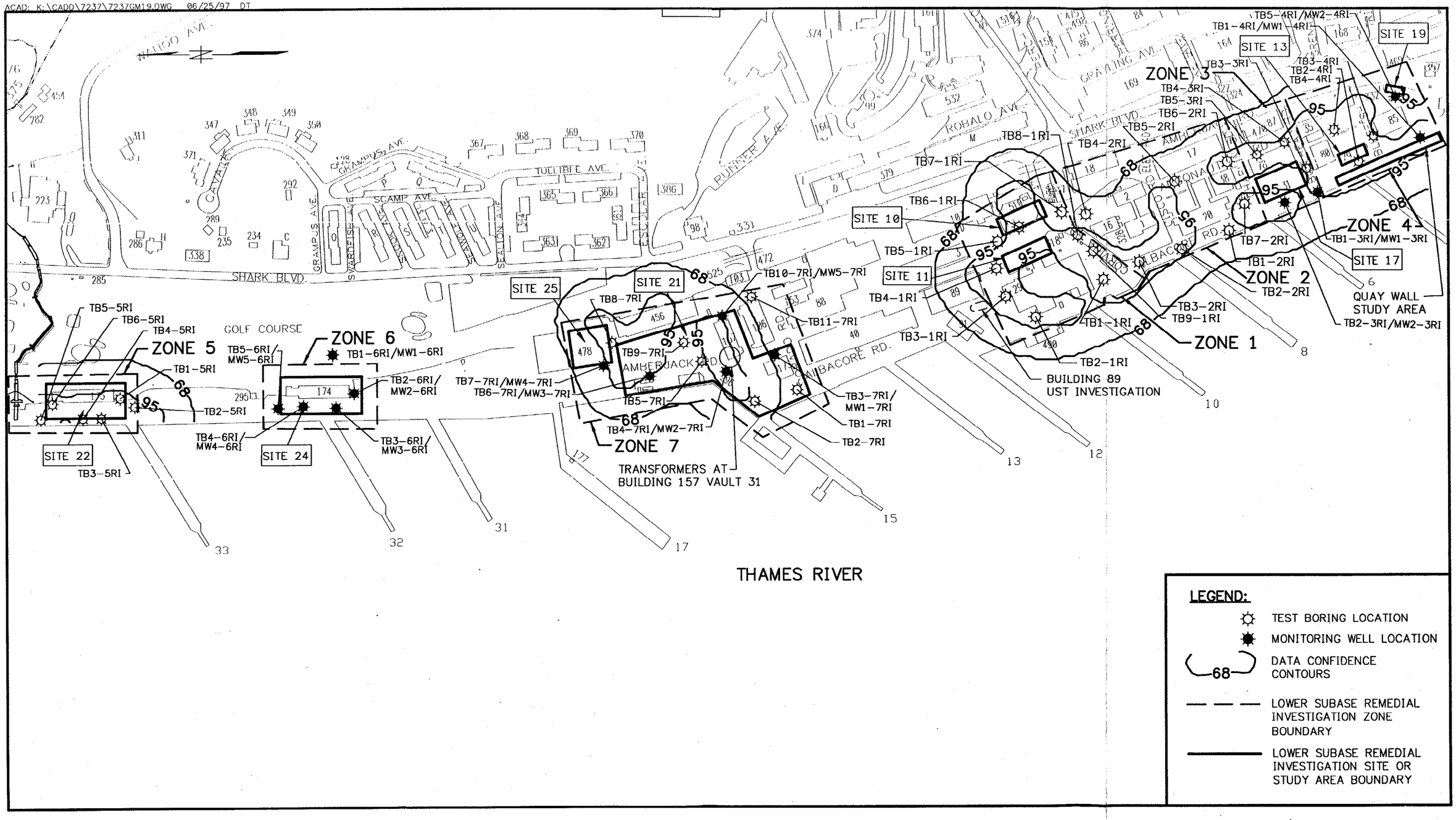
Brown & Root Environmental

019707/P (WP)

CTO 0260

0132811Z

ACAD: K:\CADD\7237\7237GM19.DWG 06/25/97 DT



LEGEND:

- TEST BORING LOCATION
- MONITORING WELL LOCATION
- 68 — DATA CONFIDENCE CONTOURS
- LOWER SUBASE REMEDIAL INVESTIGATION ZONE BOUNDARY
- LOWER SUBASE REMEDIAL INVESTIGATION SITE OR STUDY AREA BOUNDARY

0 300 600
SCALE IN FEET

FIGURE 1-12

DATA CONFIDENCE LIMITS
FOR DEEP SOIL SAMPLES RESULTS (TPH)
NSB-NLON, GROTON, CONNECTICUT

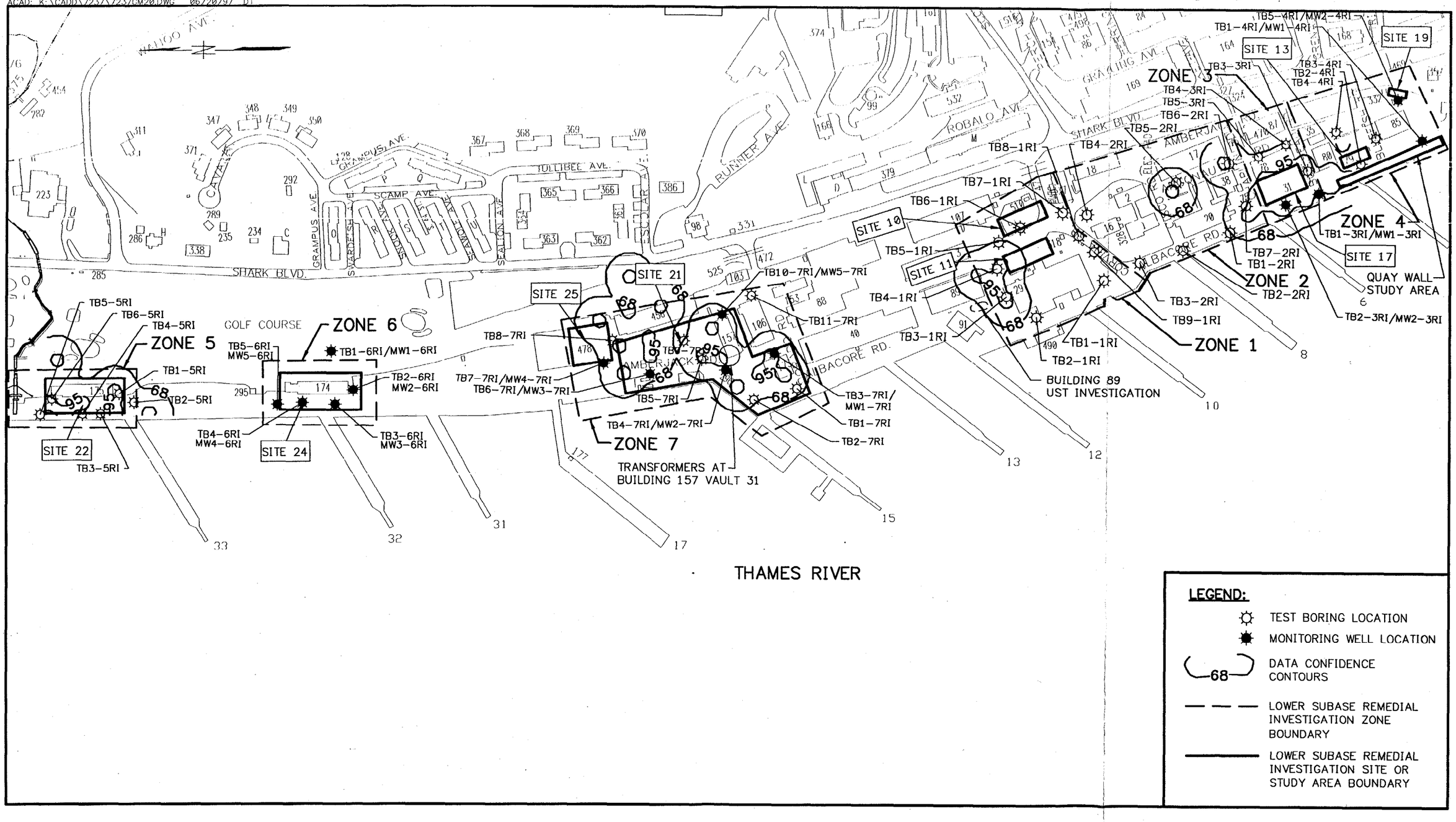
Brown & Root Environmental

019707/P (WP)

CTO 0260

0132812Z

ACAD: K:\CADD\7237\7237CM20.DWG 06/20/97 DT



DATA CONFIDENCE LIMITS
FOR SHALLOW SOIL SAMPLES RESULTS (LEAD)
NSB-NLON, GROTON, CONNECTICUT

0 300 600
SCALE IN FEET

FIGURE 1-13

Brown & Root Environmental

019707/P (WP)

CTO 0260

01328132

ACAD: K:\CADD\7237\7237GM21.DWG 06/20/97 DT

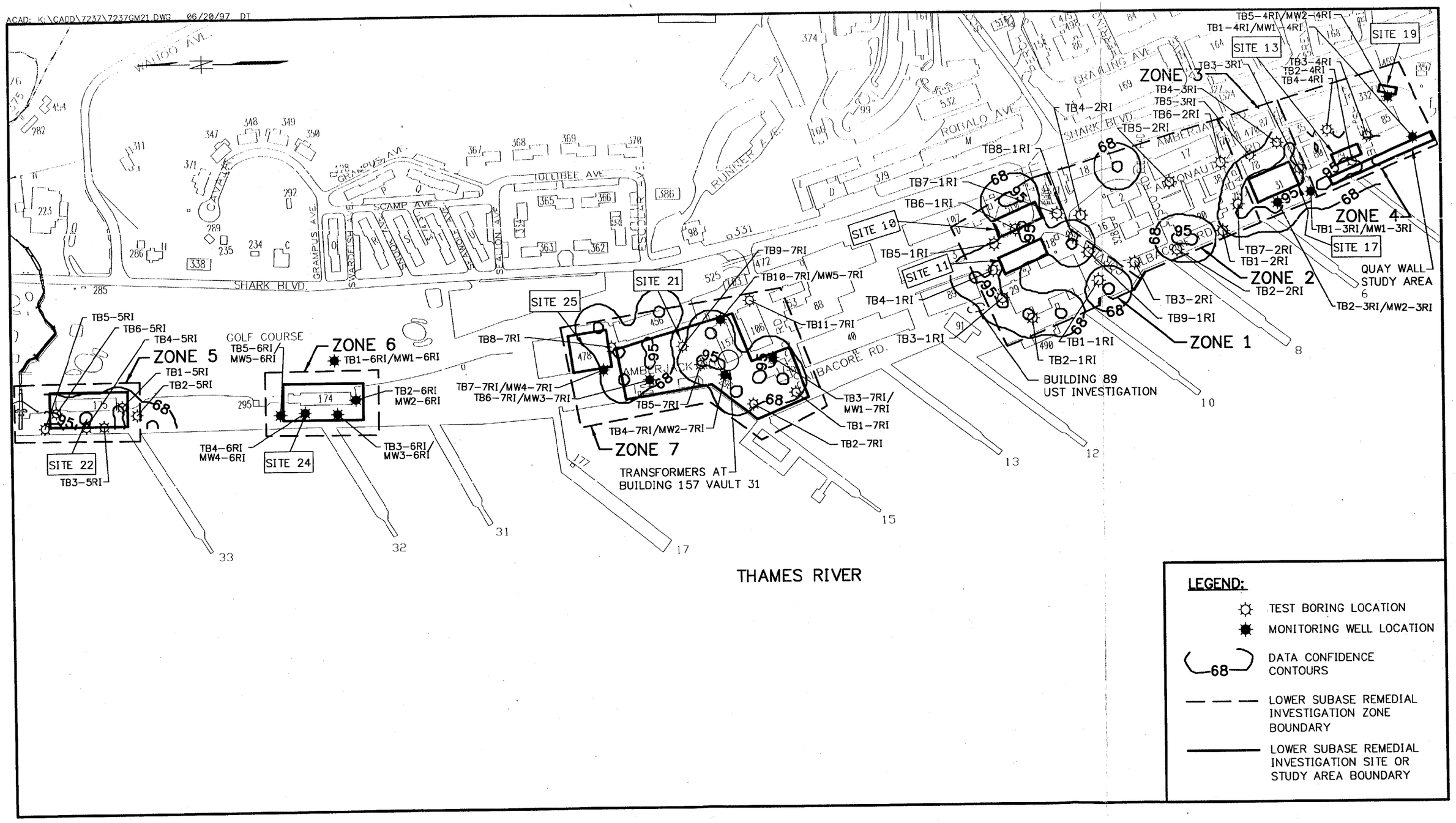


FIGURE 1-14

DATA CONFIDENCE LIMITS
FOR DEEP SOIL SAMPLE RESULTS (LEAD)
NSB-NLON, GROTON, CONNECTICUT

Brown & Root Environmental

0132814Z

ACAD: K:\CADD\7237\7237GM22.DWG 06/25/97 DT

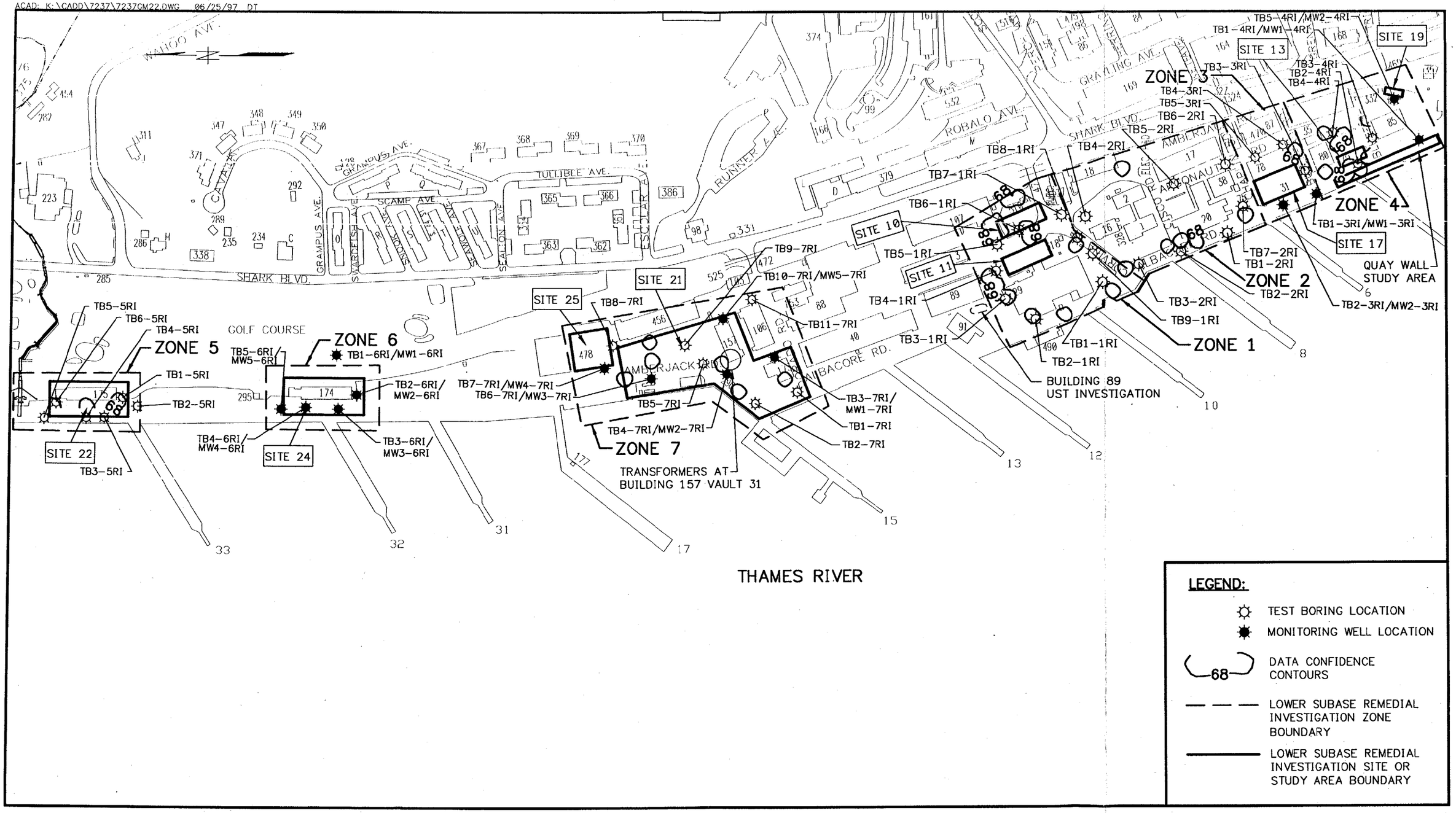


FIGURE 1-15

DATA CONFIDENCE LIMITS
FOR GROUNDWATER SAMPLE RESULTS (TPH)
NSB-NLON, GROTON, CONNECTICUT

Brown & Root Environmental

0132815Z

ACAD: K:\CADD\7237\7237GM23.DWG 06/25/97 DT

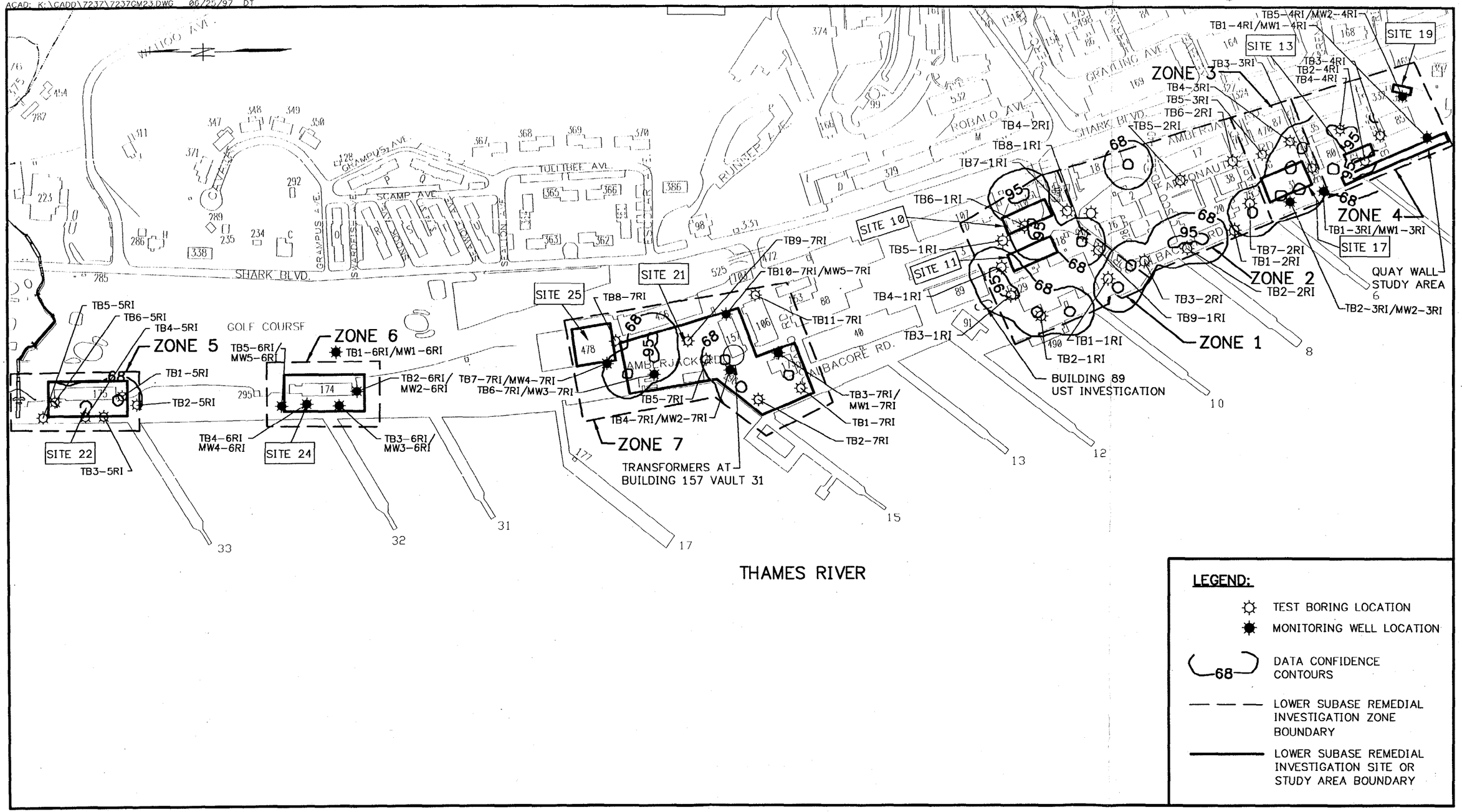


FIGURE 1-16

DATA CONFIDENCE LIMITS
FOR UNFILTERED GROUNDWATER RESULTS (LEAD)
NSB-NLON, GROTON, CONNECTICUT

0 300 600
SCALE IN FEET

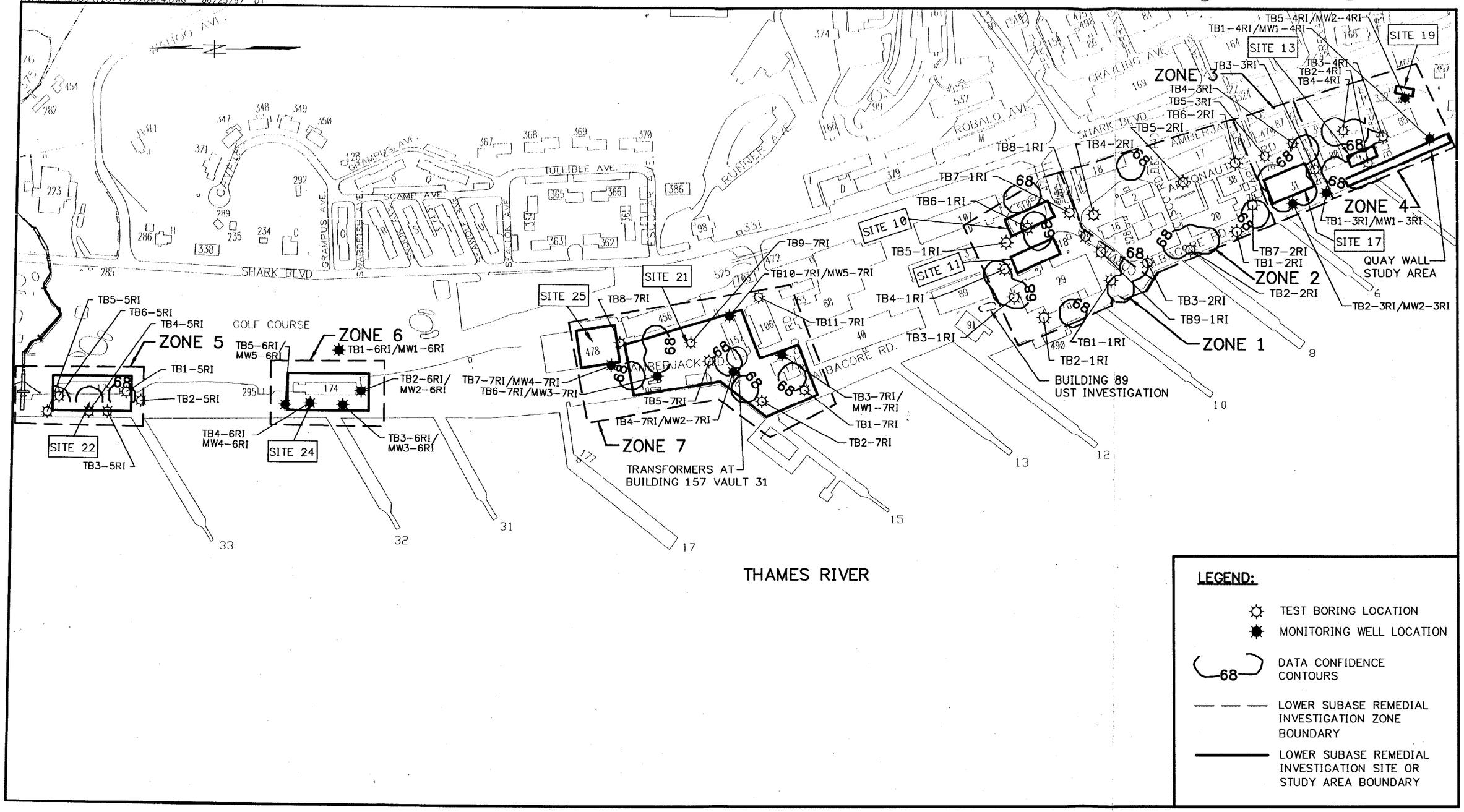
Brown & Root Environmental

019707/P (WP)

CTO 0260

0132816Z

ACAD: K:\CADD\7237\7237GM24.DWG 06/25/97 DT



LEGEND:

- TEST BORING LOCATION
- MONITORING WELL LOCATION
- 68 — DATA CONFIDENCE CONTOURS
- LOWER SUBASE REMEDIAL INVESTIGATION ZONE BOUNDARY
- LOWER SUBASE REMEDIAL INVESTIGATION SITE OR STUDY AREA BOUNDARY

FIGURE 1-17

DATA CONFIDENCE LIMITS
FOR FILTERED GROUNDWATER SAMPLE RESULTS (LEAD)
NSB-NLON, GROTON, CONNECTICUT

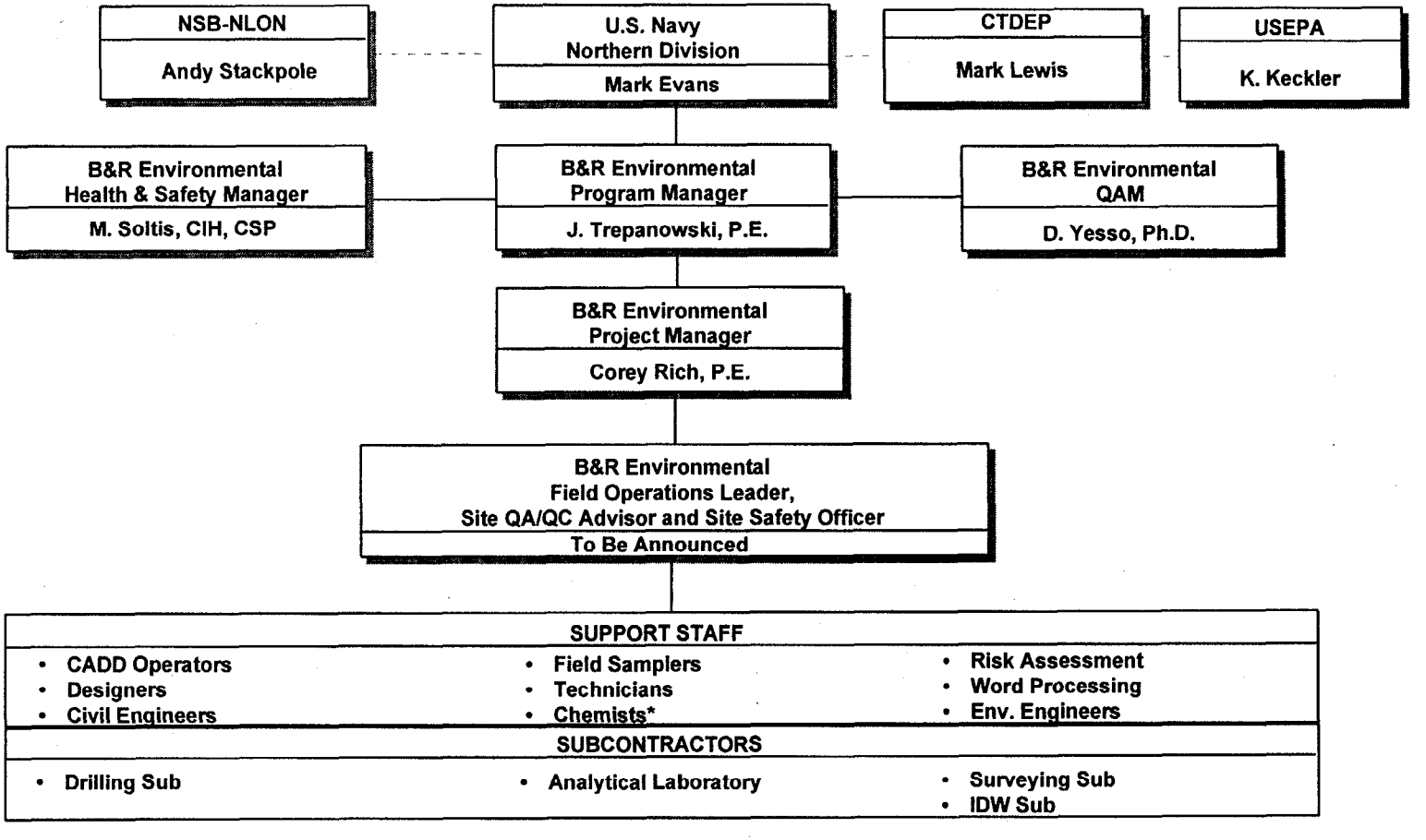
0 300 600
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

FIGURE 1-18
ORGANIZATIONAL CHART
NSB-NLON, GROTON, CONNECTICUT



*J. Samchuck will be responsible for data validation.

2.0 SAMPLING AND ANALYSIS PLAN

This Sampling and Analysis Plan discusses general sampling operations and procedures for the proposed sampling events to be performed at NSB-NLON. Details of the sampling events, including sample locations, sample analytes and rationale are provided.

2.1 FIELD OPERATIONS SUMMARY

The field operations are to be divided into two phases. Phase 1 involves site characterization at Zone 6 to identify the possible presence of contamination in soil and groundwater; collection of shallow and deep soil samples in Zones 1 through 5 and 7; and the installation and development of permanent groundwater monitoring wells at Zones 3, 4, 6 and 7. Phase 2 involves collection of groundwater samples, water level measurements and free-product thickness measurements from existing and newly installed monitoring wells and collection of sediment and surface water samples in the Thames River. Additional soil borings and groundwater monitoring wells (temporary or permanent) may be installed during Phase 2 at locations to be defined by the results of a geostatistical analysis of the soil and groundwater chemistry data collected from Phase 1. Table 2-1 summarizes the sample parameters, laboratory methods, and number of samples for each zone. Table 2-2 summarizes the test boring/monitoring well identifier, sample nomenclature and parameters to be tested at each location and sampling rationale. Figures 2-1 through 2-7 show proposed test boring, monitoring well and sediment sample locations.

Phase 1: Test borings will be drilled in the seven zones and shallow water table groundwater monitoring wells will be installed and developed at Zone 3 (2 wells), Zone 4 (2 wells), Zone 6 (5 wells), and Zone 7 (5 wells). Soil samples for this RI will be collected from two depths that are as follows:

1. Shallow depth [less than 5 feet below ground surface (bgs)]
2. Deep depth (5 to 12 feet bgs, to the top of the wooden pier platform or the water table)

Soil samples will be collected using direct push or hollow-stem auger (HSA) drilling techniques. Continuous soil coring or split-spoon sampling will be performed during this investigation to identify stratigraphy and potential contaminant zones. The majority of the soil sample will be placed in a laboratory sample jar immediately upon opening the split spoon sampler. A portion of each soil sample will be retained in a zip lock bag for purposes of screening with a PID/FID. Two soil samples with the highest PID/FID readings will be retained for laboratory analysis. The first soil sample will be the sample

with the highest PID/FID from a depth of 0 to 5-feet below ground surface (bgs) and the second will be the sample with the highest PID/FID reading from a depth of 5 to 12-feet bgs. In the absence of PID/FID readings above background levels, one soil sample will be collected from across the 2 to 4-foot bgs interval and one soil sample from across the water table/unsaturated soil interface or the top of the wooden pier platform.

Additional groundwater monitoring wells will be installed across the water table using HSA techniques. The additional groundwater monitoring wells will be installed in Zones 3, 4, 6, and 7. The newly installed groundwater monitoring wells will be developed with a submersible pump or polypropylene Waterra pump.

Phase 2: Selected existing groundwater monitoring wells will be sampled once during this investigation to compare to historic data trends (refer to Section 1.4.2 for rationale for selection of wells). The existing monitoring wells will be inspected for damage and surface water impact. Existing and newly installed groundwater monitoring wells will be purged and sampled using low flow purge and sampling techniques as described in Section 2.5 and USEPA Region I Standard Operating Procedure (SOP) GW001.

Sediment samples will be collected from the Thames River adjacent to the seven zones being investigated as part of this RI. Surface water quality parameters will be measured at each sediment sampling station. Measurements will be taken at the surface and bottom of the water column. The sediment sampling and surface water measurements will be conducted from a boat. Sample collection will occur adjacent to the potential contaminant source areas and storm sewer outfalls of each zone. Sediment and surface water sample locations will be surveyed at the time of sampling using a Global Positioning System (GPS). The sediment samples will be analyzed for TCL SVOC, TCL Pesticides (Zone 5, 1 sample only), TAL metals, TOC, grain size, AVS/SEM, pH and ammonia to fill data gaps and to evaluate bioavailability and toxicity for the ecological risk assessment.

Additional soil borings and/or groundwater monitoring wells (temporary or permanent) may be completed during Phase 2 using direct push or HSA drilling techniques. The locations of these borings and monitoring wells will be defined by the results of the geostatistical analysis of soil and groundwater data collected during Phase 1. In addition, the concentrations of lead detected in each zone will be evaluated between Phase 1 and Phase 2 to determine if the calculated average concentration is representative. It is possible that additional sampling for lead will need to be completed in Zones 3, 4, 6, and 7 during Phase 2. The final scope of the Phase 2 investigation will not be defined in this Sampling and Analysis Plan, but will be defined and approved by the regulators prior to initiation of the fieldwork.

2.2 MOBILIZATION AND DEMOBILIZATION

Following approval of the Work Plan, B&R Environmental will begin mobilization activities. These activities will include coordinating on-base utility clearances, subcontracted utility search services, mobilization of subcontractors, and mobilization of B&R Environmental staff and equipment. The FOL will coordinate the mobilization activities for this project. The equipment required for the field activities will be mobilized from the B&R Environmental Pittsburgh, Pennsylvania warehouse to the site by the FOL and the field crew. B&R Environmental personnel will submit proposed test boring and groundwater monitoring well location drawings to NSB-NLON engineering personnel for utility clearance purposes. These drawings will be submitted prior to the mobilization of staff or equipment. The FOL will then mobilize to the site to mark the proposed drilling locations with NSB-NLON personnel. The purpose of this mobilization will be to review each location for equipment access or logistic problems with on-going base activities. Subcontracted utility personnel will be mobilized to the site at this time to assist in the clearance of drilling locations. The FOL, NSB-NLON personnel, and project manager will review and agree upon any locations that have to be moved due to access, utility, or logistic problems prior to finalization.

All field team members will review the Sampling and Analysis Plan, the Health and Safety Plan and the Quality Assurance Project Plan upon completion of utility clearance activities. Prior to mobilization, a field team orientation meeting will be held to familiarize personnel with the scope of the field activities. Site specific Health and Safety training will be given to the field crew after they have mobilized to the site.

The FOL and crew will demobilize from the site upon completion of the field operations and transport all field equipment back to the Pittsburgh warehouse.

2.3 SAMPLE LOCATIONS

2.3.1 Zone 1

Nine test borings will be installed at Zone 1 with two soil samples collected from each location during Phase 1 of this RI. These test borings will be designated TB1-1RI through TB9-1RI (Figure 2-1). SVOC analysis will be performed on the shallow and deep soil samples collected from each of the soil boring locations. TPH and metals analysis will be performed on shallow soils samples collected at locations TB1-1RI, TB2-1RI and TB6-1RI (Tables 2-1, 2-2). Synthetic Precipitation Leaching Procedure (SPLP) for lead will be performed on samples collected from TB1-1RI and TB2-1RI.

Groundwater samples will also be collected from 16 of the existing groundwater monitoring wells at this site during Phase 2 of this RI. The monitoring well samples will be analyzed for TPH, TCL SVOCs, filtered and unfiltered TAL metals and natural attenuation parameters, as discussed in Section 1.4.4.

Four sediment samples will be collected and eight surface water quality measurements will be taken in the Thames River adjacent to Zone 1 during Phase 2 of this RI. The sediment samples will be designated SD1-1RI through SD4-1RI; and the surface water quality measurements will be designated SW1-1RI [shallow (S) or deep (D)] through SW4-1RI (S or D). Two of the sampling stations (i.e., SW/SD1-1RI and SW/SD4-1RI) are located adjacent to storm sewer outfalls from Zone 1. Station SW/SD3-1RI is located adjacent to areas of Zone 1 where high levels of contamination were detected. Station SW/SD2-1RI will provide further information to evaluate the nature and extent of contamination in the Thames River. The sediment samples are to be analyzed for TCL SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia. The surface water quality parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.3.2 Zone 2

Seven test borings will be installed at Zone 2 during Phase 1 of this RI. These test borings are designated TB1-2RI through TB7-2RI (Figure 2-2). SVOC analysis will be performed for each soil sample at each test boring location. Shallow soil samples will be analyzed for the presence of TPH at locations TB1-2RI, TB2-2RI and TB3-2RI. TAL metals analysis will be performed on deep soil samples from locations TB4-2RI, TB5-2RI and TB6-2RI. SPLP lead analysis will be performed on samples collected from TB5-2RI and TB6-2RI.

Groundwater samples will be collected from five existing groundwater monitoring wells at Zone 2 during Phase 2 of this RI. The monitoring well samples will be analyzed for TPH, TCL SVOCs, filtered and unfiltered TAL metals and natural attenuation parameters as discussed in Section 1.4.4.

Two sediment samples will be collected and four surface water quality measurements will be taken in the Thames River adjacent to Zone 2 during Phase 2 of this RI. The sediment samples will be designated SD1-2RI and SD2-2RI and the surface water quality measurements will be designated SW1-2RI (S or D) through SW2-2RI (S or D). Station SW/SD2-2RI is located adjacent to a storm sewer outfall from Zone 2. Station SW/SD1-2RI is located upgradient of Pier 6 and will provide further information to determine the nature and extent of contamination in the Thames River. The sediment samples will be analyzed for TCL SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia. The surface water quality

parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.3.3 Zone 3

Five test borings will be installed at Zone 3 during Phase 1 of this RI. These test borings are designated TB1-3RI through TB5-3RI (Figure 2-3). SVOC analysis will be performed on each soil sample from each test boring location. Shallow soil samples from test borings TB1-3RI, TB2-3RI, and TB4-3RI will be analyzed for TPH. TAL metals analysis will be performed on the shallow and deep soil samples at locations TB1-3RI, TB2-3RI and TB5-3RI. SPLP lead analysis will be performed on shallow soil samples collected at TB1-3RI and TB2-3RI and on deep soil samples collected at TB2-3RI and TB5-3RI.

Groundwater samples will be collected from existing groundwater monitoring well 13MW12 and newly installed groundwater monitoring wells MW1-3RI and MW2-3RI during Phase 2 of this RI. The screened interval of the newly installed monitoring wells will intersect the water table. The groundwater sample will be analyzed for TPH, TCL SVOC, filtered and unfiltered TAL metals and natural attenuation parameters.

Two sediment samples will be collected and four surface water quality measurements will be taken in the Thames River adjacent to Zone 3 during Phase 2 of this RI. The sediment samples will be designated SD1-3RI and SD2-3RI and the surface water quality measurements will be designated SW1-3RI (S or D) through SW2-3RI (S or D). Station SW/SD2-3RI is located adjacent to Zone 3 where high levels of contamination were detected. Station SW/SD1-3RI is centrally located between Piers 4 and 6 and will provide additional information on the nature and extent of contamination in the Thames River. The sediment samples will be analyzed for TCL SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia. The surface water quality parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.3.4 Zone 4

Five test borings will be installed at Zone 4 during Phase 1 of this RI. These test borings are designated TB1-4RI through TB5-4RI (Figure 2-4). SVOC analysis will be performed on each soil sample from each test boring. TPH and TAL metals analysis are to be performed on shallow soil samples from location TB1-4RI, TB3-4RI and TB5-4RI. TAL metals analyses will be performed on the deep soil samples from these same locations. SPLP lead analysis will be performed on shallow and deep soil samples from location TB1-4RI, TB3-4RI, and TB5-4RI.

Groundwater samples will be collected from eleven existing groundwater monitoring wells and two new groundwater monitoring wells to be installed during Phase 1 of this RI investigation. The newly installed groundwater monitoring wells will be designated MW1-4RI and MW2-4RI. The screened interval of the newly installed monitoring wells will intersect the water table. The groundwater samples will be analyzed for TPH, TCL SVOCs, filtered and unfiltered TAL metals and natural attenuation parameters.

Three sediment samples will be collected and six surface water quality measurements will be taken in the Thames River adjacent Zone 4 during Phase 2 of this RI. The sediment samples will be designated SD1-4RI through SD3-4RI, and the surface water quality measurements will be designated SW1-4RI (S or D) through SW3-4RI (S or D). Stations SW/SD1-4RI and SW/SD3-4RI are located adjacent to areas of Zone 4 where high levels of contamination have been detected. Station SW/SD2-4RI is centrally located between Piers 2 and 4 and will provide additional information on the nature and extent of contamination the Thames River. The sediment samples will be analyzed for TCL SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia. The surface water quality parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.3.5 Zone 5

Six test borings will be installed at Zone 5 during Phase 1 of this RI. These test borings are designated TB1-5RI through TB6-5RI (Figure 2-5). SVOC analysis will be performed for each soil sample from each test boring. Samples collected within the shallow soil depths at each of the five test boring locations will be analyzed for TPH. TAL metals analysis and SPLP lead analysis will be performed on the shallow and deep soil samples collected from TB1-5RI and TB6-5RI.

Groundwater samples will be collected from three existing groundwater monitoring wells at Zone 5 during Phase 2 of this RI. The monitoring well samples will be analyzed for TPH, TCL SVOCs, filtered and unfiltered TAL metals and natural attenuation parameters.

Four sediment samples will be collected and eight surface water quality measurements will be taken in the Thames River adjacent to Zone 5 during Phase 2 of this RI. The sediment samples will be designated SD1-5RI through SD4-5RI, and the surface water quality measurements will be designated SW1-5RI (S or D) through SW4-5RI (S or D). Stations SW/SD1-5RI and SW/SD3-5RI are located adjacent to storm sewer outfalls from Zone 5. Station SW/SD4-5RI is located at the confluence of Stream 6 from the Area A Downstream and the Thames River. Station SW/SD2-5RI is located upstream of Pier 33 and will provide additional information on the nature and extent of contamination in the Thames River. The sediment samples are to be analyzed for TCL SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia.

One sediment sample (i.e., the one collected at SD4-5RI) will also be analyzed for TCL pesticides. The surface water quality parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.3.6 Zone 6

Five test borings (TB1-6RI through TB5-6RI) will be installed and converted to groundwater monitoring wells at Zone 6 during Phase 1 of this RI. The groundwater monitoring wells will be designated MW1-6RI through MW5-6RI (Figure 2-6). The screened interval of the newly installed monitoring wells will intersect the water table.

Shallow and deep soil samples will be analyzed for TPH, TCL SVOCs, TCL VOCs and TAL metals. TCL VOC analysis is included because no data is available for this Zone. SPLP followed by TAL metals analysis will be performed on shallow and deep soil samples collected from TB1-6RI/MW1-6RI, TB3-6RI/MW3-6RI and TB4-6RI/MW4-6RI.

Groundwater samples will be collected from the five newly installed monitoring wells during Phase 2. The groundwater samples will be analyzed for TPH, TCL SVOCs, TCL VOCs, TAL metals (unfiltered and filtered), and natural attenuation parameters.

Two sediment samples will be collected and four surface water quality measurements will be taken in the Thames River adjacent to Zone 6 during Phase 2 of this RI. The sediment samples will be designated SD1-6RI through SD2-6RI, and the surface water samples will be designated SW1-6RI (S or D) through SW2-6RI (S or D). Both sampling stations are located adjacent to storm sewer outfalls from Zone 6. The sediment samples will be analyzed for SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia. The surface water quality parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.3.7 Zone 7

Eleven test borings will be installed at Zone 7 during Phase 1 of this RI. These test borings will be designated TB1-7RI through TB11-7RI (Figure 2-7). Five of the borings will be converted into groundwater monitoring wells with screened intervals that intersect the groundwater table. The borings to be converted and the associated monitoring well name are as follows: TB3-7RI/MW1-7RI, TB4-7RI/MW2-7RI, TB6-7RI/MW3-7RI, TB7-7RI/MW4-7RI, and TB10-7RI/MW5-7RI. Soil samples from each test boring location will be analyzed for SVOCs. Shallow soil samples will be analyzed for TPH at

locations TB1-7RI through TB11-7RI. Shallow and deep soil samples from TB6-7RI, TB9-7RI, TB10-7RI, and TB11-7RI will be analyzed for TAL metals. Shallow and deep soil samples from TB6-7RI and TB10-7RI will also be analyzed for SPLP lead.

Groundwater samples will be collected during Phase 2 from six existing ground water monitoring wells and five groundwater monitoring wells installed during Phase 1 of this RI. The groundwater samples will be analyzed for TPH, TCL SVOCs, filtered and unfiltered TAL metals and natural attenuation parameters.

Three sediment samples will be collected and six surface water quality measurements will be taken in the Thames River adjacent to Zone 7. The sediment samples will be designated SD1-7RI through SD3-7RI, and the surface water quality measurements will be designated SW1-7RI (S or D) through SW3-7RI (S or D). Stations SW/SD1-7RI and SW/SD3-7RI are located adjacent to storm sewer outfalls from Zone 7. Station SW/SD2-7RI is located in an area between Piers 15 and 17 which could be depositional in nature. The sediment samples will be analyzed for TCL SVOCs, TAL metals, TOC, grain size, AVS/SEM, pH, and ammonia. The surface water quality parameters to be measured include temperature, salinity, turbidity, pH, specific conductance, and dissolved oxygen.

2.4 INVESTIGATION METHODOLOGIES AND TECHNIQUES

2.4.1 Direct Push Methods

A Geoprobe™ or other similar direct push technology will be used to collect shallow and deep soil samples during Phase 1 and to collect additional soil samples or to install temporary groundwater monitoring wells during Phase 2, if determined necessary. The purpose of using a Geoprobe™ or other similar technology is to generate less investigation derived waste (IDW), minimize decontamination time, and minimize access space required relative to conventional drilling methods. HSA drilling methods will be used at locations where permanent monitoring wells are to be installed.

The limitation of using direct push methods is the volume of sample that can be recovered. Because of this limitation, this methodology will only be used at locations that require a limited suite of analysis (i.e., two analytes or less). A total of 25 of the 48 borings to be installed for the investigation will be completed by direct push methods.

A concrete coring device will be concurrently mobilized to the site with the Geoprobe™ equipment. The coring device will cut concrete to minimize borehole drill time and to extend the life of the drill bit.

Continuous soil sampling will be performed from below the concrete or asphalt surface to the top of the wooden pier structure or the water table, which ever is encountered first, using a macro-core sampler and following procedures outlined in B&R Environmental SOP SA-1.3 (Appendix B). The purpose of performing continuous soil sampling is to identify potential zones of contamination, collect soil samples for field screening with a PID/FID, collect soil samples for laboratory analysis and to characterize the soil stratigraphy. Each sample will be monitored with a PID/FID meter. Results of the vapor monitoring will be recorded onto B&R Environmental Boring Logs (Appendix A). Soil samples will be collected and logged following procedures outlined in B&R Environmental's SOP SA 1.3 (Appendix B).

A shallow and deep soil sample will be collected for laboratory analysis at each test boring location. The shallow soil sample will be collected from a depth of less than five feet bgs, and the deep soil sample will be collected from a depth greater than five feet bgs. The purpose of the shallow soil sampling is to identify the presence of contaminant sources such as spills or releases from tanks or pipelines. The purpose of the deep sample will be to delineate the extent of contaminated soils associated with past releases or spills. The selection of samples for laboratory analysis will be based on the results of field screening with a PID/FID. If no PID/FID readings above background levels are observed, the shallow sample from a depth of 2 to 4 feet bgs and the deep soil sample from the water table/soil interface or from the top of the wooden pier structure, which ever is encountered first, will be selected for laboratory analysis.

All borings will be backfilled with bentonite chips and patched with neat cement and/or cold-patch asphalt at grade. Care will be taken to return each location to its original condition prior to sampling. Each boring location will be revisited after 24 hours of backfilling to re-apply cement-grout or cold-patch, if necessary.

All direct push equipment will be steam cleaned prior to the start of the field investigation, decontaminated between each borehole to prevent cross-borehole contamination and steam cleaned prior to leaving the site, as discussed in Section 2.7.

2.4.2 Hollow Stem Augering and Permanent Monitoring Well Drilling/Installation

Forty-eight soil borings will be completed during Phase 1 of the investigation. Twenty-three will be installed by direct push methods, fourteen will be installed by HSA drilling techniques and converted to monitoring wells, and eleven will also be installed by HSA drilling techniques for shallow and deep soil sampling purposes only. HSA drilling techniques are necessary at eleven locations because of the larger sample volume required for the suite of analytes. These locations typically have three or more parameters in the suite of analytes.

Five groundwater monitoring wells will be installed at Zones 6 and 7, and two at Zones 3 and 4 during Phase 1 of this RI. The purpose of these groundwater monitoring wells will be to examine the presence or absence of TPH, VOC (Zone 6 only), SVOC and total/dissolved metals contamination within the shallow groundwater regime and the viability of natural attenuation.

Borings and monitoring wells will be installed using HSA drilling techniques, as per B&R Environmental SOPs GH-1.3 and GH-2.8, respectively (Appendix B) with the following exception. A secondary sand filter pack will be used during monitoring well installation in place of the normal bentonite seal specified in SOP GH-2.8. The use of the filter pack is necessary because of the following reasons. The monitoring wells will be installed across the groundwater table in which case the bentonite seal would typically be above the water table and could become dehydrated, shrink or crack. If this would happen, the seal would be ineffective. Furthermore, the groundwater at the Lower Subase is tidally influenced and the bentonite seals could, on occasion, be inundated with groundwater with high concentrations of chloride and total dissolved solids. It has been shown that the effectiveness of bentonite may be reduced in groundwater that exhibits high total dissolved solids, high chloride content, and several classes of contaminants (i.e., xylene, acetone, acetic acid, aniline, ethylene glycol methanol heptane, some chlorinated solvents and some petroleum hydrocarbons).

A secondary filter pack is a layer of material placed in the annulus between the primary filter pack and the cement-bentonite grout. The secondary filter pack should be uniformly graded fine sand with 100 percent by weight passing the No. 30 U.S. Standard sieve, and less than 2 percent by weight passing the 200 U.S. Standard sieve. The secondary filter pack will be unaffected by high total dissolved solids, high chloride content, or the class of contaminants.

Continuous split spoon sampling will be performed at each proposed boring and monitoring well location following methods outlined in B&R Environmental SOP SA-1.3 (Appendix B). The purpose of performing continuous split spoon sampling is to identify potential zones of contamination, collect soil samples for field screening with a PID/FID, collect soil samples for laboratory analysis and to characterize the soil stratigraphy. Vapors from the split spoon samples will be monitored with a PID/FID meter. Results of the vapor monitoring will be recorded on boring logs.

Two soil samples from each boring and groundwater monitoring well location will be collected and analyzed at a fixed base laboratory. The same criteria for selection of direct push samples for analyses (Section 2.4.1) will be applied for soil samples collected using split spoon sampling.

HSAs will have a minimum 4¼-inch inside diameter (ID) to accommodate installation of casing, sand pack, and well seal materials. A 2-foot long, 3-inch inside diameter split-spoon sampler will be used for sampling. This size split-spoon will provide an adequate volume of soil for samples, duplicates, and MS/MSDs.

All groundwater monitoring wells will be constructed of two-inch ID flush jointed riser pipe and five-foot-long slotted screens. Clean sand (No. 20 to 30 U.S. Standard Sieve size) will be filled in the annulus from six-inches below the well screen, around the well screen, and up to three feet above the top of the screen. A secondary sand filter pack (total thickness of two feet) will be installed above the sand as described above. The remaining annular space will be backfilled with a cement-bentonite grout. Each monitoring well will be equipped with a slightly raised flush-mounted surface steel protective casing with a neat Portland cement pad.

All field related data will be recorded by a B&R Environmental geologist on boring log forms and in the field log book dedicated to this project. Examples of field forms are provided in Appendix A. At a minimum, the boring logs will contain the sample numbers and types, sample depths, standard penetration data, sample recovery/interval, soil density or cohesiveness, soil color and moisture, Unified Soil Classification System (USCS) material description, and organic vapor information. Well completion details will also be recorded onto B&R Environmental forms. This information will include borehole diameter, type and diameter of casing, total installation depth, screen elevations, sand filter pack elevations, seal elevations and type of protective casing.

The borings not converted to monitoring wells will be abandoned. Abandonment will include backfilling with cement-bentonite grout using a tremie pipe if standing water is present. If standing water is not present, then borings will be backfilled with bentonite chips to 2 feet bgs. The remaining two feet will be backfilled using a cement bentonite grout. The borings will be revisited after 24 hours of completion to re-apply grout, if necessary.

All drilling equipment will be steam cleaned prior to the start of the field investigation, steam cleaned between each borehole to prevent cross-borehole contamination and steam cleaned prior to leaving the site.

2.4.3 Sediment and Surface Water Sampling

Sediment sampling and surface water quality measurements will occur at the stations presented on Figures 2-1 through 2-7. Supplemental sampling will also be conducted as described in Appendix E.

Sampling activities will be conducted from a boat equipped with a GPS unit so that survey information can be recorded for each sample station. The boat will be anchored at each sample station and the engines will be shut off while sampling activities are being conducted.

In-situ surface water quality measurements will be taken prior to sediment sampling. At each sample station the surface water at the surface (shallow) and near the sediment-water column interface (deep) will be in-situ field analyzed for temperature, pH, DO, specific conductivity, turbidity and salinity using a multi-parameter water quality meter (YSI or equivalent). The depth to the sediment-water column interface will also be measured. Sampling will be conducted near low tide and the level of the tide will be recorded during sampling.

Sediment samples will be collected according to the procedures outlined in B&R Environmental's SOP SA-1.2 (Appendix B). A minor modification to this procedure will be used for the collection of the sediment samples for AVS/SEM and ammonia analyses. The procedure is discussed below. Sediment samples will be collected by using a stainless steel dredge, Ponar, or Van Veen sampler and stainless steel trowels. Samples will be collected from a sediment depth of approximately 0.0 to 0.5 feet below the bottom of the Thames River. The sampling equipment will be decontaminated prior to the sampling activity and in-between samples to minimize the possibility of sample cross-contamination. Decontamination procedures will follow those outlined in Section 2-7.

Ammonia and sulfide are unstable in the presence of oxygen, therefore, the sediment samples collected for ammonia, and AVS/SEM analysis must be protected from exposure to oxygen during sampling and storage. A stainless steel sampler will be used to collect the sediment samples for analysis at each sample station. The sediment sample will be obtained directly from the sampler in an attempt to minimize disturbance and aeration of the sample. The sample will be placed in a wide-mouth jar with no headspace and capped with a teflon-lined lid. Teflon tape will then be wrapped around the lid to seal it and minimize the possibility of air leaks. The samples will immediately be cooled to 4°C. The samples will be shipped overnight at 4°C to the laboratory for immediate processing due to the potential exposure to the oxygenated atmosphere.

Sample nomenclature and rationale are presented in Table 2-2. Bottle and sample preservation requirements are presented in Table 2-3.

2.5 GROUNDWATER MONITORING WELL SAMPLING

The objective of this section is to provide guidance for the proper sampling equipment and techniques for groundwater sample collection. All groundwater sampling shall be conducted in accordance with USEPA Region I SOP GW001 and B&R Environmental's SOP SA-1.1 (Appendix B).

2.5.1 Water-Level and Product Thickness Measurements

Water-level and product thickness measurements will be obtained at each existing and newly installed monitoring well locations at the Lower Subase. Water-level and product thickness measurements will be taken simultaneously within a 24 hour period of consistent weather conditions. Both measurements will be taken during low tide conditions. All water-level measurements will be taken using an electronic water-level meter. Water-level elevations will be recorded to within 0.01 foot accuracy from a marked reference point at each location. Water-levels will be recorded on a B&R Environmental Water-Level Form. A blank Water-Level Form is appended for reference purposes (Appendix A).

The thickness of free-phase product in a well shall be measured by two methods, an interface probe and a clear bailer. The measurements will be done under static conditions prior to any purging or removal of water or free-phase product from the monitoring well. The depth to the top and bottom of the free-phase product will be measured using a hydrocarbon interface probe. The interface probe will be used to detect free-phase product at both the surface of the water table and at the bottom of each well because there is the potential that some of the petroleum products at the Lower Subase may have a specific gravity greater than water. Interface probes (e.g., Keck, ORS, or Solinst brand meters) emit a single tone when the probe is in the free-phase product and an intermittent tone when the probe reaches water. A clear 3-foot long by 2-inch diameter disposable bailer will be used to collect a free-phase product sample in order to confirm the interface probe measurement and to visually observe and describe the free-phase product. The bailed free-phase product shall be examined for thickness, layering, color, color gradation, coagulation, and apparent viscosity.

The interface probe shall be decontaminated, as described in Section 2-7, between each well measurement to minimize cross-contamination. All measurements will be referenced to the top of the riser pipe. All appropriate measurements, observations and calculations will be recorded in the field notebook and the groundwater sample log sheets. Any bailed free-phase product will be placed into a temporary container in order to transport it, without spillage, to a designated on-site containment system (i.e., 55-gallon drum).

An evaluation of each existing groundwater monitoring well's condition will be performed prior to the initiation of well purging and sampling. The wells will be examined for the presence of a silted screen, a damaged surface casing or a damaged concrete surface pad. Water-level measurements and monitoring well evaluations will be performed following procedures outlined in B&R Environmental SOP GH-1.2 (Appendix B).

A PID/FID will be used to monitor the presence of organic vapors in the well annulus. The organic vapor monitor will be calibrated daily following procedures outlined in the manufacturers operations manual. Organic vapor monitor calibration records will be recorded daily onto B&R Environmental Equipment Calibrations Sheets as per B&R Environmental SOP SA-6.3 (Appendix B).

2.5.2 Monitoring Well Development

Each newly installed groundwater monitoring well will be developed after waiting a minimum of 12-hours after the installation is completed. The installed monitoring wells will be developed using a stainless steel submersible or polypropylene Waterra pump. The purpose of the well development is to remove sediments from inside the casing and within the sand filter which surrounds the well screen.

Each groundwater monitoring well will be developed by repeatedly pumping the well, creating drawdown, then allowing the well to recover thus causing a surging effect. Repeated pumping and recovery surge development will continue for a minimum of one hour per well location. Water-level elevation data will be collected periodically during the well development process to ensure that the well is not pumped dry and to obtain specific capacity data regarding the aquifer. Specific capacity data are useful in determining a wells potential yield and for estimating the aquifers hydraulic conductivity.

The sequence for developing the groundwater monitoring wells at this site will proceed from anticipated background and upgradient locations to known or suspected contaminated areas. This sequence will be used to minimize the potential for cross-well contamination.

2.5.3 Monitoring Well Purging and Groundwater Sampling

Groundwater monitoring well purging will be performed immediately before sampling, utilizing low flow purging methods. The water-level elevation, free-product thickness and the depth of the water column will be measured prior to the start of groundwater monitoring well purging.

The wells will be purged using a peristaltic pump with Teflon® tubing lowered to the middle of the screen interval or to the middle of the remaining screen interval below the lowest depth of any free-product. Pharmaceutical-grade silicon tubing will be used in the rotaries of the peristaltic pump. The wells will be purged at a flow rate of 0.1 to 0.4 liters per minute.

Water quality parameters including pH, specific conductivity, temperature, DO, REDOX potential, salinity, and turbidity will be measured at three to five minute intervals. All measurements except turbidity must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, the well will continue to be pumped while the cell is disconnected, cleaned, and then reconnected. The flow-through-cell must be set up and operated in a way that prevents air bubble entrapment in the cell. Monitoring probes must be submerged in water at all times (USEPA, Region I, 1996). Turbidity will be measured using a meter with a visible light source.

Purging will be completed and sampling will begin when the following parameters have stabilized for three consecutive readings to within the following limits:

- pH to $\pm$ 0.1 units
- specific conductivity 3%
- temperature 3%
- DO 10%
- REDOX/Eh $\pm$ 10 millivolts
- turbidity 10% for values greater than 1 NTU

If the groundwater quality parameters do not stabilize at nontidally influenced wells within four hours and the water level has not been drawndown more than 0.3 feet, then the sample will be collected and the lack of stabilization will be noted in the field notes.

The level of water will not be allowed to drawdown to the level of the pump intake. All purged water will be containerized.

Tidally influenced wells (i.e., those shown to be within the tidally influenced zone during previous tidal studies) will be sampled during low tide. Purging will begin approximately 2 hours before low tide.

Sampling will begin approximately 1 hour before low tide even if parameters have not stabilized. Sampling will not continue more than 2 hours after low tide.

Groundwater samples will be collected using the low flow techniques described above. TPH, SVOC and total metals samples will be transferred directly from the peristaltic pumps tubing to the container. Groundwater samples collected for dissolved metals analysis will be filtered in the field prior to preservation with HNO_3. Volatile organic samples will be collected from the inlet end of the tubing. The discharge end of the tubing will be crimped while filled. The inlet end of the tubing will then be removed from the well and suspended above the sample bottle. The sample will be allowed to fill each sample bottle by gravity flow. VOC samples will be collected such that zero head space is present in the sample container once filled. Sample nomenclature and rationale are presented in Table 2-2. Bottle and sample preservation requirements are presented in Table 2-3.

The groundwater samples will be analyzed for TPH, TCL Volatile Organic Compounds (VOCs), TCL SVOCs, total and dissolved metals and natural attenuation parameters. Natural attenuation and water quality parameters such as DO, salinity, turbidity, pH, temperature and REDOX will be measured using a flow-through-cell and the appropriate instruments in the field. Divalent iron will be measured in the field using a Hach kit Model IR-18C. Laboratory analysis will be used for the following natural attenuation parameters: alkalinity, chlorides, dissolved sulfates, nitrates, TOC, hardness, phosphate, ammonia and dissolved methane.

One ambient blank will be collected per media sampled per sampling event. One source water blank will be collected per type of source water used for the decontamination of sampling equipment. One duplicate sample will be collected per 10 units of a media sampled. One trip blank will be shipped with each container containing VOC samples and one equipment rinsate blank will be collected per day of sampling. One equipment rinsate blank per dedicated sampling device type will also be collected during this RI. A summary of the QA/QC sample requirements is provided in Table 2-4.

Sampling chain-of-custody requirements are addressed in Section 3.3. All pertinent field data will be recorded using a B&R Environmental sample log sheet and the field log book. An example of a B&R Environmental sample log sheet and chain-of-custody form is included in Appendix A.

2.6 FIELD MEASUREMENTS

Measurements recorded during field sampling operations include ambient air monitoring around the work-space area, screening soil samples, screening air quality within the well casing, measuring groundwater

natural attenuation/water quality parameters and surface water quality parameters. The following instruments are anticipated to be used during the field activities:

- Flame or photo ionization detector
- YSI 6820 with data logger (both groundwater and surface water quality parameters)
- Turbidity meter
- Electronic water-level meter
- Hach Model IR-18C, Divalent Iron Kit

Field instruments will be calibrated according to the manufacturer's recommendations. A field check will also be completed at the end of each day. Duplicate measurements of pH, specific conductance, temperature and turbidity will be taken at a frequency of 1 in 10 samples and will be used to estimate the precision of the field analytical measurements.

All instrument calibrations will be recorded on an Equipment Calibration Log Sheet. An example sheet is provided in Appendix B. During calibration, a 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 can be repaired or the instrument replaced.

2.7 DECONTAMINATION

The drilling and sampling equipment involved in the field sampling activities will be decontaminated upon arrival at the site, in between each borehole location and at the completion of the sampling program as per B&R Environmental SOP SA-7.1. The sampling equipment may include split spoon samplers, a submersible pump or a Waterra foot valve pump. A centralized decontamination pad will be constructed in a Navy approved location and will be used throughout the investigation.

The following sampling equipment decontamination steps will be taken:

1. Potable water rinse
2. Alconox or liquinox detergent wash
3. Potable water rinse
4. Pesticide Grade Isopropanol rinse
5. Analyte-free water rinse
6. Air dry

7. Wrap in aluminum foil if not used immediately

The drilling equipment will be steam cleaned prior to the start of drilling operations, between each borehole location to minimize the potential for cross-contamination and at the completion of the project. Steam cleaning will be performed using a portable steam cleaner supplied by the driller and municipal water supplied by NSB-NLON.

2.8 INVESTIGATION DERIVED WASTE (IDW)

It is anticipated that this investigation will generate four types of potentially contaminated residues:

- personal protective equipment (PPE);
- soil cuttings;
- development and purge fluids; and,
- equipment decontamination fluids.

PPE - All PPE will be double bagged and placed in trash receptacles at the facility.

Soil Cuttings - Soil cuttings will be placed in clean DOT-approved 55-gallon steel drums. The drums will be labeled with the facilities name, zone number, and address, the type of contents, the boring or groundwater monitoring wells identifier, the date the container was filled, and the name and phone number of the party responsible for disposal. The IDW disposal contractor will collect and analyze a soil sample from each drum at the completion of the field operations to determine the best method for disposal. The drums will be temporarily stored by B&R Environmental at a Navy-designated location.

Development and Purge Fluids - Purge and development fluids will be collected in 55-gallon, steel drums or a large portable tank and temporarily stored at a Navy-designated location. If 55-gallon drums are used, each drum will be labeled with the facilities name and address, the type of contents, the groundwater monitoring well identifier, the date the drum was filled, and the name and phone number of the party responsible for disposal. A liquid sample will be collected from each drum or the portable tank by the IDW disposal contractor at the completion of the field operations. The results of the analysis will be used to determine the best method for disposal.

Equipment Decontamination Fluids - Equipment decontamination fluids will be containerized and handled in the same manner as the development and purge fluids.

B&R Environmental will arrange for disposal of all IDW by a subcontractor. All IDW will be removed from the temporary storage location after receipt of analytical results. B&R Environmental's subcontractor will prepare waste manifests. The IDW will be considered the property of the Navy.

2.9 SURVEYING

The vertical and horizontal locations of the soil borings and groundwater monitoring wells will be surveyed by a Connecticut licensed professional surveyor. All control points shall be tied into the Connecticut State Plane coordinate system for horizontal location and to the National Geodedic Vertical Datum (NGVD 1929) for elevation. The monitoring wells shall be surveyed horizontally to the nearest 0.1 foot and vertically to the nearest 0.01 foot. At all well locations, the well casing elevation shall be surveyed at the measuring point where the uncapped PVC riser pipe is notched or marked. The elevation of the ground surface in the vicinity of the monitoring wells will also be measured.

Sediment and surface water locations will be surveyed using GPS equipment during sample collection. Two GPS receivers will be used for this task. One GPS receiver, a base station device, will be located over a known point on-shore that is referenced to Connecticut State Plane coordinates. The second GPS receiver, the mobile unit, will be interfaced and time-synchronized to the base station receiver. The mobile GPS receiver will then be used in the boat to collect the northing and easting location data for each sediment and surface water sample location. The mobile and base station GPS units will be downloaded daily to a laptop computer. The data will be reviewed for accuracy and archived onto floppy disks and the computers hard drive. Data will be collected in a digital format and in Connecticut State Plane coordinates.

TABLE 2-1

ENVIRONMENTAL SAMPLE SUMMARY
NSB-NLON, GROTON, CONNECTICUT
PAGE 1 OF 2

Analyte	Proposed Method	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Total
Shallow Soil(1, 10)									
TPH	EPA 418.1	3	3	3	3	6	5	11	34
TAL Metals	CLP ILM03.0	3	0	3	3	2	5	4	20
SPLP Metals(11)	SW 846 1312/CLP OLM03.0	0	0	0	0	0	3	0	3
SPLP Lead(12)	SW 846 1312/CLP OLM03.0	2	0	2	3	2	0	2	11
TCL VOC	CLP OLM01.8	0	0	0	0	0	5	0	5
TCL SVOC	CLP OLM01.8	9	7	5	5	6	5	11	48
Deep Soil(1, 10)									
TPH	EPA 418.1	0	0	0	0	0	5	0	5
TAL Metals	CLP ILM03.0	0	3	3	3	2	5	4	20
SPLP Metals(11)	SW 846 1312/CLP OLM03.0	0	0	0	0	0	3	0	3
SPLP Lead(12)	SW 846 1312/CLP OLM03.0	0	2	2	3	2	0	2	11
TCL VOC	CLP OLM01.8	0	0	0	0	0	5	0	5
TCL SVOC	CLP OLM01.8	9	7	5	5	6	5	11	48
Groundwater									
TPH	EPA 418.1	16	5	3	13	3	5	11	56
TAL Metals (total and dissolved)(3)	CLP ILM03.0	16	5	3	13	3	5	11	56
TCL VOC - Low Concentration	CLP OLC02.0	0	0	0	0	0	5	0	5
TCL SVOC	CLP OLM01.8	16	5	3	13	3	5	11	56
Natural Atten. (4)	See footnote (4).	16	5	3	13	3	5	11	56
Surface Water									
Water Quality Parameters(5)	B&RE SOP SA 1.1	8	4	4	6	8	4 (6)	6	40

TABLE 2-1

ENVIRONMENTAL SAMPLE SUMMARY
NSB-NLON, GROTON, CONNECTICUT
PAGE 2 OF 2

Analyte	Proposed Method	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Total
Sediment(10)									
TCL SVOC	CLP OLM01.8	4	2	2	3	4	2 (6)	3	20
TCL Pesticides	CLP OLM01.8	0	0	0	0	1	0	0	1
TAL Metals	CLP ILM03.0	4	2	2	3	4	2 (6)	3	20
AVS/SEM(7)	USEPA, 1991(8)	4	2	2	3	4	2 (6)	3	20
Ammonia	Modified EPA 350.1	4	2	2	3	4	2 (6)	3	20
pH	SW 846 9045	4	2	2	3	4	2 (6)	3	20
TOC	Lloyd Kahn(9)	4	2	2	3	4	2 (6)	3	20
Grain Size Analysis	ASTM D422	4	2	2	3	4	2 (6)	3	20
TOTAL		**126**	**60**	**53**	**104**	**75**	**89**	**116**	**623**

Laboratory analyses to include a minimum of one MS/MSD per 20 samples per matrix.
All media sampled during Plase 1 will be analyzed using a 7-day laboratory turnaround time, and media sampled during Phase 2 will be analyzed using a 30-day laboratory turnaround time.

1 Shallow soils are defined as samples collected from depths less than five feet below ground surface
2 Deep soils are defined as samples collected from depths greater than five feet below ground surface
3 TAL metals analysis does not include cyanide, but it does include total and dissolved analyses for groundwater samples.
4 The natural attenuation analysis will include the following field and laboratory measurements: total organic carbon (TOC) (EPA 415.1), dissolved oxygen, salinity, oxidation-reduction (REDOX) potential, pH, alkalinity (EPA 310.1), hardness (EPA 130.2), divalent iron, chloride (EPA 325.2), nitrate (EPA 353.2), sulfate (EPA 375.4), phosphate (EPA 365.4), ammonia (EPA 350.1), and methane (EPA RSK SOP-175).
5 Water quality parameters include pH, temperature, specific conductivity, dissolved oxygen, REDOX potential, turbidity, and salinity.
6 Parameters for Zone 6 surface water and sediment sample analysis will be based on the Phase 1 soil and groundwater sample analysis for Zone 6.
7 Acid Volatile Sulfide (AVS)/Simultaneously Extracted Metals (SEM).
8 USEPA, 1991, Draft Analytical Method for Determination of Acid Volatile Sulfide in Sediments.
9 USEPA Region II, Environmental Services Division, Monitoring Management Branch, Lloyd Kahn, Determination of Total Organic Carbon In Sediments.
10 Percent solids will be determined as specified in CLP protocol.
11 Synthetic Precipitation Leaching Procedure followed by TAL metals analysis.
12 Synthetic Precipitation Leaching Procedure followed by lead analysis.

TABLE 2-2

SUMMARY OF SAMPLING ACTIVITIES
NSB-NLON, GROTON, CONNECTICUT
PAGE 1 OF 18

Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
ZONE 1 SAMPLES (SEE FIGURE 2-1)				
Zone 1 Soil				
LS1SB0010201	TB1-1RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/ Metals contamination and determine mobility of lead
LS1SB0010401	TB1-1RI	6 to 10	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0020201	TB2-1RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/ Metals contamination and determine mobility of lead
LS1SB0020401	TB2-1RI	6 to 10	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0030201	TB3-1RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS1SB0030401	TB3-1RI	6 to 10	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0040201	TB4-1RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS1SB0040401	TB4-1RI	6 to 10	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0050201	TB5-1RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS1SB0050401	TB5-1RI	6 to 10	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0060201	TB6-1RI	2 to 4	TPH, TCL SVOC, TAL Metals	Determine source of TPH/SVOC/ Metals contamination
LS1SB0060601	TB6-1RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0070201	TB7-1RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS1SB0070601	TB7-1RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0080201	TB8-1RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS1SB0080601	TB8-1RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS1SB0090201	TB9-1RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS1SB0090601	TB9-1RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination

TABLE 2-2

SUMMARY OF SAMPLING ACTIVITIES
NSB-NLON, GROTON, CONNECTICUT
PAGE 2 OF 18

Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
Zone 1 Groundwater Samples				
LS1GW13MW101	13MW1	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW201	13MW2	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW301	13MW3	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW701	13MW7	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW801	13MW8	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW901	13MW9	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW1401	13MW14	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW1901	13MW19	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation

TABLE 2-2

SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS1GW13MW2001	13MW20	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GW13MW2101	13MW21	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GWFOMW1301	FOMW13	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GWFOMW1401	FOMW14	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GWFOMW1501	FOMW15	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GWFOMW1601	FOMW16	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GWNESO401	NESO4	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS1GWNESO701	NESO7	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
Zone 1 Sediment				
LS1SD00101	SD1-1RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS1SD00201	SD2-1RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS1SD00301	SD3-1RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS1SD00401	SD4-1RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
Zone 1 Surface Water				
n/a	SW1-1RI	S and D	Water Quality	Data gap
n/a	SW2-1RI	S and D	Water Quality	Data gap
n/a	SW3-1RI	S and D	Water Quality	Data gap
n/a	SW4-1RI	S and D	Water Quality	Data gap
ZONE 2 SAMPLES (SEE FIGURE 2-2)				
Zone 2 Soils				
LS2SB0010201	TB1-2RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS2SB0010601	TB1-2RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS2SB0020201	TB2-2RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS2SB0020601	TB2-2RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS2SB0030201	TB3-2RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS2SB0030601	TB3-2RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS2SB0040201	TB4-2RI	2 to 4	TCL SVOC	Determine lateral extent of SVOC contamination
LS2SB0040601	TB4-2RI	10 to 12	TCL SVOC, TAL Metals	Determine lateral extent of SVOC/metals contamination
LS2SB0050201	TB5-2RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS2SB0050601	TB5-2RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC/Metals contamination, and determine mobility of lead
LS2SB0060201	TB6-2RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS2SB0060601	TB6-2RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC/Metals contamination, and determine mobility of lead
LS2SB0070201	TB7-2RI	2 to 4	TCL SVOC	Determine source of SVOC contamination
LS2SB0070601	TB7-2RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
Zone 2 Groundwater				
LS2GW13MW601	13MW6	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS2GW13MW1001	13MW10	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS2GW13MW1101	13MW11	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
LS2GW13MW1701	13MW17	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS2GWNESO601	NESO6	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attenuation
Zone 2 Sediment				
LS2SD00101	SD1-2RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS2SD00201	SD2-2RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
Zone 2 Surface Water				
n/a	SW1-2RI	S and D	Water Quality	Data gap
n/a	SW2-2RI	S and D	Water Quality	Data gap
ZONE 3 SAMPLES (SEE FIGURE 2-3)				
Zone 3 Soils				
LS3SB0010201	TB1-3RI/ MW1-3RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/Metals contamination and determine mobility of lead
LS3SB0010601	TB1-3RI/ MW1-3RI	10 to 12	TCL SVOC, TAL Metals	Determine lateral extent of SVOC/Metals contamination
LS3SB0020201	TB2-3RI/ MW2-3RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/Metals contamination and determine mobility of lead
LS3SB0020601	TB2-3RI/ MW2-3RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC/ Metals contamination and determine mobility of lead
LS3SB0030201	TB3-3RI	2 to 4	TCL SVOC	Determine source of TPH/SVOC contamination
LS3SB0030601	TB3-3RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS3SB0040201	TB4-3RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS3SB0040601	TB4-3RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS3SB0050201	TB5-3RI	2 to 4	TCL SVOC, TAL Metals	Determine source of SVOC/Metals contamination
LS3SB0050601	TB5-3RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC/Metals contamination and determine mobility of lead
Zone 3 Groundwater				
LS3GW13MW1201	13MW12	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS3GW00101	MW1-3RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Data gap, and determine thickness of free-product and viability of natural attenuation
LS3GW00201	MW2-3RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Data gap, and determine thickness of free-product and viability of natural attenuation
Zone 3 Sediment				
LS3SD00101	SD1-3RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS3SD00201	SD2-3RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
Zone 3 Surface Water				
n/a	SW1-1RI	S and D	Water Quality	Data gap
n/a	SW2-2RI	S and D	Water Quality	Data gap

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
ZONE 4 SAMPLES (SEE FIGURE 2-4)				
Zone 4 Soils				
LS4SB0010201	TB1-4RI/MW1-4RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/Metals contamination and determine mobility of lead
LS4SB0010601	TB1-4RI/MW1-4RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC contamination and determine mobility of lead
LS4SB0020201	TB2-4RI	2 to 4	TCL SVOC	Determine lateral extent of SVOC contamination
LS4SB0020601	TB2-4RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS4SB0030201	TB3-4RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/Metals contamination and determine mobility of lead
LS4SB0030601	TB3-4RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC contamination and determine mobility of lead
LS4SB0040201	TB4-4RI	2 to 4	TCL SVOC	Determine lateral extent of SVOC contamination
LS4SB0040601	TB4-4RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS4SB0050201	TB5-4RI/MW2-4RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC/Metals contamination and determine mobility of lead
LS4SB0050601	TB5-4RI/MW2-4RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of TPH contamination and determine mobility of lead
Zone 4 Groundwater				
LS4GWWE101	WE1	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GWWE401	WE4	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS4GWWE501	WE5	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GWNESO1001	NESO10	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GWNESO1101	NESO11	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GW13MW1301	13MW13	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GW13MW1401	13MW14	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GW13MW1501	13MW15	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GW13MW1601	13MW16	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine thickness of free-product and viability of natural attentuation
LS4GWQW401	QW4	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Data Gap, and determine thickness of free-product and viability of natural attentuation
LS4GWQW501	QW5	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Data Gap, and determine thickness of free-product and viability of natural attentuation

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS4GW00101	MW1-4RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Data Gap, and determine thickness of free-product and viability of natural attentuation
LS4GW00201	MW2-4RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Data Gap, and determine thickness of free-product and viability of natural attentuation
Zone 4 Sediment				
LS4SD00101	SD1-4RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS4SD00201	SD2-4RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS4SD00301	SD3-4RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
Zone 4 Surface Water				
n/a	SW1-4RI	S and D	Water Quality	Data gap
n/a	SW2-4RI	S and D	Water Quality	Data gap
n/a	SW3-4RI	S and D	Water Quality	Data gap

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
ZONE 5 SAMPLES (SEE FIGURE 2-5)				
Zone 5 Soils				
LS5SB0010201	TB1-5RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC contamination, confirm mobility of lead
LS5SB0010601	TB1-5RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC contamination, confirm mobility of lead
LS5SB0020201	TB2-5RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS5SB0020601	TB2-5RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS5SB0030201	TB3-5RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS5SB0030601	TB3-5RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS5SB0040201	TB4-5RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS5SB0040601	TB4-5RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS5SB0050201	TB5-5RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS5SB0050601	TB5-5RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS5SB0060201	TB6-5RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC contamination, confirm mobility of lead
LS5SB0060601	TB6-5RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC contamination, confirm mobility of lead

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
Zone 5 Groundwater				
LS5GW19MW201	19MW2	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS5GW19MW301	19MW3	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS5GW19MW401	19MW4	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
Zone 5 Sediment				
LS5SD00101	SD1-5RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS5SD00201	SD2-5RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS5SD00301	SD3-5RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap
LS5SD00401	SD4-5RI	0.0 to 0.5	TCL SVOC, TCL Pesticides, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Data gap

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SUMMARY OF SAMPLING ACTIVITIES
NSB-NLON, GROTON, CONNECTICUT
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
Zone 5 Surface Water				
n/a	SW1-5RI	S and D	Water Quality	Data gap
n/a	SW2-5RI	S and D	Water Quality	Data gap
n/a	SW3-5RI	S and D	Water Quality	Data gap
n/a	SW4-5RI	S and D	Water Quality	Data gap
ZONE 6 SAMPLES (SEE FIGURE 2-6)				
Zone 6 Soils				
LS6SB0010201	TB1-6RI/MW1-6RI	2 to 4	TPH, TCL SVOC, TCL VOC, TAL Metals, SPLP-TAL Metals	Determine the nature and extent of contamination and the mobility of metals
LS6SB0010601	TB1-6RI/MW1-6RI	10 to 12	TPH, TCL SVOC, TCL VOC, TAL Metals, SPLP-TAL Metals	Determine the nature and extent of contamination and the mobility of metals
LS6SB0020201	TB2-6RI/MW2-6RI	2 to 4	TPH, TCL SVOC, TCL VOC, TAL Metals	Determine the nature and extent of contamination
LS6SB0020601	TB2-6RI/MW2-6RI	10 to 12	TPH, TCL SVOC, TCL VOC, TAL Metals	Determine the nature and extent of contamination
LS6SB0030201	TB3-6RI/MW3-6RI	2 to 4	TPH, TCL SVOC, TCL VOC, TAL Metals, SPLP-TAL Metals	Determine the nature and extent of contamination and the mobility of metals
LS6SB0030601	TB3-6RI/MW3-6RI	10 to 12	TPH, TCL SVOC, TCL VOC, TAL Metals, SPLP-TAL Metals	Determine the nature and extent of contamination and the mobility of metals

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS6SB0040201	TB4-6RI/MW4-6RI	2 to 4	TPH, TCL SVOC, TCL VOC, TAL Metals, SPLP Metals	Determine the nature and extent of contamination and the mobility of metals
LS6SB0040601	TB4-6RI/MW4-6RI	10 to 12	TPH, TCL SVOC, TCL VOC, TAL Metals, SPLP-TAL Metals	Determine the nature and extent of contamination and the mobility of metals
LS6SB0050201	TB5-6RI/MW5-6RI	2 to 4	TPH, TCL SVOC, TCL VOC, TAL Metals	Determine the nature and extent of contamination
LS6SB0050601	TB5-6RI/MW5-6RI	10 to 12	TPH, TCL SVOC, TCL VOC, TAL Metals	Determine the nature and extent of contamination
Zone 6 Groundwater				
LS6GW00101	MW1-6RI	n/a	TPH, TCL SVOC, TCL VOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, the thickness of free-product, and the viability of natural attenuation
LS6GW00201	MW2-6RI	n/a	TPH, TCL SVOC, TCL VOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, the thickness of free-product, and the viability of natural attenuation
LS6GW00301	MW3-6RI	n/a	TPH, TCL SVOC, TCL VOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, the thickness of free-product, and the viability of natural attenuation
LS6GW00401	MW4-6RI	n/a	TPH, TCL SVOC, TCL VOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, the thickness of free-product, and the viability of natural attenuation
LS6GW00501	MW5-6RI	n/a	TPH, TCL SVOC, TCL VOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, the thickness of free-product, and the viability of natural attenuation

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SUMMARY OF SAMPLING ACTIVITIES
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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
Zone 6 Sediment				
LS6SD00101	SD1-6RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Determine the nature and extent of contamination
LS6SD00201	SD2-6RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Determine the nature and extent of contamination
Zone 6 Surface Water				
n/a	SW6-1RI	S and D	Water Quality	Determine the nature and extent of contamination
n/a	SW6-2RI	S and D	Water Quality	Determine the nature and extent of contamination
ZONE 7 SAMPLES (SEE FIGURE 2-7)				
Soils				
LS7SB0010201	TB1-7RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS7SB0010601	TB1-7RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS7SB0020201	TB2-7RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS7SB0020601	TB2-7RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS7SB0030201	TB3-7RI/MW1-7RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS7SB0030601	TB3-7RI/MW1-7RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS7SB0040201	TB4-7RI/MW2-7RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS7SB0040601	TB4-7RI/MW2-7RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS7SB0050201	TB5-7RI	2 to 4	TPH, TCL SVOC	Determine the source of TPH/SVOC
LS7SB0050601	TB5-7RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC
LS7SB006021	TB6-7RI/MW3-7RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine source of TPH/SVOC contamination and metals contamination and determine the mobility of lead

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Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS7SB0060601	TB6-7RI/MW3-7RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine lateral extent of SVOC contamination and metals contamination and determine the mobility of lead
LS7SB0070201	TB7-7RI/MW4-7RI	2 to 4	TPH, TCL SVOC	Determine source of TPH/SVOC contamination
LS7SB0070601	TB7-7RI/MW4-7RI	10 to 12	TCL SVOC	Determine the nature and extent of contamination
LS7SB0080201	TB8-7RI	2 to 4	TPH, TCL SVOC	Determine the source of SVOC contamination
LS7SB0080601	TB8-7RI	10 to 12	TCL SVOC	Determine lateral extent of SVOC contamination
LS7SB0090201	TB9-7RI	2 to 4	TPH, TCL SVOC, TAL Metals	Determine the nature and extent of contamination
LS7SB0090601	TB9-7RI	10 to 12	TCL SVOC, TAL Metals	Determine lateral extent of SVOC and metals contamination
LS7SB0100201	TB10-7RI/MW5-7RI	2 to 4	TPH, TCL SVOC, TAL Metals, SPLP-Lead	Determine the source of TPH/SVOC and metals contamination and determine the mobility of lead
LS7SB0100601	TB10-7RI/MW5-7RI	10 to 12	TCL SVOC, TAL Metals, SPLP-Lead	Determine the extent of SVOC and metals contamination and determine the mobility of lead
LS7SB0110201	TB11-7RI	2 to 4	TPH, TCL SVOC, TAL Metals	Determine the source of TPH/SVOC and metals contamination
LS7SB0110601	TB11-7RI	10 to 12	TCL SVOC, TAL Metals	Determine the extent of SVOC and metals contamination
Zone 7 Groundwater				
LS7GW20MW201	20MW2	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS7GW20MW301	20MW3	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation

TABLE 2-2

SUMMARY OF SAMPLING ACTIVITIES
NSB-NLON, GROTON, CONNECTICUT
PAGE 17 OF 18

Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
LS7GW20MW401	20MW4	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS7GW20MW501	20MW5	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS7GW20MW601	20MW6	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS7GW20MW701	20MW7	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Compare to historical database, and determine free-product thickness and viability of natural attenuation
LS7GW00301	MW1-7RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, and determine free-product thickness and viability of natural attenuation
LS7GW00401	MW2-7RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, and determine free-product thickness and viability of natural attenuation
LS7GW00701	MW3-7RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, and determine free-product thickness and viability of natural attenuation
LS7GW00901	MW4-7RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, and determine free-product thickness and viability of natural attenuation
LS7GW001001	MW5-7RI	n/a	TPH, TCL SVOC, TAL Metals (total and dissolved), Nat. Att.	Determine the nature and extent of contamination, and determine free-product thickness and viability of natural attenuation

TABLE 2-2

SUMMARY OF SAMPLING ACTIVITIES
NSB-NLON, GROTON, CONNECTICUT
PAGE 18 OF 18

Sample I.D.	Sample Location	Sample Depth (Feet)	Analytical Parameters	Sample Rationale
Zone 7 Sediment				
LS7SD00101	SD1-7RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Determine the nature and extent of contamination
LS7SD00201	SD2-7RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Determine the nature and extent of contamination
LS7SD00301	SD3-7RI	0.0 to 0.5	TCL SVOC, TAL Metals, NH_3, AVS/SEM, pH, TOC, Grain Size	Determine the nature and extent of contamination
Zone 7 Surface Water				
n/a	SW1-7RI	S and D	Water Quality	Determine the nature and extent of contamination
n/a	SW2-7RI	S and D	Water Quality	Determine the nature and extent of contamination
n/a	SW3-7RI	S and D	Water Quality	Determine the nature and extent of contamination

TABLE 2-3

ANALYTICAL METHODS, BOTTLE REQUIREMENTS, PRESERVATIVE REQUIREMENTS AND HOLDING TIMES
NSB-NLON, GROTON, CONNECTICUT
PAGE 1 OF 3

Parameter	Sample Container	Container Volume[1]	Preservation[2]	Maximum Holding Time[3]	Analytical Methodology
Groundwater					
TCL Volatile Organic Compounds	Glass, black phenolic plastic screw cap, Teflon-lined Septum	(2) 40 mL	Cool to 4°C, dark, zero headspace, HCl to pH < 2	14 days	OLC02.0[12]
TCL Semivolatile Organic Compounds	Amber glass, Teflon-lined cap	1000 mL	Cool to 4°C, dark	Extraction 7 days; analysis within 40 days	OLM01.8[4]
TAL Metals (total and dissolved)	Polyethylene bottle, plastic cap, plastic liner	500 mL	HNO_3 to pH < 2[13]	Within 180 days; mercury within 28 days	ILM03.0[5]
Total Petroleum Hydrocarbons (TPH)	Amber glass, Teflon-lined cap	1000 mL	Cool to 4°C, HCl to pH <2	28 days	EPA[6] Method 418.1
Total Organic Carbon (TOC)	Polyethylene bottle, plastic cap, plastic liner	250 mL	Cool to 4°C, HCl or H_2SO_4 to pH <2	28 days	EPA Method 415.1
Alkalinity (as $CaCO_3$)	Polyethylene bottle, plastic cap, plastic liner	250 mL	Cool to 4°C	14 days	EPA Method 310.1
Hardness (as $CaCO_3$)	Polyethylene bottle, plastic cap, plastic liner	250 mL	HNO_3 to pH <2	180 days	EPA Method 130.2
Sulfate	Polyethylene bottle, plastic cap, plastic liner	250 mL	Cool to 4°C	28 days	EPA Method 375.4
Nitrate	Polyethylene bottle, plastic cap, plastic liner	250 mL	Cool to 4°C	48 hours	EPA Method 353.2
Chloride	Polyethylene bottle, plastic cap, plastic liner	250 mL	None required	28 days	EPA Method 325.2
Methane	Septated serum vial	(2) 30 mL	HCl to pH <2	14 days	EPA RSK SOP-175[7]

TABLE 2-3

ANALYTICAL METHODS, BOTTLE REQUIREMENTS, PRESERVATIVE REQUIREMENTS AND HOLDING TIMES
NSB-NLON, GROTON, CONNECTICUT
PAGE 2 OF 3

Parameter	Sample Container	Container Volume[1]	Preservation[2]	Maximum Holding Time[3]	Analytical Methodology
Phosphate (Total)	Polyethylene bottles plastic cap, plastic liner	250 mL	Cool to 4°C, H_2SO_4 to pH <2	28 days	EPA 365.4
Ammonia	Polyethylene bottles plastic cap, plastic liner	1000 mL	Cool to 4°C, H_2SO_4 to pH <2	28 days	EPA 350.1
Soil/Sediment					
TCL Volatile Organic Compounds	Glass, polypropylene cap, white Teflon-liner	4 oz.	Cool to 4°C, dark, zero to minimal headspace	14 days	OLM01.8
TCL Semivolatile Organic Compounds	Glass, Teflon-lined cap	8 oz.[8]	Cool to 4°C, dark	Extract 14 days; analyze 40 days	OLM01.8
TCL Pesticides	Glass, Teflon-lined cap	8 oz. [8]	Cool to 4°C	Extract 14 days; analyze 40 days	OLM01.8
TAL Metals	Glass, Teflon-lined cap	8 oz.[8]	Cool to 4°C	Within 180 days; mercury 28 days	ILM03.0
Total Petroleum Hydrocarbons (TPH)	Glass, Teflon-lined cap	8 oz.	Cool to 4°C	28 days	EPA Method 418.1
Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM)	Glass, Teflon-lined cap	8 oz.	Cool to 4°C, no headspace	14 days if headspace of sample is purged with nitrogen or argon	USEPA, 1991[9]
Ammonia	Glass, Teflon-lined cap	4 oz.	Cool to 4°C	28 days	Modified EPA Method 350.1
pH	Glass, Teflon-lined cap	4 oz.	Cool to 4°C	Analyze immediately	SW-846[10] 9045
Total Organic Carbon (TOC)	Glass, Teflon-lined cap	8 oz.	Cool to 4°C	14 days	Lloyd Kahn[11]

TABLE 2-3

ANALYTICAL METHODS, BOTTLE REQUIREMENTS, PRESERVATIVE REQUIREMENTS AND HOLDING TIMES
NSB-NLON, GROTON, CONNECTICUT
PAGE 3 OF 3

Parameter	Sample Container	Container Volume[1]	Preservation[2]	Maximum Holding Time[3]	Analytical Methodology
Grain Size Analysis	Glass, Teflon-lined cap	4 oz.	None required	None	ASTM D422
Synthetic Precipitation Leaching Procedure (SPLP)	Glass, Teflon-lined cap	(2) 8 oz.	None required	Mercury: 28 days to extraction; 28 days to analysis. Other metals: 180 days to extraction; 180 days to analysis	SW-846 1312

1 Container volume may vary based on laboratory.
2 HCl = Hydrochloric acid, NaOH = Sodium Hydroxide, HNO_3 = Nitric Acid, H_2SO_4 = Sulfuric acid.
3 All holding times are from date of collection.
4 USEPA (United States Environmental Protection Agency) CLP, 1991. Statement of Work for Organic Analysis, Multi-Media, Multi-Concentration, OLM01.8.
5 USEPA CLP. Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration, ILM03.0.
6 USEPA, 1983. Methods for Chemical Analysis of Water and Wastes.
7 USEPA R. S. Kerr Environmental Laboratory, B. S. Newell, Sample Preparation and Calculations for Dissolved Gas Analysis in Water Samples Using a GC Headspace Equilibration Technique, Revision No. 0, August 1994.
8 For soil/sediment samples, semivolatile organics, pesticides, and metals samples may be provided for analysis in the same 8-ounce jar.
9 USEPA, 1991, Draft Analytical Method for Determination of Acid Volatile Sulfide in Sediments..
10 USEPA, 1986. Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods. SW-846, 3rd ed.
11 USEPA Region II, Environmental Services Division, Monitoring Management Branch. Lloyd Kahn, Determination of Total Organic Carbon in Sediment.
12 USEPA CLP, 1992. Superfund Analytical Methods for Low Concentration Water for Organics Analysis, OLC02.0.
13 Groundwater samples for dissolved metals analysis will be filtered in the field prior to preservation with HNO_3.

TABLE 2-4

SUMMARY OF QA/QC SAMPLES AND ANALYSIS
NSB-NLON, GROTON, CONNECTICUT
PAGE 1 OF 2

Analysis	Method	Environmental Samples	Field Duplicates	Trip Blanks(1)	Rinsate Blanks	MS/MSD	Source Blanks(2)	Ambient Blank(3)	Totals
Soils									
TPH	EPA 418.1	39	4	NA (4)	TBD (5)	2	TBD	TBD	45+
TAL Metals	CLP ILM03.0	40	4	NA	TBD	2	TBD	TBD	46+
SPLP Metals(6)	SW-846 1312	6	1	NA	NA	1	TBD	TBD	8+
SPLP Lead(12)	SW-846 1312	22	3	NA	NA	2	TBD	TBD	27+
TCL VOC	CLP OLM01.8	10	1	TBD	TBD	1	TBD	TBD	12+
TCL SVOC	CLP OLM01.8	96	10	NA	TBD	5	TBD	TBD	111+
Groundwater									
TPH	EPA 418.1	56	6	NA	TBD	3	TBD	TBD	65+
TAL Metals (total and dissolved)	CLP ILM03.0	56 each (Total 112)	6 each (Total 12)	NA	TBD	3 each (Total 6)	TBD	TBD	65+ (Total 130+)
TCL VOC-Low Conc.	CLP OLC02.0	5	1	TBD	TBD	1	TBD	TBD	7+
TCL SVOC	CLP OLM01.8	56	6	NA	TBD	3	TBD	TBD	65+
Natural Atten.	See footnote(7)	56	6	NA	TBD	NA	TBD	TBD	62+
Field Parameters (8)	B&RE SOP SA. 1-1	56	6	NA	NA	NA	NA	NA	62
Surface Water									
Field Parameters (8)	B&RE SOP SA. 1-1	40	4	NA	NA	NA	NA	NA	44
Sediment									
TCL SVOC	CLP OLM01.8	20	2	NA	TBD	1	TBD	NA	23+
TAL Metals	CLP ILM03.0	20	2	NA	TBD	1	TBD	NA	23+
TCL Pesticides	CLP OLM01.8	1	1	NA	NA	1	TBD	NA	3+
AVS/SEM	USEPA, 1991(9)	20	2	NA	NA	1	TBD	NA	23+
Ammonia	Modified EPA 350.1	20	2	NA	TBD	1	TBD	NA	23+
pH	SW-846 9045	20	2	NA	NA	1(11)	TBD	NA	23+
TOC	Lloyd Kahn(10)	20	2	NA	TBD	1(11)	TBD	NA	23+
Grain Size Analysis	ASTM D422	20	2	NA	NA	1(11)	TBD	NA	23+

TABLE 2-4

SUMMARY OF QA/QC SAMPLES AND ANALYSIS
NSB-NLON, GROTON, CONNECTICUT
PAGE 2 OF 2

1 Trip blanks will be generated at a frequency of one per cooler containing samples for volatile organic analysis. All trip blanks will be analyzed for low-concentration volatile organics (OLC02.0).
2 Source water blanks will be generated at a rate of one per decontamination water source (e.g., DI and potable water).
3 Number of ambient blanks will be determined on site depending on conditions during sampling (e.g., organic vapors, exhaust and/or the presence of windy and dusty conditions), with a minimum of one ambient blank being collected during the investigation.
4 NA Not Applicable
5 TBD To be determined; rinsate blanks will be generated at a minimum rate of one per day of sampling (per matrix). If pre-cleaned, dedicated, or disposable equipment is used, one rinsate blank per type of equipment used will be collected as a "batch blank".
6 Synthetic Precipitation Leaching Procedure followed by TAL Metals analysis.
7 Total organic carbon (TOC) (EPA 415.1), alkalinity (EPA 310.1), hardness (EPA 130.2), chloride (EPA 325.2), nitrate (EPA 353.2), sulfate (EPA 375.4), phosphate (EPA 365.4), ammonia (EPA 350.1), and methane (EPA RSKSOP-175). Additional field parameters for natural attenuation include oxidation-reduction (REDOX) potential and divalent iron.
8 Field parameters include temperature, pH, specific conductance, turbidity, salinity, and dissolved oxygen.
9 USEPA, 1991. Draft Analytical Method for Determination of Acid Volatile Sulfide in Sediment.
10 USEPA Region II, Environmental Services Division, Monitoring Management Branch. Lloyd Kahn, Determination of Total Organic Carbon in Sediment.
11 Matrix spike analysis is not applicable for this parameter. However, laboratory duplicate analysis will be performed.
12 Synthetic Precipitation Leaching Procedure followed by CLP lead analysis.

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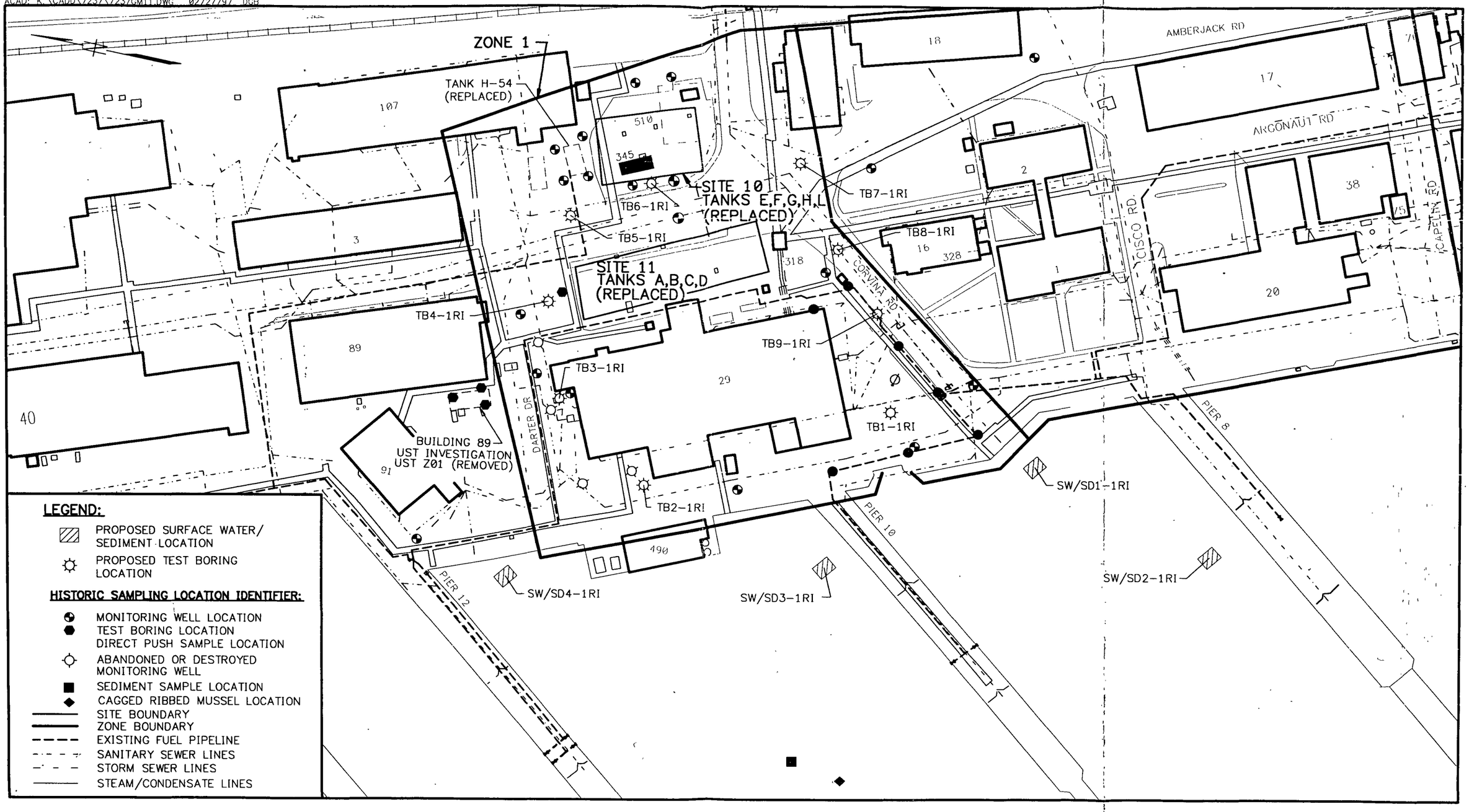

FIGURE 2-1

SAMPLE LOCATION MAP
ZONE 1
NSB-NLON, GROTON, CONNECTICUT

0 90 180
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

ACAD K:\CADD\7237\7237GM12.DWG 02/27/97 DCB

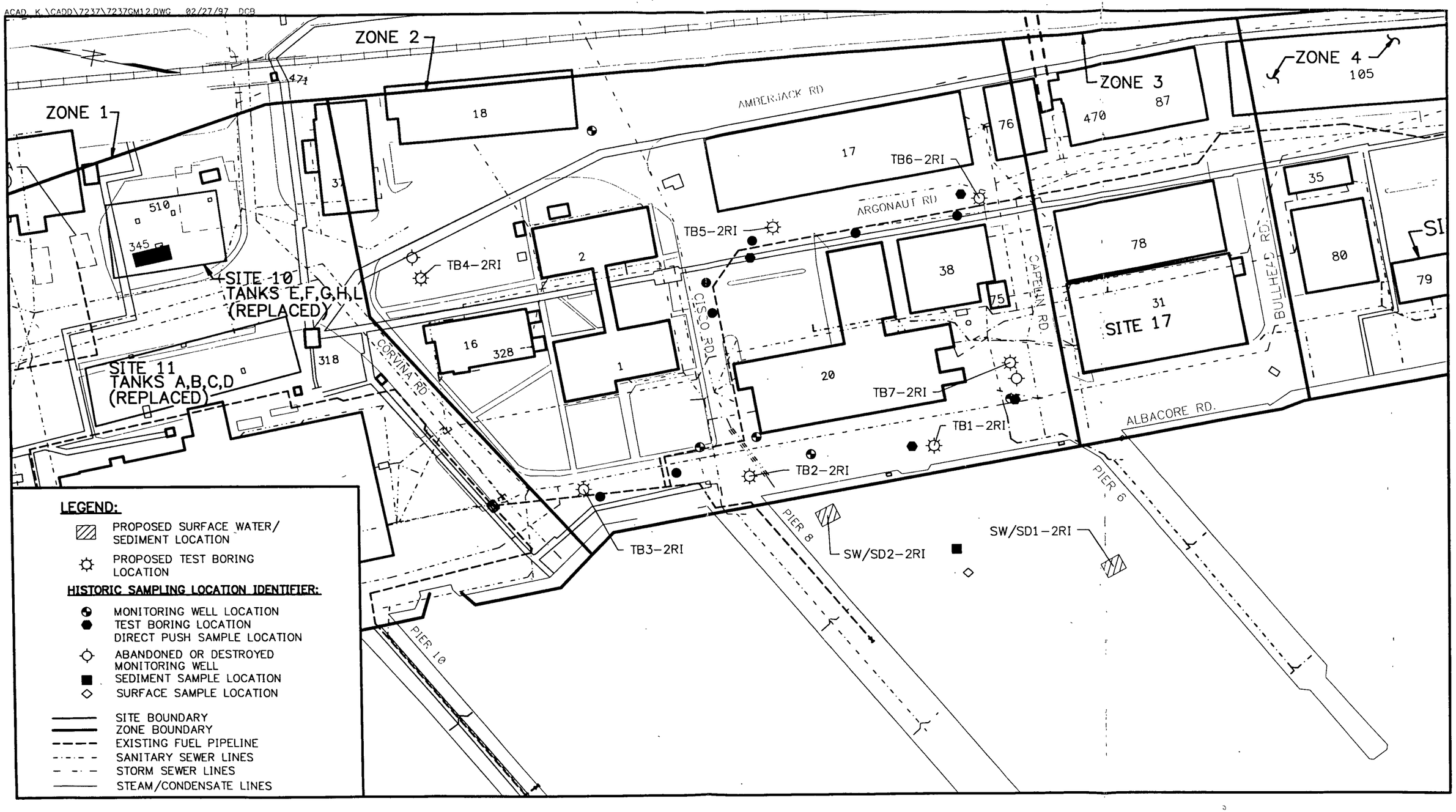

FIGURE 2-2

SAMPLE LOCATION MAP
ZONE 2
NSB-NLON, GROTON, CONNECTICUT

Brown & Root Environmental

CTO 0260

019707/P (WP)

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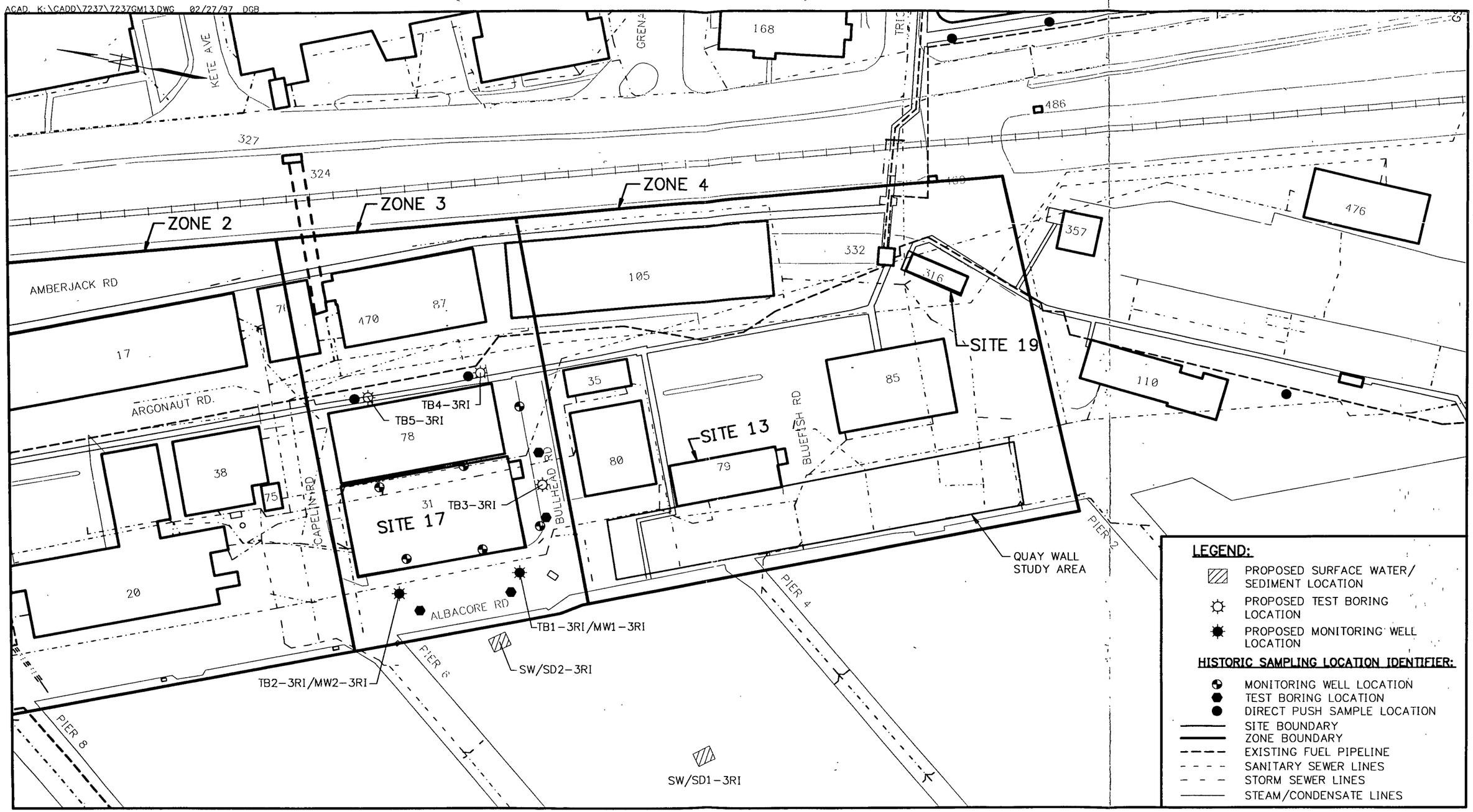

FIGURE 2-3

SAMPLE LOCATION MAP
ZONE 3
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

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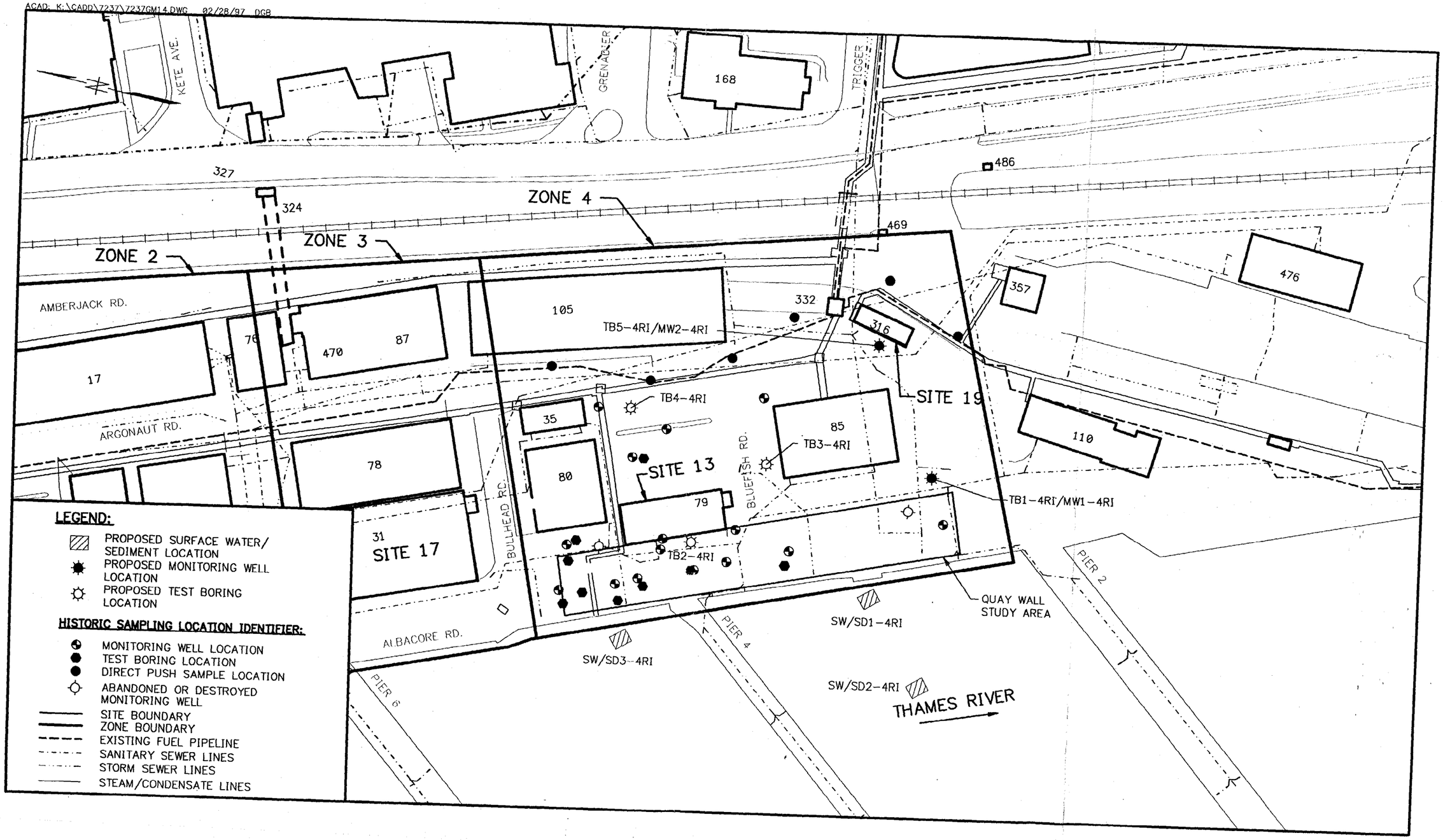

SAMPLE LOCATION MAP
ZONE 4
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

FIGURE 2-4

019707/P (WP)

Brown & Root Environmental

CTO 0260

01328202

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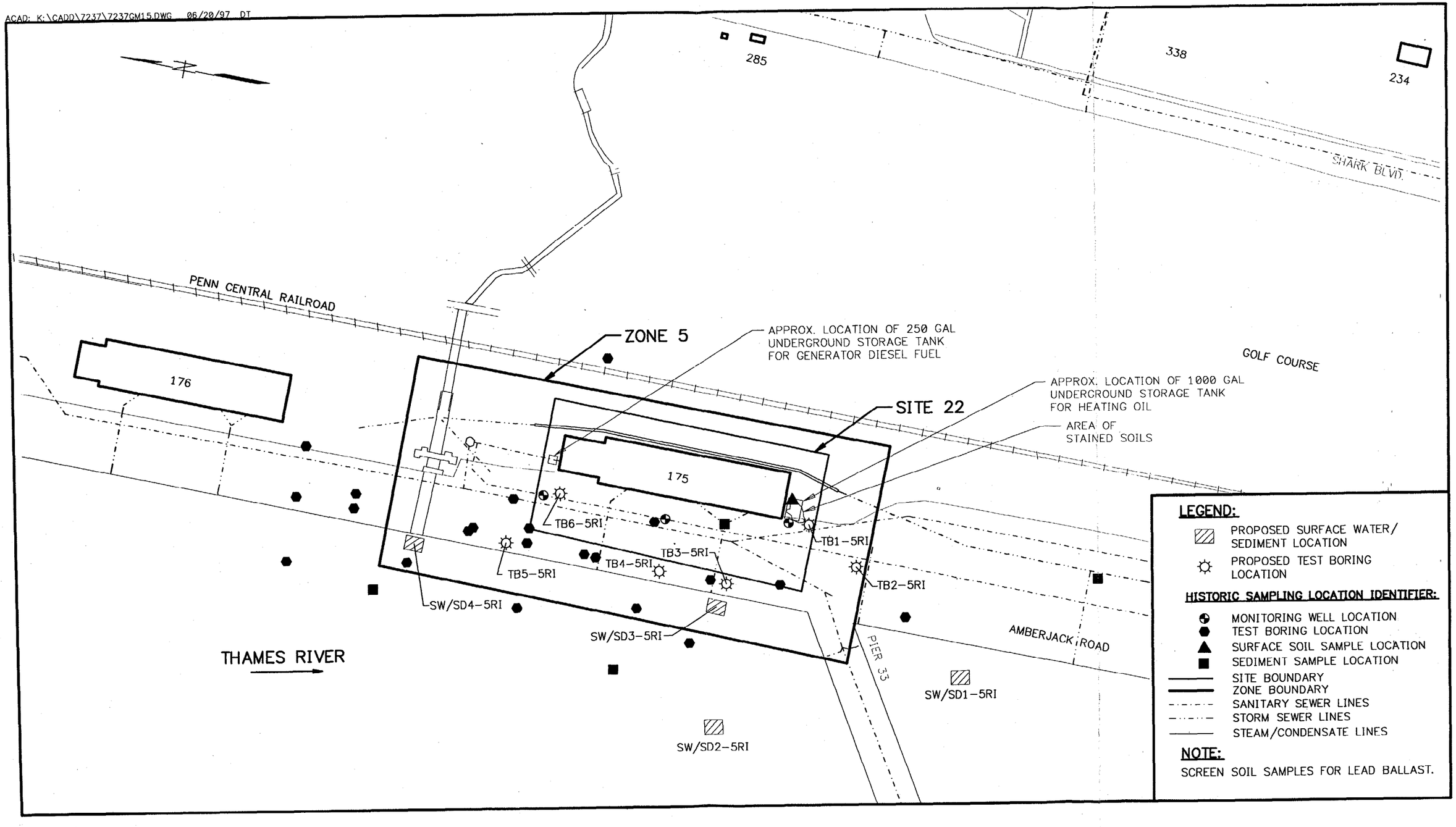

FIGURE 2-5

SAMPLE LOCATION MAP
ZONE 5
NSB-NLON, GROTON, CONNECTICUT

Brown & Root Environmental

CTO 0260

019707/P (WP)

01328212

ACAD: K:\CADD\7237\7237GM16.DWG 02/27/97 DGB

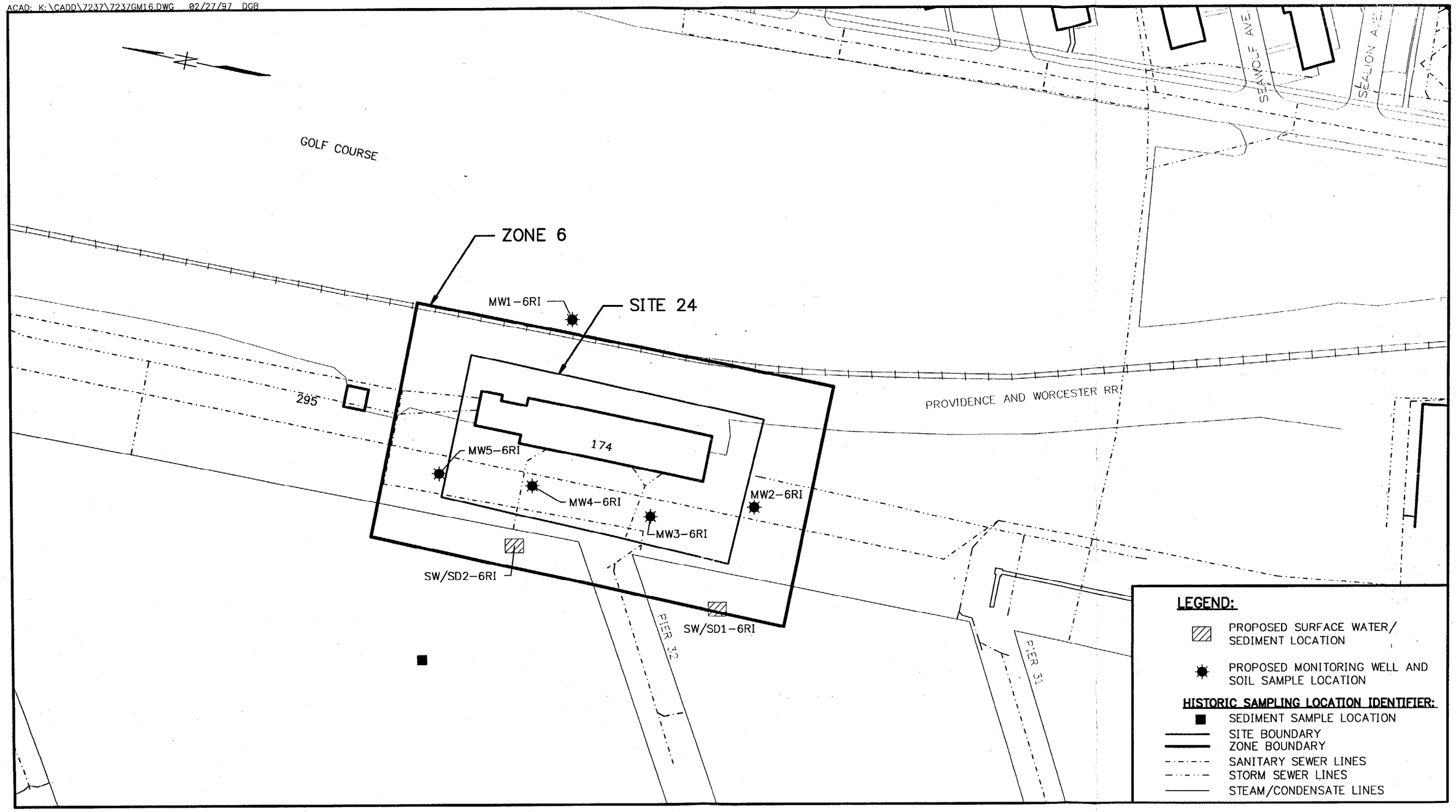

FIGURE 2-6

SAMPLE LOCATION MAP
ZONE 6
NSB-NLON, GROTON, CONNECTICUT

0 80 160
SCALE IN FEET

Brown & Root Environmental

019707/P (WP)

CTO 0260

01328222

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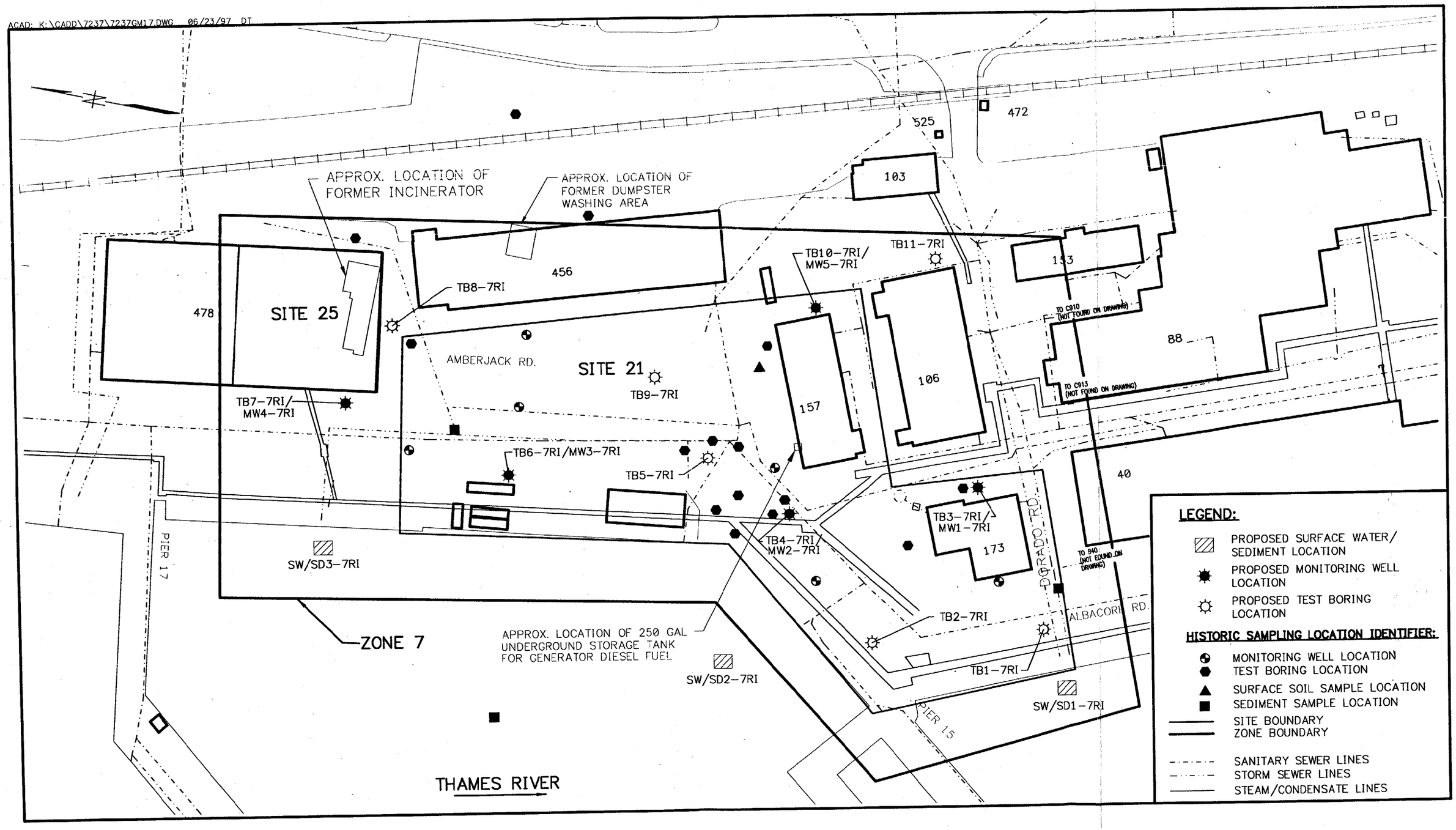

FIGURE 2-7

SAMPLE LOCATION MAP
ZONE 7
NSB-NLON, GROTON, CONNECTICUT

Brown & Root Environmental

019707/P (WP)

CTO 0260

01328232

3.0 SAMPLE HANDLING PROCEDURES

Sample handling includes the field related considerations for the sample identification system, sample packaging, sample custody, quality control samples and record keeping. The selection of sample containers, preservatives, allowable holding times and analyses are summarized in Table 2-3.

3.1 SAMPLING IDENTIFICATION SYSTEM

Each sample collected will be assigned a unique sample tracking number. The sample tracking number generally follows the B&R Environmental SOP CT-04 (Appendix B). The sample tracking number consists of up to 13 digits that identifies the site, the sample media, the sample location, the split spoon number (soils only) and sample round. All other pertinent information regarding sample identification will be recorded in the field log books. Examples of the sample numbers to be used for this project are provided below and in Table 2-2.

Soil Sample: LS1SB0010201

LS1 - Lower Subase, Zone 1
SB - Soil Boring
001 - Sample Location
02 - Split-Spoon Number
01 - Round 1 for Lower Subase RI

Groundwater Sample: LS1GW13MW101

LS1 - Lower Subase, Zone 1
GW - Groundwater
13MW1 - Existing well identification number
01 - Round 1 for Lower Subase RI

3.2 SAMPLE PACKAGING AND SHIPPING

Samples will be packaged and shipped in accordance with B&R Environmental SOP SA-6.1 (Appendix B). The FOL will be responsible for the completion of the following forms:

- Sample Labels
- Chain-of-Custody Forms
- Chain-of-Custody Labels
- Shipping Labels for Coolers
- Express Mail Air Bills

A majority of the analytical samples are to be shipped to the following address:

Katahdin Analytical Services
340 County Road #5
Westbrook, Maine 04098
Phone: (207) 874-2400
Fax: (207) 775-4029

Other laboratories may be necessary for some of the unique analyses and these laboratories and their addresses will be identified at a later date.

All media sampled during Phase 1 will be analyzed using a 7-day turnaround time, and media sampled during Phase 2 will be analyzed using a standard 30-day laboratory turnaround time.

3.3 SAMPLE CUSTODY

Custody of samples must be maintained and documented at all times as per B&R Environmental SOP SA-6.1 (Appendix B). Chain-of-custody begins with the collection of samples in the field. A sample chain-of custody record is provided in Appendix A.

3.4 QUALITY CONTROL SAMPLES

Several types of quality control (QC) samples will be collected or generated during environmental sampling activities. QC samples include ambient blanks, field duplicates, equipment rinsate blanks, source water blanks and trip blanks. Section 2.5.3 of this document presents the type and frequency of collection required for QC samples. The number of QC samples required for the project are summarized in Table 2-4. The five types of field QC samples are defined as follows:

Ambient Blanks. Ambient blanks are collected to check for background contamination during a sampling event. A minimum of one ambient blank will be collected per matrix during the RI. If ambient conditions change during the sampling event, then additional ambient blanks will be prepared and analyzed for each

change. The need for additional ambient blanks will be determined by the FOL. Ambient blanks are prepared by the field personnel by filling the sample containers with laboratory grade de-ionized water while under typical sampling conditions.

Field Duplicates Field duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. Field duplicates will be collected at a frequency of 10% per sampling matrix. Duplicates shall be analyzed for the same parameters in the laboratory as their environmental sample counterparts.

Equipment Rinsate Blanks. Equipment rinsate blanks are obtained under representative field conditions by running analyte-free water through decontaminated sample collection equipment (bailer, split-spoon, etc.). 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. One equipment rinsate blank will also be collected from each dedicated sampling device for this RI. Equipment rinsate blanks will be analyzed for the same suite of analytical parameters as the associated environmental samples and will be collected in the appropriate sample containers.

Source Water Blank - Source water blanks are collected to asses the presence of contamination in the water used to decontaminate the sampling equipment. Source water blanks are prepared by the field personnel. One source water blank is to be collected for each type of decontamination water (i.e. de-ionized water, tap water, etc.) used during this sampling event.

Trip Blanks. Trip blanks are included when analyzing for volatile organics and will be prepared and provided by the subcontract laboratory. Trip blanks will remain with the sample containers at all times and are thus subjected to the same field conditions as the field samples. One trip blank will be included in every shipping cooler that contains samples of volatile organics to be analyzed, regardless of sample matrix.

3.5 RECORD KEEPING

In addition to chain-of-custody records, certain standard forms will be completed for sample description and documentation. These forms shall include sample log sheets, boring logs, daily activity records and logbooks. A bound, weatherproof notebook shall be maintained by each work team (i.e., sampling crew, well installation supervisor, etc.). 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 logbook shall be maintained by the FOL. The requirements are outlined in B&R Environmental SOP SA-6.3 (Appendix B). This book will contain a summary of the day's activities and will reference the field notebooks when applicable. At completion of the field activities, the FOL shall submit all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample log sheets and daily activity logs to the Project Manager.

Field Task Modification Records (FTMRs) are specific forms initiated when a change or deviation from procedures in the project planning documents occurs. The procedure for requesting and recording field changes follows:

- The FOL notifies the Project Manager of the need for the change.
- If necessary, the Project Manager discusses the change with the pertinent individuals [e.g., the Navy Remedial Project Manager (RPM), B&R Environmental Quality Assurance Manager (QAM)]. Verbal approval or denial of the proposed change is given at this time.
- The FOL then documents the change on an FTMR and forwards the form to the Project Manager at the earliest convenient time (e.g., end of the workweek).
- The Project Manager signs the form and distributes copies to the Navy RPM, B&R Environmental QAM, FOL, and project file.
- A copy of the completed FTMR is attached to the field copy of the affected document.

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APPENDIX A

FIELD FORMS

- Boring Log
- Well Construction Diagram
- Well Development Form
- Groundwater Level Measurement Sheet
- Groundwater Sample Log Sheet
- Low Flow Purge Data Sheet
- Surface Water Log Sheet
- Soil and Sediment Sample Log Sheet
- Equipment Calibration Log
- Chain of Custody Record

BORING LOG

PROJECT NAME: _____ BORING NUMBER: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS*	Remarks	PID/FID Reading (p: Sample	PID/FID Reading (p: Sampler BZ	PID/FID Reading (p: Borehole**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

Drilling Area Background (ppm): ____

Remarks: _____

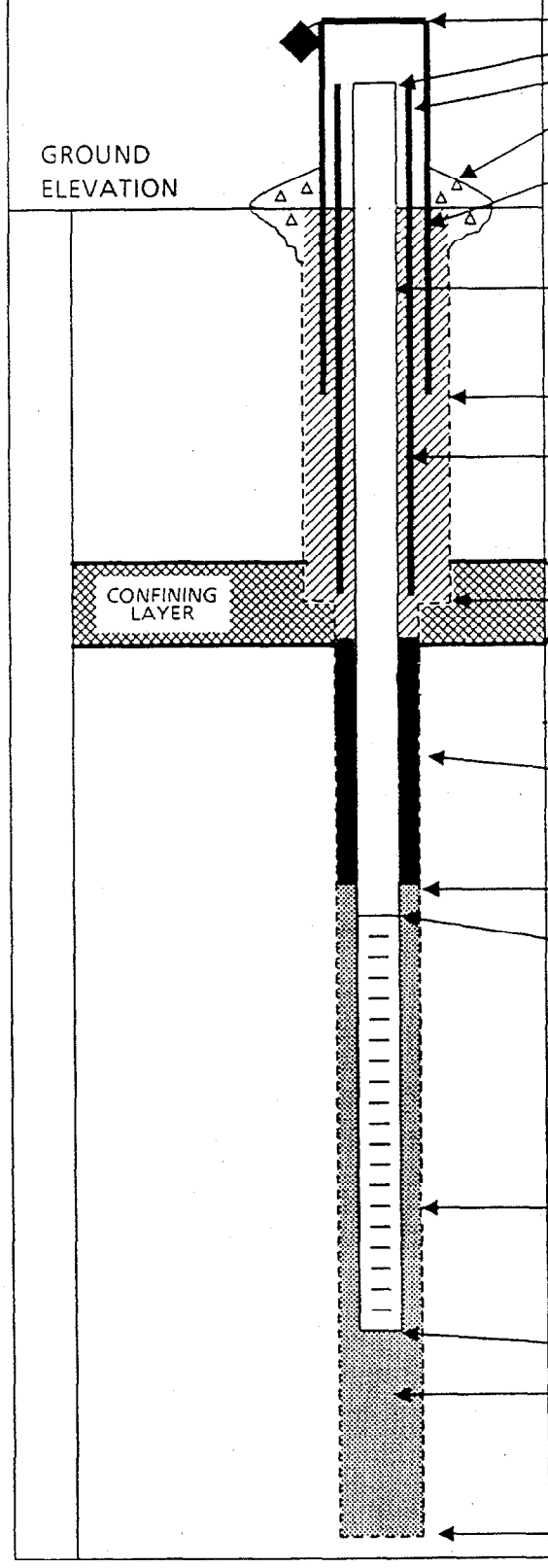
Converted to Well: Yes _____ No _____ Well I.D. #: _____

BORING NO.: _____

CONFINING LAYER
MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING : _____
ELEVATION OF TOP OF RISER PIPE: _____
ELEVATION TOP OF PERM. CASING: _____
TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

RISER PIPE I.D. _____
TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____

PERM. CASING I.D. _____
TYPE OF CASING & BACKFILL: _____

ELEVATION / DEPTH TOP CONFINING LAYER: ____/____
ELEVATION / DEPTH BOTTOM OF CASING: ____/____
ELEVATION / DEPTH BOT. CONFINING LAYER: ____/____

ELEVATION / DEPTH TOP OF SEAL: ____/____
TYPE OF SEAL: _____

DEPTH TOP OF SAND PACK: _____

ELEVATION/DEPTH TOP OF SCREEN: ____/____
TYPE OF SCREEN: _____

TYPE OF SAND PACK: _____

BOREHOLE DIA. BELOW CASING: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: ____/____

ELEVATION / DEPTH BOTTOM OF SAND PACK: ____/____
TYPE OF BACKFILL BELOW OBSERVATION WELL: _____

ELEVATION / DEPTH OF HOLE: ____/____

WELL DEVELOPMENT SHEET

PROJECT SITE NAME: _____ SITE/LOCATION _____
PROJECT NUMBER: _____ WELL ID.: _____
WEATHER: _____ DATE: _____
STATIC WATER LEVEL: _____ PERSONNEL: _____
TOTAL WELL DEPTH: _____ WELL TYPE: [PVC], [S.S.], or
ONE CASING VOLUME: _____ OTHER _____
START TIME: _____ MEASURING DEVICE: _____
END TIME: _____ ADJUSTMENT FACTOR: _____

[ ] DOMESTIC WELL, [ ] MONITORING WELL, [ ] OTHER _____

METHOD & REMARKS _____

Approximate Volume	Time	Color	pH (S.U.)	Cond. (mS/cm)	Turbidity (NTU)	DO (mg/L)	Temp. (Celcius)	Salinity (%)

NOTE: All measurements to nearest 0.01 foot measured from top of well riser pipe unless otherwise noted.

ADDITIONAL COMMENTS: _____

SIGNATURE(s): _____ PAGE___OF___

GROUNDWATER LEVEL MEASUREMENT SHEET

Page ___ of ___

PROJECT NAME: _____ LOCATION: _____
PROJECT NUMBER: _____ MEASURING DEVICE: _____
PERSONNEL: _____ ADJUSTMENT FACTOR: _____
DATE: _____ REMARKS: _____
WEATHER CONDITIONS: _____

Well or Piezometer Number	Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Groundwater Elevation (Feet)*	Comments

*Measurements to nearest 0.01 foot.

Signature(s): _____

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Domestic Well Data
[] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Method:								

PURGE DATA:

Date:	Volume	pH	S.C.	Temp. (C)	Turbidity	DO	Salinity	Other
Method:	Initial							
Monitor Reading (ppm):	1							
Well Casing Diameter & Material	2							
Type:	3							
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: _____ WELL I.D.: _____

PROJECT NUMBER: _____ DATE: _____

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	Temp. (Celcius)	pH (S.U.)	Cond.	DO (mg/L)	Sal. %	Turb. (NTU)	Comments

SIGNATURE(S) _____ PAGE of __

SURFACE WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Stream
[] Spring
[] Pond
[] Lake
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Time:								
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Date:			
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME/MODEL : _____

PROJECT NAME : _____

MANUFACTURER : _____

PROJECT NUMBER : _____

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

CHAIN OF CUSTODY RECORD

PROJECT NO.:	SITE NAME:
SAMPLERS (SIGNATURE):	

STATION NO.	DATE	TIME	COMP	GRAB	STATION LOCATION	NO. OF CON-TAINERS							REMARKS

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

Order No. 70440 (0693)

APPENDIX B

STANDARD OPERATING PROCEDURES

CT-04 Sample Nomenclature
GH-1.2 Evaluation of Existing Monitoring Wells and Water Level Measurement
GH-1.3 Rock and Soil Drilling
GH-2.8 Groundwater Monitoring Point Installation
GW0001 USEPA Region I - Low Stress (low flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells
SA-1.1 Groundwater Sample Acquisition and Onsite Water Quality Testing
SA-1.2 Surface Water and Sediment Sampling
SA-1.3 Soil Sampling Procedures
SA-6.1 Non-Radiological Sampling Handling
SA-6.3 Field Documentation
SA-7.1 Decontamination of Field Equipment and Waste Handling
ME-12 Photovac 2020 Photionization air Monitor
ME-15 Photovac Micro-FID Handheld Flame Ionization Detector
Format for Electronic Data Deliverables

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1.0 PURPOSE

The purpose of this document is to specify a consistent sample nomenclature system that will facilitate subsequent data management in a cost-effective manner. The sample nomenclature system has been devised such that the following objectives can be attained:

- Sorting of data by matrix.
- Sorting of data by depth.
- Maintenance of consistency (field, laboratory, and data base sample numbers).
- Accommodation of all project-specific requirements on a global basis.
- Accommodation of laboratory sample number length constraints (10 characters).

2.0 SCOPE

The methods described in this procedure shall be used consistently for all projects requiring electronic data handling managed by personnel located in the Northeast Region of Brown & Root Environmental (Pittsburgh, Wayne, Holt, and Wilmington) and for any large contracts managed by the Northeast Region (e.g., NORTHDIV CLEAN, SOUTHDIV CLEAN, ARCS I, ARCS III, etc.). Smaller projects (as determined by Project Manager) are outside the scope of this SOP.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Program Manager - It shall be the responsibility of the Program Manager (or designee) to inform contract-specific Project Managers of the existence and requirements of this Standard Operating Procedure.

Project Manager - It shall be the responsibility of the Project Manager to determine the applicability of this Standard Operating Procedure based on: (1) program-specific requirements, and (2) project size and objectives. It shall be the responsibility of the Project Manager (or designee) to ensure that the sample nomenclature is thoroughly specified in the relevant project planning document (e.g., sampling and analysis plan) and is consistent with this Standard Operating Procedure if relevant. It shall be the responsibility of the project manager to ensure that the Field Operations Leader is familiar with the sample nomenclature system.

Field Operations Leader - It shall be the responsibility of the Field Operations Leader to ensure that all field technicians or sampling personnel are thoroughly familiar with this Standard Operating Procedure and the project-specific sample nomenclature system. It shall be the responsibility of the Field Operations Leader to ensure that the sample nomenclature system is used during all project-specific sampling efforts.

5.0 PROCEDURES

5.1 Introduction

The sample numbering system consists of 12 distinct alpha-numeric characters, only 10 of which will be provided to the laboratory on the sample labels and chain-of-custody forms. The sample number provided to the lab shall be as follows where "A" indicates "alpha," "N" indicates "numeric," and "E" indicates "either"):

$$\overline{E}\ \overline{E}\ \overline{E}\ \overline{A}\ \overline{A}\ \overline{E}\ \overline{E}\ \overline{E}\ \overline{N}\ \overline{N}$$

Once the analytical results are received from the laboratory the sample number will be revised by a subroutine such that the sample number is more user friendly (i.e., dashes will be inserted). The sample number will then appear as follows:

$$\overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{A}\ \overline{A}\ -\ \overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{N}\ \overline{N}$$

If multiple sampling events occur (or are planned) for a given matrix, a subroutine within the database will be used to append two additional characters such that the sample number will appear as follows:

$$\overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{A}\ \overline{A}\ -\ \overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{N}\ \overline{N}\ -\ \overline{N}\ \overline{N}$$

Site Type Location Depth Round

5.2 Sample Number Field Requirements

The various fields in the sample number will include the following:

- Site Identifier
- Sample Type
- Sample Location
- Sample Depth Indicator
- Sampling Round

The site identifier must be a three-character field (numeric characters, alpha characters, or a mixture of alpha and numeric characters may be used). A site number is necessary since many facilities/sites have multiple individual sites, SWMUs, operable units, etc.

The sample type must be a two-character alpha field. Suggested codes are provided in Section 5.3 of this SOP.

The sample location must be a three-character field (alpha, numeric, or a mixture).

The depth field must be provided for all samples, regardless if it is strictly applicable (as discussed in Section 5.3).

The sampling round is optional, but, if provided, must be two numeric characters.

5.3 Example Sample Field Designations

Examples of each of the fields are as follows:

Site Number - Examples of site numbers/designations are as follows:

A01 - Area of Concern Number 1
125 - Solid Waste Management Unit Number 125
000 - Base or Facility Wide Sample (e.g., upgradient well)
BBG - Base Background

The examples cited are only suggestions. Each Project Manager (or designee) must designate appropriate (and consistent) site designations for their individual project.

Sample Type - Examples of sample types are as follows:

AS - Air Sample
BS - Biota Sample (See Note)
CP - Composite Sample
CS - Chip Sample
DS - Drum Sample
DU - Dust Sample
FP - Free Product
ID - Investigation Derived Waste Sample
LT - Leachate Sample
MW - Monitoring Well
OF - Outfall Sample
RW - Residential Well Sample
SB - Soil Boring Sample
SD - Sediment Sample
SC - Scrape Sample
SG - Soil Gas Sample
SP - Seep Sample
SS - Surface Soil Sample
SU - Subsurface Soil Sample
SW - Surface Water Sample
TP - Test Pit Sample
TW - Temporary Well Sample
WC - Well Construction Material Sample
WI - Wipe Sample
WP - Well Point Sample
WS - Waste/Sludge Sample

Note: The biota sample designation may be contingent upon the type of biota sampled (e.g., BL - Lobster; BF - Finfish; BC - Clam; BO - Oyster). Numerous other examples can be cited but will be site-specific.

This field will also be used to designate field Quality Control Samples, as follows:

TB - Trip Blank
FB - Field Blank
RB - Rinsate Blank (Equipment Blank)
BB - Bottle Blank
AB - Ambient Condition Blank

Field quality control samples should be numbered sequentially (e.g., RB-001; FB-010, etc.).

Filtered/unfiltered surface water or groundwater samples shall be handled in an separate manner, as subsequently discussed.

Location - Examples of the location field are as follows:

A01 - Grid node A1
001 - Monitoring Well 1

It is important that consistency be maintained with respect to the use of the characters "0" and O. Data base subroutines will not sort correctly if a mixture are used (e.g, AO1 and A02).

Depth - Formerly, depth specifications were indicated with a four digit field (e.g., 0002 - 0 to 2 feet). While this is effective for depth sorting, it is difficult to include this level of detail in a 10-character lab number (FormMaster limitations). In addition, this approach will not accommodate non-integer depths (e.g., 2.5 feet to 4.5 feet).

Based on such potential problems, the following approach shall be used: Sample depths will simply represent the horizon from which the sample was obtained: For example, if ten split-spoon samples are collected from a boring, they will be numbered 01 through 10. The sample log sheet will be used to record the specific depth of the sample, and this information will be entered in a separator field in the data base.

Similar nomenclature will be used for depth-specific surface water and sediment samples, etc. If no depth information is required (e.g., groundwater samples), the field must still be filled (e.g., Ø, Ø).

This field will also be used for the designation of filtered and unfiltered samples. An unfiltered groundwater sample shall be designated as U0, if and only if, a corresponding filtered sample is collected. Such as sample shall be designated as F0.

Sampling Round - The sampling round field is straightforward. It can range from 01 to 99.

5.4 Example Sample Numbers

Examples of complete sample numbers (field/data base versus laboratory) are as follows:

Field/Data Base ID	Lab ID	Description
101-SB-A01-01	101SBA0101	The first sample (e.g., 0 to 2 feet) from soil boring A01 (grid) at Site 101.
101-SB-A01-02	101SBA0102	The second sample from boring A01 (could be the next depth interval or a duplicate of 101-SB-A01-01).
125-MW-001-01-01	125MW00101	A groundwater sample from monitoring well MW001 (first sampling round)
125-MW-001-02-01	125MW00102	A duplicate groundwater sample from monitoring well MW001 (first sampling round)
130-MW-003-U1-01	130MW003U1	An unfiltered groundwater sample from monitoring well MW003 (first sampling round)
130-MW-003-F1-01	130MW003F1	A filtered groundwater sample from monitoring well MW003 (first sampling round)
137-RB-001-00-01	137RB00100	The first rinsate blank collected at site 137.
137-TB-004-00-02	137TB00400	The fourth trip blank collected during the second sampling event at Site 137.
155-SW-003-01-01	155SW00301	A surface water sample collected from the surface of a pond at Site 155.
155-SW-003-02-01	155SW00302	A surface water sample collected from the bottom of the water column in a pond at Site 155.

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1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the proper methods for evaluating existing monitoring wells, and determining water level measurements.

2.0 SCOPE

The procedures described herein are applicable to all existing monitoring wells and, for the most part, are independent of construction materials and methods.

3.0 GLOSSARY

Hydraulic Head - The height to which water will rise in a well.

Water Table - A surface in an unconfined aquifer where groundwater pressure is equal to atmospheric pressure (i.e., the pressure head is zero).

4.0 RESPONSIBILITIES

Site Geologist/Hydrogeologist - Has overall responsibility for obtaining water level measurements and developing groundwater contour maps. The site geologist/hydrogeologist (in concurrence with the Project Manager) shall specify the reference point from which water levels are measured (usually a specific point on the upper edge of the inner well casing), the number of data points needed and which wells shall be used for a contour map, and how many complete sets of water levels are required to adequately define groundwater flow directions (e.g., if there are seasonal variations).

Field Personnel - Must have a basic familiarity with the equipment and procedures involved in obtaining water levels, and must be aware of any project-specific requirements.

5.0 PROCEDURES

Accurate, valid and useful groundwater monitoring requires that four important conditions be met:

- Proper characterization of site hydrogeology.
- Proper design of the groundwater monitoring program, including adequate numbers of wells installed at appropriate locations and depths.
- Satisfactory methods of groundwater sampling and analysis to meet the data quality objectives (DQOs).
- The assurance that specific monitoring well samples are representative of water quality conditions in the monitored interval

To insure that these conditions are met, adequate descriptions of subsurface geology, well construction methods and well testing results must be available. The following steps will help to insure that the required data are available to permit an evaluation of the utility of existing monitoring wells for collecting additional samples.

5.1 Preliminary Evaluation

A necessary first step in evaluating existing monitoring well data is the study and review of the original work plan for monitoring well installation (if available). This helps to familiarize the site geologist/hydrogeologist with site-specific conditions, and will promote an understanding of the original purpose of the monitoring wells.

The next step of the evaluation should involve a review of all available information concerning borehole drilling and well construction. This will allow interpretation of groundwater flow conditions and area geology, and will help to establish consistency between hydraulic properties of the well and physical features of the well or formation. The physical features which should be identified and detailed, if available, include:

- The well identification number, permit number and location by referenced coordinates, the distance from prominent site features, or the location of the well on a map.
- The installation dates, drilling methods, well development methods, and contractors.
- The depth to bedrock -- where rock cores were not taken, auger refusal, drive casing refusal or penetration test results (blow counts for split-barrel sampling) may be used to estimate bedrock interface.
- The soil profile and stratigraphy.
- The borehole depth and diameter.
- The elevation of the top of the protective casing, the top of the well riser, and the ground surface.
- The total depth of the well.
- The type of well materials, screen type, slot size, and length, and the elevation/depths of the screen, interval, and/or monitored interval.
- The elevation/depths of the tops and bottom of the filter pack and well seals and the type and size.

5.2 Field Inspection

During the onsite inspection of existing monitoring wells, features to be noted include:

- The condition of the protective casing, cap and lock.
- The condition of the cement seal surrounding the protective casing.
- The presence of depressions or standing water around the casing.
- The presence of any electrical cable and its connections.

If the protective casing, cap and lock have been damaged or the cement collar appears deteriorated, or if there are any depressions around the well casing capable of holding water, surface water may have

infiltrated into the well. This may invalidate previous sampling results since the time when leakage started is unknown.

The routine physical inspection must be followed by a more detailed investigation to identify other potential routes of contamination or sampling equipment malfunction. Any of these occurrences may invalidate previously-collected water quality data. If the monitoring well is to be used in the future, considerations shown in the steps described above should be rectified to rehabilitate the well. After disconnecting any wires, cables or electrical sources, remove the lock and open the cap. Check for the presence of organic vapors with a photoionization detector (PID) or flame-ionization detector (FID) and combustible gas meter to determine the appropriate worker safety level. The following information should be noted:

- Cap function.
- Physical characteristics and composition of the inner casing or riser, including inner diameter and annular space.
- Presence of grout between the riser and outer protective casing and the existence of drain holes in the protective casing.
- Presence of a riser cap, method of attachment to casing, and venting of the riser.
- Presence of dedicated sampling equipment; if possible, remove such equipment and inspect size, materials of construction and condition.

The final step of the field inspection is to confirm previous hydraulic or physical property data and to obtain data not previously available. This includes the determination of static water levels, total well depth and well obstruction. This may be accomplished using a weighted tape measure which can also be used to check for sediment (the weight will advance slowly if sediment is present, and the presence of sediment on the weight upon removal should be noted). If sediment is present, the well be should be redeveloped before sampling.

Lastly, as a final step, the location, condition and expected water quality of the wells should be reviewed in light of their usefulness for the intended purpose of the investigation.

5.3 Water Level (Hydraulic Head) Measurements

5.3.1 General

Groundwater level measurements can be made in monitoring wells, private or public water wells, piezometers, open boreholes, or test pits (after stabilization). Groundwater measurements should generally not be made in boreholes with drilling rods or auger flights present. If groundwater sampling activities are to occur, groundwater level measurements shall take place prior to well evacuation or sampling.

All groundwater level measurements shall be made to the nearest 0.01 foot, and recorded in the site geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A), along with the date and time of the reading. The total depth of the well shall be measured and recorded, if not already known. Weather changes that occur over the period of time during which water levels are being taken, such as precipitation and barometric pressure changes, should be noted.

In measuring groundwater levels, there shall be a clearly-established reference point of known elevation, which is normally identified by a mark on the upper edge of the inner well casing. The reference point shall be noted in the field notebook. To be useful, the reference point should be tied in with an established USGS benchmark or other properly surveyed elevation datum. An arbitrary datum could be used for an isolated group of wells, if necessary.

Cascading water within a borehole or steel well casings can cause false readings with some types of sounding devices (chalked line, electrical). Oil layers may also cause problems in determining the true water level in a well. Special devices (interface probes) are available for measuring the thickness of oil layers and true depth to groundwater, if required.

Water level readings shall be taken regularly, as required by the site geologist/hydrogeologist. Monitoring wells or open-cased boreholes that are subject to tidal fluctuations should be read in conjunction with a tidal chart (or preferably in conjunction with readings of a tide staff or tide level recorder installed in the adjacent water body); the frequency of such readings shall be established by the site hydrogeologist. All water level measurements at a site used to develop a groundwater contour map shall be made in the shortest practical time to minimize affects due weather changes, and at least during the same day.

5.3.2 Water Level Measuring Techniques

There are several methods for determining standing or changing water levels in boreholes and monitoring wells. Certain methods have particular advantages and disadvantages depending upon well conditions. A general description of these methods is presented, along with a listing of various advantages and disadvantages of each technique. An effective technique shall be selected for the particular site conditions by the site geologist/hydrogeologist.

In most instances, preparation of accurate potentiometric surface maps require that static water level measurements be obtained to a precision of 0.01 feet. To obtain such measurements in individual accessible wells, chalked tape or electrical water level indicator methods have been found best, and thus are the most often utilized. Other, less precise methods, such as the popper or bell sound, or bailer line methods, may be appropriate for developing preliminary estimates of hydraulic conditions. When a large number of (or continuous) readings are required, time-consuming individual readings are not usually feasible. In such cases, it is best to use the float recorder or pressure transducer methods. When conditions in the well limit readings (i.e., turbulence in the water surface or limited access through small diameter tubing), less precise, but appropriate methods such as the air line or capillary tubing methods can be used (see subsequent SOP section for discussion of these devices).

5.3.3 Methods

Water levels can be measured by several different techniques, but the same steps shall be followed in each case. The proper sequence is as follows

1. Check operation of recording equipment above ground. Prior to opening the well, don personal protective equipment, as required.

2. Record all information specified below in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A):

   - Well number.

- Water level (to the nearest 0.01 foot; 0.3 cm). Water levels shall be taken from the surveyed reference mark on the top edge of the inner well casing.

- Time and day of the measurement.

Water level measuring devices with permanently marked intervals shall be used when possible. If water level measuring devices marked by metal or plastic bands clamped at intervals along the measuring line are used, the spacing and accuracy of these bands shall be checked frequently as they may loosen and slide up or down the line, resulting in inaccurate reference points.

5.3.4 Water Level Measuring Devices

Chalked Steel Tape

The water level is measured by chalking a weighted steel tape and lowering it a known distance (to any convenient whole foot mark) into the well or borehole. The water level is determined by subtracting the wetted chalked mark from the total length lowered into the hole.

The tape shall be withdrawn quickly from the well because water has a tendency to rise up the chalk due to capillary action. A water finding paste may be used in place of chalk. The paste is spread on the tape the same way as the chalk, and turns red upon contacting water.

Disadvantages to this method include the following: depths are limited by the inconvenience of using heavier weights to properly tension longer tape lengths; ineffective if borehole/well wall is wet or inflow is occurring above the static water level; chalking the tape is time-consuming; difficult to use during periods of precipitation.

Electric Water Level Indicators

These devices consist of a spool of small-diameter cable and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact.

There are a number of commercial electric sounders available, none of which is entirely reliable under all conditions likely to occur in a contaminated monitoring well. In conditions where there is oil on the water, groundwater with high specific conductance, water cascading into the well, steel well casing, or a turbulent water surface in the well, measuring with an electric sounder may be difficult.

For accurate readings, the probe shall be lowered slowly into the well. The electric tape is marked at the measuring point where contact with the water surface was indicated. The distance from the mark to the nearest tape band is measured using an engineer's folding ruler or steel tape, and added to the band reading to obtain the depth to water. If the band is not a permanent marking band, spacing shall be checked periodically as described in Section 5.3.6.

Popper or Bell Sounder

A bell- or cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "plopping" or "popping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes, and reading the tape when the weight strikes the water. This method is not sufficiently accurate to obtain water levels to 0.01 feet, and thus is more appropriate for obtaining only approximate water levels quickly.

Float Recorder

A float or an electromechanically actuated water-seeking probe may be used to detect vertical changes of the water surface in the hole. A paper-covered recording chart drum is rotated by the up and down motion of the float via a pulley and reduction gear mechanism, while a clock drive moves a recording pen horizontally across the chart. To ensure continuous records, the recorder shall be inspected, maintained, and adjusted periodically. This type of device is useful for continuously measuring periodic water level fluctuations, such as tidal fluctuations or influences of pumping wells.

Air Line

An air line is especially useful in pumped wells where water turbulence may preclude the use of other devices. A small-diameter weighted tube of known length is installed from the surface to a depth below the lowest water level expected. Compressed air (from a compressor, bottled air, or air pump) is used to purge the water from the tube, until air begins to escape the lower end of the tube, and is seen (or heard) to be bubbling up through the water in the well. The pressure needed to purge the water from the air line multiplied by 2.307 (feet of water for 1 psi) equals the length in feet of submerged air line. The depth to water below the center of the pressure gauge can be calculated by subtracting the length of air line below the water surface from the total length of the air line.

The disadvantages to this method include the need for an air supply and lower level of accuracy (unless a very accurate air pressure gauge is used, this method cannot be used to obtain water level readings to the nearest 0.01 ft).

Capillary Tubing

In small diameter piezometer tubing, water levels are determined by using a capillary tube. Colored or clear water is placed in a small "U"-shaped loop in one end of the tube (the rest of the tube contains air). The other end of the capillary tube is lowered down the piezometer tubing until the water in the loop moves, indicating that the water level has been reached. The point is then measured from the bottom of the capillary tube or recorded if the capillary tube is calibrated. This is the best method for very small diameter tubing monitoring systems such as Barcad and other multilevel systems. Unless the capillary tube is calibrated, two people may be required to measure the length of capillary tubing used to reach the groundwater. Since the piezometer tubing and capillary tubing usually are somewhat coiled when installed, it is difficult to accurately measure absolute water level elevations using this method. However, the method is useful in accurately measuring differences or changes in water levels (i.e., during pumping tests).

Pressure Transducer

Pressure transducers can be lowered into a well or borehole to measure the pressure of water and therefore the water elevation above the transducer. The transducer is wired into a recorder at the surface to record changes in water level with time. The recorder digitizes the information and can provide a printout or transfer the information to a computer for evaluation (using a well drawdown/recovery model). The pressure transducer should be initially calibrated with another water level measurement technique to ensure accuracy. This technique is very useful for hydraulic conductivity testing in highly permeable material where repeated, accurate water level measurements are required in a very short period of time. A sensitive transducer element is required to measure water levels to 0.01 foot accuracy.

Borehole Geophysics

Approximate water levels can be determined during geophysical logging of the borehole (although this is not the primary purpose for geophysical logging and such logging is not cost effective if used only for this purpose). Several logging techniques will indicate water level. Commonly-used logs which will indicate saturated/unsaturated conditions include the spontaneous potential (SP) log and the neutron log.

5.3.5 Data Recording

Water level measurements, time, data, and weather conditions shall be recorded in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet. All water level measurements shall be measured from a known reference point. The reference point is generally a marked point on the upper edge of the inner well casing that has been surveyed for an elevation. The exact reference point shall be marked with permanent ink on the casing since the top of the casing may not be entirely level. It is important to note changes in weather conditions because changes in the barometric pressure may affect the water level within the well.

5.3.6 Specific Quality Control Procedures for Water Level Measuring Devices

All groundwater level measurement devices must be cleaned before and after each use to prevent cross contamination of wells. Manufacturer's instructions for cleaning the device shall be strictly followed. Some devices used to measure groundwater levels may need to be calibrated. These devices shall be calibrated to 0.01 foot accuracy and any adjustments/corrections shall be recorded in the field logbook/notebook. After the corrections/adjustments are made to the measuring device and entered in the field logbook/notebook, the corrected readings shall be entered onto the Groundwater Level Measurement Sheet (Attachment A). Elevations will be entered on the sheet when they become available.

5.4 Health and Safety Considerations

Groundwater contaminated by volatile organic compounds may release toxic vapors into the air space inside the well pipe. The release of this air when the well is initially opened is a health/safety hazard which must be considered. Initial monitoring of the well headspace and breathing zone concentrations using a PID (e.g., HNu) or FID (e.g., OVA) and combustible gas meters shall be performed to determine required levels of protection.

6.0 RECORDS

A record of all field procedures, tests and observations must be recorded in the site logbook or designated field notebook. Entries in the log/notebook should include the individuals participating in the field effort, and the date and time. The use of annotated sketches may help to supplement the evaluation.

ATTACHMENT A
EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET

GROUNDWATER LEVEL MEASUREMENT SHEET

Page ___ of ___

PROJECT NAME: _____ LOCATION: _____
PROJECT NUMBER: _____ MEASURING DEVICE: _____
PERSONNEL: _____ ADJUSTMENT FACTOR: _____
DATE: _____ REMARKS: _____
WEATHER CONDITIONS: _____

Well or Piezometer Number	Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Groundwater Elevation (Feet)*	Comments

*Measurements to nearest 0.01 foot.

Signature(s): _____

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1.0 PURPOSE

The purpose of this procedure is to describe the methods and equipment necessary to perform soil and rock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain soil, both surface and subsurface, and rock samples during field sampling activities.

2.0 SCOPE

This guideline addresses most of the accepted and standard drilling techniques, their benefits, and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of sampling required.

The sampling methods described within this procedure are applicable to collecting surface and subsurface soil samples, and obtaining rock core samples for lithologic and hydrogeologic evaluation, excavation/foundation design and related civil engineering purposes.

3.0 GLOSSARY

Rock Coring - A method in which a continuous solid cylindrical sample of rock or compact rock-like soil is obtained by the use of a double tube core barrel that is equipped with an appropriate diamond-studded drill bit which is advanced with a hydraulic rotary drilling machine.

Wire-Line Coring - As an alternative to conventional coring, this technique is valuable in deep hole drilling, since this method eliminates trips in and out of the hole with the coring equipment. With this technique, the core barrel becomes an integral part of the drill rod string. The drill rod serves as both a coring device and casing.

4.0 RESPONSIBILITIES

Project Manager - In consultation with the project geologist, the Project Manager is 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. The Project Manager also determines 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.

Field Operations Leader (FOL) - The FOL is responsible for the overall supervision and scheduling of drilling activities, and is strongly supported by the project geologist.

Project Geologist - The project geologist is responsible for ensuring 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 SOPs SA-6.3 and GH-1.5). 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 and/or Sampling and Analysis Plan.

Drilling Subcontractor - Operates under the supervision of the FOL. 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 FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager).

The drilling subcontractor is responsible for following decontamination procedures specified in the project plan documents. Upon completion of the work, the driller is 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.
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP SA-7.1. 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 SOPs SA-6.3 and GH-1.5). 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, the waste conditions at the site, and reviewing the purpose of drilling 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 rotating 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 requires 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 4 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 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 objective of the borehole 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
  - Rotosonic
  - 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 guidelines established in SOP SA-1.3 shall also be followed. 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.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation. However, 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 drilling configuration 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 SOP GH-2.8 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).

At the option of the Field Operations Leader (in communication with the Project Manager), 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 penetrate only the water table aquifer, since loose soil backfill in the boring may still provide a preferred pathway for surface liquids to reach the water table.

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

This drilling method is similar to hollow-stem augering. Practical application of this method is severely restricted compared to use of hollow-stem augers. Split-barrel (split-spoon) sampling cannot be performed without pulling the augers out, which may allow the hole to collapse. The continuous-flight solid-stem auger drilling 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, 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, this 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. 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.

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

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 (Shelby) 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 subsequent 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 requires 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.
- Groundwater 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.

Soil samples shall be taken as specified by project plan documents, or more frequently, if requested by the project 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 project geologist.

5.2.4 Rotosonic Drilling

The Rotosonic drilling method employs a high frequency vibrational and low speed rotational motion coupled with down pressure to advance the cutting edge of a drill string. This produces a uniform borehole while providing a continuous, undisturbed core sample of both unconsolidated and most bedrock formations. Rotosonic drilling advances a 4-inch diameter to 12-inch diameter core barrel for sampling and can advance up to a 12-inch diameter outer casing for the construcito of standard and telescoped monitoring wells. During drilling, the core barrel is advanced ahead of the outer barrel in increments as determined by the site geologist and depending upon type of material, degree of subsurface contamination and sampling objectives.

The outer casing can be advanced at the same time as the inner drill string and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed sample and has been pulled out of the borehole. The outer casing can be advanced dry in most cases, or can be advanced with water or air depending upon the formations being drilled, the depth and diameter of the hole, or requirements of the project.

Advantages of this method include:

- Sampling and well installation are faster as compared to other drilling methods.
- Continuous sampling, with larger sample volume as compared to split-spoon sampling.
- The ability to drill through difficult formations such as cobbles or boulders, hard till and bedrock.
- Reduction of IDW by an average of 70 to 80 percent.
- Well installations are quick and controlled by elimination of potential bridging of annular materials during well installation, due to the ability to vibrate the outer casing during removal.

Disadvantages include:

- The cost for Rotosonic drilling as compared to other methods are generally higher. However, the net result can be a significant savings considering reduced IDW and shortened project duration.
- Rotosonic drill rigs are large and need ample room to drill, however, Rotosonic units can be placed on the ground or placed on an ATV.
- There are a limited number of Rotosonic drilling contractors at the present time.

5.2.5 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.

5.2.6 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 SOP GH-1.5). The casing is normally advanced by a 300-pound 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 within which wash water is used and in which the casing is driven must be clearly 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 4 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).

5.2.7 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 needs to 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).

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, cable 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 (Shelby) 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 (e.g., such 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.

5.2.8 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 this method has also been used to install 3- to 4-inch-diameter casings to a depth of 200 feet.

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.

5.2.9 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 project plan documents. 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 Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). These techniques are slow but effective where larger pieces of equipment do not have access, and where very shallow holes are desired (less than 15 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.10 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 of 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 project plans. 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).
- 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.

5.2.11 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 using 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 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 include:

  - 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.

5.2.12 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-inch or 7-7/8-inch bits will nominally drill 6-inch and 8-inch holes, respectively).

For obtaining split-barrel samples of a formation, samplers are commonly manufactured in sizes ranging from 2 inches to 3-1/2 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 project plan documents.

5.2.13 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 feet to 50 feet) 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)
Rotosonic Drilling	100'-160' (continuous core)
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 5.2.10, except that larger casing is used) or by using a driven-casing method (see Section 5.2.6 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 ensure 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.

Clean sand is placed in the annulus around and to a point of 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 clean out 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 as to 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.

- 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 measuring 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 of 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 SOP GH-2.8. 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 Project Manager. The specific slurry composition and the concentration of suspected contaminants 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 by the judgment of the site geologist and noted in the site logbook, and only after approval by the Project 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.

5.6 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 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.

Surface protocols for various soil sampling techniques are discussed in SOP SA-1.3. Continuous-core soil sampling and rock coring are discussed below. 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, 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.

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. Rotosonic drilling methods also provide a continuous soil sample.

5.7 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. Rock coring can, however, proceed for thousands of feet continuously, depending on the size of the drill rig, and 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. Down hole 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 Figure 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.

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).

5.7.1 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-barrel 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, leveling 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); sample soils per SOP SA-1.3. 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 conditions warrant.

FIGURE 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring Bit Size	Nominal*		Set Size*	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	0.735
EWT	1 1/2	29/32	1.470	0.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	0.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.889	3.187
HWG	3 29/32	3	3.889	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line ___|___/	1 7/8	1	1.875	1.000
BX Wire line ___|___/	2 3/8	1 7/16	2.345	1.437
NX Wire line ___|___/	3	1 15/16	2.965	1.937

* All dimensions are in inches; to convert to millimeters, multiply by 254.

___ ___/ Wire line dimensions and designations may vary according to manufacturer.

FIGURE 1
STANDARD SIZES OF CORE BARRELS AND CASING
PAGE TWO

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	---	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
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	---	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
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 __|__\	---	---	---	---	1.875	1.750	1.000	---
---	BX __|__\	---	---	---	---	2.345	2.250	1.437	---
---	NX __|__\	---	---	---	---	2.965	2.813	1.937	---

* All dimensions are in inches; to convert to millimeters, multiply by 254.
__\|__/ Wire line dimensions and designations may vary according to manufacturer.

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

- 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.

5.7.2 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 SOP GH-1.5. If moisture content will be determined or if it is desirable to prevent drying (e.g., 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 designating 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 Project 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. 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.

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).

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ATTACHMENT A

DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Hollow-stem augers (Ref. 7)	6 1/4	5	2 1/4	
	6 3/4	5 3/4	2 3/4	---
	7 1/4	6 1/4	3 1/4	---
	13 1/4	12	6	---
Thin Wall Tube Samplers (Ref. 7)	---	2	1 7/8	---
	---	2 1/2	2 3/8	---
	---	3	2 7/8	---
	---	3 1/2	3 3/8	---
	---	4 1/2	4 3/8	---
	---	5	4 3/4	---
Drill Rods (Ref. 7)	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (Inches)
Driven External Coupled Extra Strong Steel* Casing (Ref. 8)	2 1/2	2.875	2.323	0.276
	3	3.5	2.9	0.300
	3 1/2	4.0	3.364	0.318
	4	4.5	3.826	0.337
	5	5.63	4.813	0.375
	6	6.625	5.761	0.432
	8	8.625	7.625	0.500
	10	10.750	9.750	0.500
	12	12.750	11.750	0.500

* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

ATTACHMENT A
DRILLING EQUIPMENT SIZES
PAGE TWO

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Flush Coupled Casing (Ref. 7)	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flush Joint Casing (Ref. 7)	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels (Ref. 7)	EWM	1 1/2	7/8**	
	AWM	1 7/8	1 1/8**	
	BWM	2 3/8	1 5/8**	
	NWM	3	2 1/8	
	HWG	3 7/8	3	
	2 3/4 x 3 7/8	3 7/8	2 11/16	
	4 x 5 1/2	5 1/2	3 15/16	
	6 x 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16**	
	BQ (wireline)	2 23/64	1 7/16**	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

** Because of the fragile nature of the core and the difficulty to identify rock details, use of small-diameter core (1 3/8") is not recommended.

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1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of permanent monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is properly screened (if screening is necessary, e.g., open borehole), cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Rig Geologist - The rig geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when 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 engineer's 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, groundwater flow and potential well locations can be determined through the review of geologic data and the site terrain. In addition, data from 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 investigative 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 contaminant 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 contamination in the water-bearing zone. The

well diameter desired depends 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 (and possibly other) 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, (i.e., 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 volume of water in the monitoring well available for sampling is dependent on the well diameter as follows:

Casing Inside Diameter (Inch)	Standing Water Depth to Obtain 1 Gallon Water (Feet)	Total Depth of Standing Water for 4 Gallons (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 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 presentation on this topic). The two most commonly used materials are PVC and stainless steel for wells in which screens are installed. Properties of these two materials 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 required 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 where samples may be collected for metal analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

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 contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

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 No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

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 poorly graded, silica sand and should relate to the grain size of the aquifer sediments. 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 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent 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 installed), and the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used 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 extending 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 shallow 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, (e.g., cement-bentonite). 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, plus

3 to 5 pounds of granular or flake-type bentonite, and 6 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6 gallons of water.

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- to 2-foot) 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 of 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

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

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 engineer's rule to ensure proper 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, the sand pack can be installed. A weighted tape measure must be used during the installation procedure 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.

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.

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 the unconfined and confined aquifer. 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 (determined by the rig geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

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 has 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.

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 of the surface (the typical range of suction pumps). Two manufacturers of these samplers are Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, and BARCAD Systems, Inc., of Concord, Massachusetts. Each manufacturer 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 second 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).

5.4.1 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.

5.4.2 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.

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

5.4.4 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.

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7.0 RECORDS

A critical part of monitoring well installation is recording of significant details and events in the site logbook or 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 (see Attachments to SOP SA-6.3) shall be completed thus ensuring 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. 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 affect the driller's final fee.

ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	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
Mineral Acid/ High Solids Content	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)

Potentially-Deteriorating Substance	Type of Casing Material								
	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 Content	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

* Trademark of DuPont

Source: Barcelona et al., 1983

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 are not critical.
Weight	Relatively heavier.	Light-weight; 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 hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when 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.

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUND WATER SAMPLES FROM MONITORING WELLS

I. SCOPE & APPLICATION

This standard operating procedure (SOP) provides a general framework for collecting ground water samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates). The SOP emphasizes the need to minimize stress by low water-level drawdowns, and low pumping rates (usually less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP is aimed primarily at sampling monitoring wells that can accept a submersible pump and have a screen, or open interval length of 10 feet or less (this is the most common situation). However, this procedure is flexible and can be used in a variety of well construction and ground-water yield situations. Samples thus obtained are suitable for analyses of ground water contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals and other inorganics), or other naturally occurring analytes.

This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs). For this the reader may wish to check: Cohen, R.M. and J.W. Mercer, 1993, DNAPL Site Evaluation; C.K. Smoley (CRC Press), Boca Raton, Florida and U.S. Environmental Protection Agency, 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance; Washington, DC (EPA/530-R-93-001).

The screen, or open interval of the monitoring well should be optimally located (both laterally and vertically) to intercept existing contaminant plume(s) or along flowpaths of potential contaminant releases. It is presumed that the analytes of interest move (or potentially move) primarily through the more permeable zones within the screen, or open interval.

Use of trademark names does not imply endorsement by U.S.EPA but is intended only to assist in identification of a specific type of device.

Proper well construction and development cannot be overemphasized, since the use of installation techniques that are appropriate to the hydrogeologic setting often prevents "problem well" situations from occurring. It is also recommended that as part of development or redevelopment the well should be tested to determine the appropriate pumping rate to obtain stabilization of field indicator parameters with minimal drawdown in shortest amount of time. With this information field crews can then conduct purging and sampling in a more expeditious manner.

The mid-point of the saturated screen length (which should not exceed 10 feet) is used by convention as the location of the pump intake. However, significant chemical or permeability contrast(s) within the screen may require additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (high(er) permealability and/or high(er) chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help insure that the low stress procedure will not underestimate contaminant concentrations. The Sampling and Analysis Plan must provide clear instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 4 hours of purging indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization) c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives).

Changes to this SOP should be proposed and discussed when the site Sampling and Analysis Plan is submitted for approval. Subsequent requests for modifications of an approved plan must include adequate technical justification for proposed changes. All changes and modifications must be approved before implementation in field.

II. EQUIPMENT

A. Extraction device

Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or Teflon).

Adjustable rate, peristaltic pumps (suction) may be used with caution. Note that EPA guidance states: "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11).

The use of inertial pumps is discouraged. These devices frequently cause greater disturbance during purging and sampling and are less easily controlled than the pumps listed above. This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

B. Tubing

Teflon or Teflon lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for inorganics analyses. However, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.

Stainless steel tubing may be used when sampling for VOCs, SVOCs, pesticides, and PCBs. However, it should be used with caution when sampling for metals.

The use of 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This will help ensure the tubing remains liquid filled when operating at very low pumping rates.

Pharmaceutical grade (Pharmed) tubing should be used for the section around the rotor head of a peristaltic pump, to minimize gaseous diffusion.

C. Water level measuring device(s), capable of measuring to 0.01 foot accuracy (electronic "tape", pressure transducer). Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use

must include check measurements with a water level "tape" at the start and end of each record.

D. Flow measurement supplies (e.g., graduated cylinder and stop watch).

E. Interface probe, if needed.

F. Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate the samples.

G. Indicator field parameter monitoring instruments - pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and temperature. Use of a flow-through-cell is required when measuring all listed parameters, except turbidity. Standards to perform field calibration of instruments. Analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846. For Eh measurements, follow manufacturer's instructions.

H. Decontamination supplies (for example, non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.).

I. Logbook(s), and other forms (for example, well purging forms).

J. Sample Bottles.

K. Sample preservation supplies (as required by the analytical methods).

L. Sample tags or labels.

M. Well construction data, location map, field data from last sampling event.

N. Well keys.

O. Site specific Sample and Analysis Plan/Quality Assurance Project Plan.

P. PID or FID instrument (if appropriate) to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

III. PRELIMINARY SITE ACTIVITIES

Check well for security damage or evidence of tampering, record pertinent observations.

Lay out sheet of clean polyethylene for monitoring and sampling equipment.

Remove well cap and immediately measure VOCs at the rim of the well with a PID or FID instrument and record the reading in the field logbook.

If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook.

A synoptic water level measurement round should be performed (in the shortest possible time) before any purging and sampling activities begin. It is recommended that water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) be measured the day before, in order to allow for re-settlement of any particulates in the water column. If measurement of total well depth is not made the day before, it should not be measured until after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe are usually not needed unless analytical data or field head space information signal a worsening situation. Note: procedures for collection of LNAPL and DNAPL samples are not addressed in this SOP.

IV. PURGING AND SAMPLING PROCEDURE

Sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred.

1. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the midpoint of the zone to be sampled. The Sampling and Analysis Plan should specify the sampling depth, or provide criteria for selection of intake depth for each well (see Section I). If possible keep the pump intake at least two

feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well. Collection of turbid free water samples may be especially difficult if there is two feet or less of standing water in the well.

2. Measure Water Level

Before starting pump, measure water level. If recording pressure transducer is used-initialize starting condition.

3. Purge Well

3a. Initial Low Stress Sampling Event

Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet but remains stable, continue purging until indicator field parameters stabilize.

Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the intake level (if the static water level is above the well screen, avoid lowering the water level into the screen). The final purge volume must be greater than the stabilized drawdown volume plus the extraction tubing volume.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic), and/or the use of dedicated equipment. If the recharge rate of the well is lower than extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well should be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (ideally the intake should not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

3b. Subsequent Low Stress Sampling Events

After synoptic water level measurement round, check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). Perform purging operations as above.

4. Monitor Indicator Field Parameters

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, Eh, DO) every three to five minutes (or less frequently, if appropriate). Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three (3) to five (5) minute intervals, are within the following limits:

turbidity (10% for values greater than 1 NTU),
DO (10%),
specific conductance (3%),
temperature (3%),
pH (± 0.1 unit),
ORP/Eh (± 10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities.

The flow-through-cell must be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must be submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe should come first (this parameter is most susceptible to error if air leaks into the system).

5. Collect Water Samples

Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (use a by-pass assembly or disconnect cell to obtain sample).

VOC samples should be collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

During purging and sampling, the tubing should remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel) or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate and new indicator field parameter values.

Add preservative, as required by analytical methods, to samples immediately after they are collected if the sample containers are not pre-preserved. Check analytical methods (e.g. EPA SW-846, water supply, etc.) for additional information on preservation. Check pH for all samples requiring pH adjustment to assure proper pH value. For VOC samples, this will require that a test sample be collected during purging to determine the amount of preservative that needs to be added to the sample containers prior to sampling.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter is required, and the filter size (0.45 um is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of ground water prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in ground water for human health risk calculations.

Label each sample as collected. Samples requiring cooling (volatile organics, cyanide, etc.) will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

6. Post Sampling Activities

If recording pressure transducer is used, remeasure water level with tape.

After collection of the samples, the pump tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth is optional after the initial low stress sampling event. However, it is recommended if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

V. DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and following sampling of each subsequent well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the well) will be decontaminated by one of the procedures listed below.

<u>Procedure 1</u>

The decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is

recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event show that the level of contaminants is insignificant, then this step may be skipped.

Flush with distilled/deionized water. The final water rinse must not be recycled.

Procedure 2

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

VI. FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the ground water samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples shall be collected for each batch of samples (a batch

VII. FIELD LOGBOOK

A field log shall be kept to document all ground water field monitoring activities (see attached example matrix), and record all of the following:

Well identification.

Well depth, and measurement technique.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, and clock time, at the appropriate time intervals; calculated or measured total volume pumped.

Well sampling sequence and time of each sample collection.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analysis.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling equipment used, including trade names, model number, diameters, material composition, etc.

VIII. DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, and whatever field logbook information is needed to allow for a full evaluation of data useability.

EXAMPLE (Minimum Requirements) Page____of____

Well PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

Location (Site/Facility Name)_____ Depth to _____/_____ of screen
Well Number_____ Date_____ (below MP) top bottom
Field Personnel_____ Pump Intake at (ft. below MP)_____
Sampling Organization_____ Purging Device; (pump type)_____
Identify MP_____

Clock Time 24 HR	Water Depth below MP ft	Pump Dial[1]	Purge Rate ml/min	Cum. Volume Purged liters	Temp. °C	Spec. Cond.[2] µS/cm	pH	ORP/ Eh[3] mv	DO mg/L	Turb-idity NTU	Comments

1. Pump dial setting (for example: hertz, cycles/min, etc).
2. µSieme per cm(same as µmhos/cm)at 25°C.
3. Oxidat reduction potential (stand in for Eh).

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information regarding the sampling of groundwater wells.

2.0 SCOPE

This procedure provides information on proper sampling equipment, onsite water quality testing, 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 modifications to methodology.

3.0 GLOSSARY

Conductance - The conductance of a conductor 1 centimeter long and 1 square centimeter in cross-sectional area. For groundwater measurements, a volume of water contained in a 1 cm x 1 cm sample container (the water acts as the conductor). Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only the current flows in the opposite direction due to the external source of applied voltage. Electrolytic cells are used in dissolved oxygen measurement.

Galvanic Cell - A electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit. Galvanic cells are used in dissolved oxygen measurement.

Ohm - Standard unit of electrical resistance (R). Used in specific conductance measurement. A siemen (or umho) is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode, immersed in water, as referenced against a standard hydrogen electrode.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Indicator paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution's pH.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law, $E = IR$, where E is the potential difference, I is the current, and R is the resistance. Used in measurement of specific conductance.

4.0 RESPONSIBILITIES

Project Hydrogeologist - Responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), and equipment to be used, and providing detailed input in this regard to the project plan documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of the site sampling personnel.

Project Geologist - is primarily responsible for the proper acquisition of the groundwater samples. He/she is also responsible for the actual analyses of onsite water quality samples, as well as instrument calibration, care, and maintenance. When appropriate, such responsibilities may be performed by other qualified personnel (e.g., field technicians).

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 analysis 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:

1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended prior to sampling. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical.

2. For wells that can be purged dry, 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 required.

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 or the 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 drops. 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 or other approved device may be used to collect the sample for analysis.

- The intake 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 low purge rate, equal to the well's recovery rate (low flow sampling).

Stratification of contaminants may exist in the aquifer. Concentration gradients as a result of mixing and dispersion processes, layers of variable permeability, and the presence of separate-phase product (i.e, floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column as it naturally occurs at that point, thus the result is the collection of a non-representative sample.

5.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with the guidelines expressed in SOP SA-6.1.

The following equipment shall be on hand when sampling ground water wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler, ice, labels and chain-of-custody documents.

- Field tools and instrumentation - Thermometer, pH paper/meter, camera and film (if appropriate), appropriate keys (for locked wells), engineer's rule, water level indicator, specific conductivity meter, and turbidity meter (as applicable).

- 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.

- Other sampling equipment - Bailers and inert line with tripod-pulley assembly (if necessary). Bailers or submersible centrifugal pumps shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

- Pails - Plastic, graduated.

- Decontamination solutions - Deionized water, laboratory detergents, 10% nitric acid solution (as required), and analytical-grade solvents (e.g., methanol, acetone, hexane), as required.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, cleaned prior to use, reusable, 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 site logbook or field notebook or on a sample log sheet form (see SOP SA-6.3):

- 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 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 $V = (0.163)(T)(r^2)$

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.

- Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

5.4 Evacuation of Static Water (Purging)

5.4.1 General

The amount of purging 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, pH, and turbidity (as applicable), have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook, field notebook, or on standardized data sheets.

5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A 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.

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.

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 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.

Air-Lift Samplers

This group of pump 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. Air (or 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.

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 can be difficult and time-consuming.

5.5 Onsite Water Quality Testing

This section describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen (DO) Concentration
- Oxidation Reduction Potential
- Certain Dissolved Constituents Using Specific Ion Elements
- Turbidity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, and colloidal material or suspended matter.

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

5.5.1 Measurement of pH

5.5.1.1 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.

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.

5.5.1.2 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 created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or basicity determination) and specific pH range hydrion paper.

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 (in this instance, 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 the ion concentration is generated and measured.

5.5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Stand-alone 150 portable pH meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- 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).
- Buffer solutions, as specified by the manufacturer.
- pH indicator paper, to cover the pH range 2 through 12.
- Manufacturer's operation manual.

5.5.1.4 Measurement Techniques for Field Determination of pH

pH Meter

The following procedure is used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

- Inspect the instrument and batteries prior to initiation of the field effort.
- Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.

- 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.

- If applicable, 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).

- Calibrate on a daily use basis following manufacturer's instructions. Record calibration data on an equipment calibration log sheet.

- 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 physical 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.

- Read and record the pH of the solution. pH shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature.

- Rinse the electrode(s) with deionized water.

- Store the electrode(s) in an appropriate manner when not in use.

Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

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 and proceed with successively narrower range paper until the sample pH is adequately determined.

5.5.2 Measurement of Specific Conductance

5.5.2.1 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.

5.5.2.2 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.

5.5.2.3 Equipment

The following equipment is needed for taking specific conductance (SC) measurements:

- Stand alone portable conductivity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

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

5.5.2.4 Measurement Techniques for Specific Conductance

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

- Check batteries and calibrate instrument before going into the field.

- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet. Potassium chloride solutions with a SC closest to the values expected in the field shall be used for calibration. Attachment B provides guidance in this regard.

- 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 (if applicable).
- Read and record the results in a field logbook or sample log sheet.
- Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for details.

5.5.3 Measurement of Temperature

5.5.3.1 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.

5.5.3.2 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.

5.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of cross-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 used, the instrument shall be calibrated according to manufacturer's recommendations.

5.5.4 Measurement of Dissolved Oxygen Concentration

5.5.4.1 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 monitoring method 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 is not susceptible to interference caused by color, turbidity, colloidal material or suspended matter.

5.5.4.2 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, while leaving the surface of the solution undisturbed.

Dissolved oxygen probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide, which are not easily depolarized from the indicating electrode. If a 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.

5.5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- Stand alone portable dissolved oxygen meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

5.5.4.4 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 warehouse 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 according to manufacturer's recommendations 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 C).

- Record all pertinent information on an equipment calibration sheet.

- Rinse the probe with deionized water.

- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. 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.

- Rinse the probe with deionized water.

- 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.

5.5.5 Measurement of Oxidation-Reduction Potential

5.5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The ORP parameter 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.

5.5.5.2 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 is 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.

5.5.5.3 Equipment

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

- 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.
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.5.4 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 deionized 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 container and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added (i.e., pH is raised) thus indicating 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 deionized water from a wash bottle. Place the sample in a clean container and insert the electrodes. Set temperature 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 or sample logsheet, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

5.5.6 Measurement of Turbidity

5.5.6.1 General

Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms, including plankton. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

It is important to obtain a turbidity reading immediately after taking a sample, since irreversible changes in turbidity may occur if the sample is stored too long.

5.5.6.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method. This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidmeter. Therefore, nephelometric turbidity units (NTU) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

5.5.6.3 Equipment

The following equipment is needed for turbidity measurement:

- Stand alone portable turbidity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.6.4 Measurements Techniques for Specific Conductance

The steps involved in taking turbidity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the probe in the sample and measure the turbidity. The reading must be taken immediately as suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.

- Read and record the results in a field logbook or sample log sheet. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.

- Rinse the electrode with deionized water.

5.6 Sampling

5.6.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the project plan documents which are approved prior to beginning work in the field:

- 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).

- 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.

- Work 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.

5.6.2 Sampling Methods

The collection of a groundwater sample consists of the following steps:

1. The site Health & Safety Officer (or designee) will first open the well cap and use volatile organic detection equipment (PID or FID) 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 on a groundwarer sampling log sheet (see SOP SA-6.3); then calculate the fluid volume in the well pipe (as previously described in this SOP).

3. Calculate well volume to be removed as stated in Section 5.3.

4. Select the appropriate purging equipment (see Attachment A). If an electric submersible pump with packer is chosen, go to Step 10.

5. Lower the 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 (as applicable). Lower the purging device, as required, to maintain submergence.

6. Measure the rate of discharge frequently. A graduated bucket and stopwatch are most commonly used; other techniques include use of pipe trajectory methods, weir boxes or flow meters.

7. Observe the 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. Purged water shall be collected in a designated container and disposed in an acceptable manner.

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 the sampling level before filling.

10. (For pump and packer assembly only). Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. 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 or greater), sample collection can be delayed until the following day. If the well has been purged 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 this occurrence in the site logbook.

12. Fill sample containers (preserve and label as described in SOP SA-6.1).

13. Replace the well cap and lock as appropriate. Make sure the well is readily identifiable as the source of the samples.

14. Process sample containers as described in SOP SA-6.1.

15. Decontaminate equipment as described in SOP SA-7.1.

5.7 Low Flow Purging and Sampling

5.7.1 Scope & Application

Low flow purging and sampling techniques are sometimes required for groundwater sampling activities. The purpose of low flow purging and sampling is to collect groundwater samples that contain

"representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at near natural flow conditions. The minimum stress procedure emphasizes negligible water level drawdown and low pumping rates in order to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 2 inches or more and a saturated screen, or open interval, length of ten feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This procedure is not designed to collect non-aqueous phase liquids samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs), using the low flow pumps.

The procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 5 NTU and to achieve a water level drawdown of less than 0.3 feet during purging and sampling. If these goals cannot be achieved, sample collection can take place provided the remaining criteria in this procedure are met.

5.7.2 Equipment

The following equipment is required (as applicable) for low flow purging and sampling:

- Adjustable rate, submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon). Peristaltic pumps may be used only for inorganic sample collection.
- Disposable clear plastic bottom filling bailers may be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing - Teflon, Teflon lined polyethylene, polyethylene, PVC, tygon steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device, 0.01 foot accuracy, (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies.
- Interface probe, if needed.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional Indicators - eH and dissolved oxygen, flow-through cell is required. Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s), and other forms (e.g., well purging forms).
- Sample Bottles.

- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Well construction data, location map, field data from last sampling event.
- Field Sampling Plan.
- PID or FID instrument for measuring VOCs (volatile organic compounds).

5.7.3 Purging and Sampling Procedure

Use a submersible pump to purge and sample monitoring wells which have a 2.0 inch or greater well casing diameter.

Measure and record the water level immediately prior to placing the pump in the well.

Lower pump, safety cable, tubing and electrical lines slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbid free water samples may be difficult if there is three feet or less of standing water in the well.

When starting the pump, slowly increase the pump speed until a discharge occurs. Check water level. Adjust pump speed to maintain little or no water level drawdown. The target drawdown should be less than 0.3 feet and it should stabilize. If the target of less than 0.3 feet cannot be achieved or maintained, the sampling is acceptable if remaining criteria in the procedure are met. Subsequent sampling rounds will probably have intake settings and extraction rates that are comparable to those used in the initial sampling rounds.

Monitor water level and pumping rate every three to five minutes (or as appropriate) during purging. Record pumping rate adjustments and depths to water. Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During initial pump start-up, drawdown may exceed the 0.3 feet target and then recover as pump flow adjustments are made (minimum purge volume calculations should utilize stabilized drawdown values, not the initial drawdown). If the recharge rate of the well is less than minimum capability of the pump do not allow the water level to fall to the intake level (if the static water level is above the screen, avoid lowering the water level into the screen). Shut off the pump if either of the above is about to occur and allow the water level to recover. Repeat the process until field indicator parameters stabilize and the minimum purge volume is removed. The minimum purge volume with negligible drawdown (0.3 feet or less) is two saturated screen length volumes. In situations where the drawdown is greater than 0.3 feet and has stabilized, the minimum purge volume is two times the saturated screen volume plus the stabilized drawdown volume. After the minimum purge volume is attained (and field parameters have stabilized) begin sampling. For low yields wells, commence sampling as soon as the well has recovered sufficiently to collect the appropriate volume for all anticipated samples.

During well purging, monitor field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every three to five minutes (or as appropriate). Purging is complete and sampling may begin when

all field indicator parameters have stabilized (variations in values are within ten percent of each other, pH +/- 0.2 units, for three consecutive readings taken at three to five minute intervals). If the parameters have stabilized, but turbidity remains above 5 NTU goal, decrease pump flow rate, and continue measurement of parameters every three to five minutes. If pumping rate cannot be decreased any further and stabilized turbidity values remain above 5 NTU goal record this information. Measurements of field parameters should be obtained (as per Section 5.5) and recorded.

VOC samples are preferably collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples: (1) Collect the non-VOCs samples first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample and record the new flow rate; (2) reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel), or clamp which should reduce the flow rate by constricting the end of the tubing; (3) insert a narrow diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, collect sample from the narrow diameter tubing.

Prepare samples for shipping as per SOP SA-6.1.

6.0 REFERENCES

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ATTACHMENT A

PURGING EQUIPMENT SELECTION

Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level <25 feet		X	X	X	X			
	Water Level >25 feet				X				
2-Inch	Water level <25 feet	X	X	X	X	X	X		
	Water Level >25 feet	X			X		X		
4-Inch	Water level <25 feet	X	X	X	X	X	X	X	X
	Water Level >25 feet	X			X		X	X	X
6-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X
8-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X

ATTACHMENT A
PURGING EQUIPMENT SELECTION
PAGE 2

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/ Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	<1.0/NA	(not submersible) Tygon®, silicone Viton®	0-30	670 mL/min with 7015-20 pump head	$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	Portable; venturi	<1.5 or <2.0/NA	PP, PE, PVC, SS, Teflon®, Tefzel®	0-100	0-500 mL/min depending on lift	$400-700	AC, DC, or gasoline-driven motors available; must be primed.
Geltek Corp.	Bailer 219-4	Portable; grab (positive displacement)	1.66/38	Teflon®	No limit	1,075 mL	$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton®	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon®, Viton®	0-250	0-2,800 mL/min	$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon®	No limit	850 mL sample volum e	$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2600 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon®, PP, PE, Detrin®, acetal	0-150	0-7,500 mL/min	$990	Requires compressed gas (40 psi minimum).
Keck Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-160	0-4,500 mL/min	$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3,500 mL/min	$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin®	No limit	Approximately 250 mL	$125-160	Other materials and models available; for measuring thickness of "floating" contaminants.
Q.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.66/36	PVC	0-230	0-2,000 mL/min	$300-400	Requires compressed gas; piezometric level indicator; other materials available.

ATTACHMENT A
PURGING EQUIPMENT SELECTION
PAGE 3

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/ Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	Portable; peristaltic (suction)	<0.5/NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 180	Portable; piston (positive displacement)	1.8/22	SS, Teflon®, Delrin® PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 514124 Pneumatic Water Sampler	Portable; gas drive (positive displacement)	1.9/18	PVC, nylon	0-1,100	250 mL/ flushing cycle	$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	5W Water Sampler	Portable; grab (positive displacement)	1.9/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	$1,300-1,800	Requires compressed gas; custom models available.
TIMCO Mfg. Co., Inc.	Std. Bailer	Portable; grab (positive displacement)	1.66/Custom	PVC, PP	No limit	250 mL/ft of bailer	$20-60	Other sizes, materials, models available; optional bottom-emptying device available; no solvents used.
TIMCO	Air or Gas Lift Sampler	Portable; gas drive (positive displacement)	1.66/30	PVC, Tygon®, Teflon®	0-150	350 mL/ flushing cycle	$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tole Devices Co.	Sampling Pump	Portable; bladder (positive displacement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	$800-1,000	Compressed gas required; DC control module; custom built.

Construction Material Abbreviations:

PE	Polyethylene
PP	Polypropylene
PVC	Polyvinyl chloride
SS	Stainless steel
PC	Polycarbonate
EPDM	Ethylene-propylene diene (synthetic rubber)

Other Abbreviations:

NA	Not applicable
AC	Alternating current
DC	Direct current

NOTE: Other manufacturers market pumping devices which could be used for groundwater sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication. No skimmer, scavenger-type, or high-capacity pumps are included.

Source: Barcelona et al., 1983.

ATTACHMENT B

SPECIFIC CONDUCTANCE OF 1 MOLAR KCl AT VARIOUS TEMPERATURES[1]

Temperature (°C)	Specific Conductance (umhos/cm)
15	1,147
16	1,173
17	1,199
18	1,225
19	1,251
20	1,278
21	1,305
22	1,332
23	1,359
24	1,368
25	1,413
26	1,441
27	1,468
28	1,496
29	1,524
30	1,552

[1] Data derived from the International Critical Tables 1-3-8.

ATTACHMENT C

VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

ATTACHMENT C
VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY
PAGE TWO

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					
46	6.0					
47	5.9					
48	5.8					
49	5.7					
50	5.6					

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore, used to correct measured D.O. concentration) using Attachment B.

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1.0 PURPOSE

This procedure describes methods and equipment commonly used for collecting environmental samples of surface water and aquatic sediment for either onsite examination and chemical testing, or for subsequent laboratory analysis.

2.0 SCOPE

The information presented in this guideline is generally applicable to all environmental sampling of surface waters (Section 5.3) and aquatic sediments (Section 5.5), except where the analyte(s) may interact with the sampling equipment. The collection of concentrated sludges or hazardous waste samples from disposal or process lagoons often requires methods, precautions and equipment different from those described herein.

3.0 GLOSSARY

Environmental Sample - a sample containing (or suspected to contain) low-level concentrations of contaminants, which does not require special handling or transport considerations as detailed in SOP SA-6.1.

Hazardous Waste Sample - a sample containing (or suspected to contain) higher concentrations of contaminants thus requiring special handling and/or transport considerations per SOP SA-6.1.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager has the overall responsibility for seeing that all surface water and sediment sampling activities are properly conducted by appropriately trained personnel.

Field Operations Leader - The Field Operations Leader (FOL) is responsible for the in-field supervision of the conduct of onsite water quality analyses, ensuring the completion and accuracy of all field documentation, and making sure that custody of all samples obtained is maintained according to proper procedures.

5.0 PROCEDURES

5.1 Introduction

Collecting a representative sample from surface water or sediments is difficult because of water movement, stratification or patchiness. To collect representative samples, one must standardize sampling bias related to site selection, sampling frequency, sample collection, sampling devices, and sample handling, preservation, and identification.

Representativeness is a qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been taken. Regardless of quality control applied during laboratory analyses and subsequent scrutiny of analytical data packages, reported data are not better than the confidence that can be placed in the representativeness of the samples.

5.2 Defining the Sampling Program

Many factors must be considered in developing a sampling program for surface water or sediments including study objectives, accessibility, site topography, physical characteristics of the water body (such as flow and mixing), point and diffuse sources of contamination, and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on the vertical and lateral mixing within the body of water. For sediments, dispersion depends on bottom current or flow characteristics, sediment characteristics (density, size) and geochemical properties (which affect adsorption/desorption). The hydrogeologist developing the sampling plan must therefore know not only the mixing characteristics of streams and lakes, but also must understand the role of fluvial-sediment transport, deposition, and chemical sorption.

5.2.1 Sampling Program Objectives

The objective of surface water sampling is to determine the surface water quality entering, leaving or remaining within the site. The scope of the sampling program must consider the sources and potential pathways for transport of contamination to or within a surface water body. Sources may include point sources (leaky tanks, outfalls, etc.) or nonpoint sources (e.g., spills). The major pathways for surface water contamination (not including airborne deposition) are overland runoff, leachate influx to the waterbody, direct waste disposal (solid or liquid) into the water body; and groundwater flow influx from upgradient. The relative importance of these pathways, and therefore the design of the sampling program, is controlled by the physiographic and hydrologic features of the site, the drainage basin(s) which encompass the site, and the history of site activities.

Physiographic and hydrologic features to be considered include slopes and runoff direction, areas of temporary flooding or pooling, tidal effects, artificial surface runoff controls such as berms or drainage ditches (and when they were constructed relative to site operation), and locations of springs, seeps, marshes, etc. In addition, the obvious considerations such as the location of man-made discharge points to the nearest stream (intermittent or flowing), pond, lake, estuary, etc., shall be considered.

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly non-detectable concentrations. Such dispersion does not, however, always readily occur. For example, obtaining a representative sample of contamination from a main stream immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation are: (1) move the site far enough downstream to allow for adequate mixing, or (2) collect integrated samples in a cross section. Also, nonhomogeneous distribution is a particular problem with regard to sediment-associated contaminants, which may accumulate in low-energy environments (coves, river bends, deep spots, or even behind boulders) near or distant from the source while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

The distribution of particulates within a sample itself is an important consideration. Many organic compounds are only slightly water soluble and tend to adsorb onto particulate matter. Nitrogen, phosphorus, and the heavy metals may also be transported by particulates. Samples must be collected with a representative amount of suspended material: transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

5.2.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and consideration of site conditions must be balanced against the costs of collection as controlled by accessibility. Bridges or piers are the first choice for locating a sampling station on a stream because bridges provide ready access and also permit the sampling technician to sample any point across the stream. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes and reservoirs, as well as those on larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment. Wading for samples is not recommended unless it is known that contaminant levels are low so that skin contact will not produce adverse health effects. This provides a built in margin of safety in the event that wading boots or other protective equipment should fail to function properly. If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample.

Sampling in marshes or tidal areas may require the use of an all-terrain vehicle (ATV). The same precautions mentioned above with regard to sediment disturbance apply.

Under ideal and uniform contaminant dispersion conditions in a flowing stream, the same concentrations of each would occur at all points along the cross section. This situation is most likely downstream of areas of high turbulence. Careful site selection is needed in order to ensure, as nearly as possible, that samples are taken where uniform flow or deposition and good mixing conditions exist.

The availability of streamflow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Streamflow data in association with contaminant concentration data are essential for estimating the total contaminant loads carried by the stream. If a gaging station is not conveniently located on a selected stream, the project hydrogeologist shall explore the possibility of obtaining streamflow data by direct or indirect methods.

5.2.3 Frequency of Sampling

The sampling frequency and the objectives of the sampling event will be defined by the project plan documents. For single-event site or area characterization sampling, both bottom material and overlying water samples shall be collected at the specified sampling stations. If valid data are available on the distribution of the contaminant between the solid and aqueous phases, it may be appropriate to sample only one phase, although this is not often recommended. If samples are collected primarily for monitoring purposes (i.e., consisting of repetitive, continuing measurements to define variations and trends at a given location), water samples shall be collected at a pre-established and constant interval as specified in the project plans (often monthly or quarterly, and during droughts and floods). Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably seasonally, during both spring and fall.

The variability in available water-quality data shall be evaluated before determining the number and collection frequency of samples required to maintain an effective monitoring program.

5.3 Surface Water Sample Collection

5.3.1 Streams, Rivers, Outfalls and Drainage Features (Ditches, Culverts)

Methods for sampling streams, rivers, outfalls and drainage features at a single point vary from the simplest of hand-sampling procedures to the more sophisticated multi-point sampling techniques known as the equal-width-increment (EWI) method or the equal-discharge-increment (EDI) methods (see below).

Samples from different depths or cross-sectional locations in the watercourse taken during the same sampling episode, shall be composited. However, samples collected along the length of the watercourse or at different times may reflect differing inputs or dilutions and therefore shall not be composited. Generally, the number and type of samples to be taken depend on the river's width, depth, discharge and on the suspended sediment the stream or river transports. The greater the number of individual points that are sampled, the more likely that the composite sample will truly represent the overall characteristics of the water.

In small streams less than about 20 feet wide, a sampling site can generally be found where the water is well mixed. In such cases, a single grab sample taken at mid-depth in the center of the channel is adequate to represent the entire cross section.

For larger streams, at least one vertical composite shall be taken with one sample each from just below the surface, at mid-depth, and just above the bottom. The measurement of DO, pH, temperature, conductivity, etc., shall be made on each aliquot of the vertical composite and on the composite itself. For rivers, several vertical composites shall be collected, as directed in the project plan documents.

5.3.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have a much greater tendency to stratify than rivers and streams. The relative lack of mixing requires that more samples be obtained.

The number of water sampling sites on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, the measurement of DO, pH, temperature, etc., is to be conducted on each aliquot of the vertical composite and on the composite itself. In naturally-formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical composites shall be composited to form a single sample. These verticals are often taken along a transect or grid. In some cases, it may be of interest to form separate composites of epilimnetic and hypolimnetic zones. In a stratified lake, the epilimnion is the thermocline which is exposed to the atmosphere. The hypolimnion is the lower, "confined" layer which is only mixed with the epilimnion and vented to the atmosphere during seasonal "overturn" (when density stratification disappears). These two zones may thus have very different concentrations of contaminants if input is only to one zone, if the contaminants are volatile (and therefore vented from the epilimnion but not the hypolimnion), or if the epilimnion only is involved in short-term flushing (i.e., inflow from or outflow to shallow streams). Normally, however, a composite consists of several verticals with samples collected at various depths.

In lakes with irregular shape and with bays and coves that are protected from the wind, separate composite samples may be needed to adequately represent water quality since it is likely that only poor mixing will occur. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements are now made in-situ using sensors and automatic readout or recording devices. Single and multi-parameter instruments are available for measuring temperature, depth, pH, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen, some cations and anions, and light penetration.

5.3.3 Estuaries

Estuarine areas are by definition, zones where inland freshwaters (both surface and ground) mix with oceanic saline waters. Estuaries are generally categorized into three types dependent upon freshwater inflow and mixing properties. Knowledge of the estuary type is necessary to determine sampling locations. Each type of estuarine area is described below:

- Mixed Estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.

- Salt Wedge Estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries, the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.

- Oceanic Estuary - characterized by salinities approaching full-strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

Sampling in estuarine areas is normally based upon the tidal phases, with samples collected on successive slack tides (i.e., when the tide turns). Estuarine sampling programs shall include vertical salinity measurements at 1- to 5-foot increments, coupled with vertical dissolved oxygen and temperature profiles.

5.3.4 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type to be acquired. The most frequently used samplers are:

- Open tube.
- Dip sampler.
- Weighted bottle.
- Hand pump.
- Kemmerer.
- Depth-Integrating Sampler.

The dip sampler and the weighted bottle sampler are used most often, and detailed discussions for these devices only (and the Kemmerer sampler) are addressed subsequently in this section.

The criteria for selecting a sampler include:

- Disposability and/or easy decontamination.
- Inexpensive cost (if the item is to be disposed).
- Ease of operation.
- Nonreactive/noncontaminating properties - Teflon-coated, glass, stainless-steel or PVC sample chambers are preferred (in that order).

As specified in the project plan document plan documents, each sample (grab or each aliquot collected for compositing) shall be measured for:

- Specific conductance.
- Temperature.
- pH.
- Dissolved oxygen (optional).

Sample measurements shall be conducted as soon as the sample is acquired. Measurement techniques described in SOP SA-1.1 shall be followed. All pertinent data and results shall be recorded in a field notebook or on sample logsheets (see SOP SA-6.3). These analyses will provide information on water mixing/stratification and potential contamination.

Dip Sampling

Water is often sampled by filling a container either attached to a pole or held directly, from just beneath the surface of the water (a dip or grab sample). Constituents measured in grab samples are only indicative of conditions near the surface of the water and may not be a true representation of the total concentration that is distributed throughout the water column and in the cross section. Therefore, whenever possible, it is recommended to augment dip samples with samples that represent both dissolved and suspended constituents and both vertical and horizontal distributions.

Weighted Bottle Sampling

A grab sample can also be taken using a weighted holder that allows a bottle to be lowered to any desired depth, opened for filling, closed, and returned to the surface. This allows discrete sampling with depth. Several of these samples can be combined to provide a vertical composite. Alternatively, an open bottle can be lowered to the bottom and raised to the surface at a uniform rate so that the bottle collects sample throughout the total depth and is just filled on reaching the surface. The resulting sample using either method will roughly approach what is known as a depth-integrated sample.

A closed weighted bottle sampler consists of a stopped glass or plastic bottle, a weight and/or holding device, and lines to open the stopper and lower or raise the bottle. The procedure for sampling with this device is:

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).
- Pull out the stopper with a sharp jerk of the sampling line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.

- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. This bottle can be used as the sample container as long as the bottle is an approved container type.

Kemmerer

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless-steel or acrylic cylinder, with rubber stoppers that leave the ends open while being lowered in a vertical position (thus allowing free passage of water through the cylinder). A "messenger" is sent down the line when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill sample bottles.

5.3.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container in the body of water; however, the following suggestions are made to help ensure that the samples obtained are representative of site conditions:

- The most representative samples are obtained from mid-channel at a 0.6 foot stream depth in a well-mixed stream.
- Even though the containers used to obtain the samples are previously laboratory cleaned, it is suggested that the sample container be rinsed at least once with the water to be sampled before the sample is taken. This is not applicable when sample containers are provided "pre-preserved."
- For sampling running water, it is suggested that the farthest downstream sample be obtained first, and that subsequent samples be taken as one works upstream. In general, work from zones suspected of low contamination to zones of high contamination.
- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid node is combined into one sample, or several grid nodes are selected at random.
- Care should be taken to avoid excessive agitation of the water, as loss of volatile constituents could result.
- When obtaining samples in 40 mL septum vials for volatile organics analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner of the septum faces in after the vial is filled and capped. The vial can be turned upside down to check for air bubbles.
- Do not sample at the surface, unless sampling specifically for a known constituent which is immiscible and on top of the water. Instead, the sample container should be inverted, lowered to the approximate depth, and held at about a 45-degree angle with the mouth of the bottle facing upstream. When sample containers are provided "pre-preserved," use a dedicated, clean, un-preserved bottle for sampling and transfer to an appropriately-preserved container.

5.4 Onsite Water Quality Testing

Onsite water quality testing shall be conducted as described in SOP SA-1.1.

5.5 Sediment Sampling

5.5.1 General

Sediment samples are usually collected at the same verticals at which water samples were collected. If only one sediment sample is to be collected, the sampling location shall be approximately at the center of the water body.

Generally, the coarser grained sediments are deposited near the headwaters of the reservoir. Bed sediments near the center of a water body will be composed of fine-grained materials which may, because of their lower porosity and greater surface area available for adsorption, contain greater concentrations of contaminants. The shape, flow pattern, bathometry (i.e., depth distribution), and water circulation patterns must all be considered when selecting sediment sampling sites. In streams, areas likely to have sediment accumulation (e.g., bends, behind islands or boulders, quiet shallow areas or very deep, low-velocity areas) shall be sampled while areas likely to show net erosion (i.e., high-velocity, turbulent areas) and suspension of fine solid materials, shall be avoided.

Chemical constituents associated with bottom material may reflect an integration of chemical and biological processes. Bottom samples reflect the historical input to streams, lakes, and estuaries with respect to time, application of chemicals, and land use. Bottom sediments (especially fine-grained material) may act as a sink or reservoir for adsorbed heavy metals and organic contaminants (even if water column concentrations are below detection limits). Therefore, it is important to minimize the loss of low-density "fines" during any sampling process.

All relevant information pertaining to sediment sampling shall be documented as applicably described in SOP SA-6.3.

5.5.2 Sampling Equipment and Techniques

A bottom-material sample may consist of a single scoop or core, or may be a composite of several individual samples in the cross section. Sediment samples may be obtained using onshore or offshore techniques.

When boats are used for sampling, life preservers must be provided and two individuals must undertake the sampling. An additional person shall remain onshore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler.
- Dredge samplers.

Each type of sampler is discussed subsequently.

Scoop Sampler

A scoop sampler consists of a pole to which a jar or scoop is attached. The pole may be made of bamboo, wood or aluminum and be either telescoping or of fixed length. The scoop or jar at the end of the pole is usually attached using a clamp.

If the water body can be sampled from the shore or if it can be waded, the easiest and best way to collect a sediment sample is to use a scoop sampler. This reduces the potential for cross-contamination. This method is accomplished by reaching over or wading into the water body and, while facing upstream (into the current), scooping the sampler along the bottom in the upstream direction. It is very difficult not to disturb fine-grained materials of the sediment-water interface when using this method.

Dredges

Dredges are generally used to sample sediments which cannot easily be obtained using coring devices (i.e., coarse-grained or partially-cemented materials) or when large quantities of sample are required. Dredges generally consist of a clam shell arrangement of two buckets. The buckets may either close upon impact or be activated by use of a "messenger". Most dredges are heavy (up to several hundred pounds) and require use of a winch and crane assembly for sample retrieval. There are three major types of dredges: Peterson, Eckman and Ponar dredges.

The Peterson dredge is used when the bottom is rocky, in very deep water, or when the flow velocity is high. The Peterson dredge shall be lowered very slowly as it approaches bottom, because it can force out and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high flow velocities.

The Ponar dredge is a Peterson dredge modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave" and permitting direct access to the secured sample without opening the closed jaws. The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates.

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		Effective Date 03/01/96	Revision 3
		Applicability B&R Environmental, NE	
		Prepared Earth Sciences Department	
Subject SOIL SAMPLING		Approved D. Senovich	

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1.0 PURPOSE

This procedure discusses the methods used to collect surface, near surface, and subsurface soil samples. Additionally, it describes the method for sampling of test pits and trenches to determine subsurface soil and rock conditions, and recover small-volume or bulk samples.

2.0 SCOPE

This procedure is applicable to the collection of surface, near surface and subsurface soils for laboratory testing, which are exposed through hand digging, hand augering, drilling,or machine excavating at hazardous substance sites.

3.0 GLOSSARY

Composite Sample - A composite sample exists as a combination of more than one sample at various locations and/or depths and times, which is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples are not to be collected for volatile organics analysis.

Grab Sample - One sample collected at one location and at one specific time.

Non-Volatile Sample - A non-volatile sample includes all other chemical parameters (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

Hand Auger - A sampling device used to extract soil from the ground in a relatively undisturbed form.

Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this devise can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-barrel sampler is typically available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-barrel samplers commonly range in size from 2-inch OD to 3-1/2 inch OD. The larger sizes are commonly used when a larger volume of sample material is required.

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine the shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher excavator, or bulldozer).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for determining sampling objectives, as well as, the field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches, and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for air quality monitoring during sampling, boring and excavation activities, to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - The FOL is responsible for finalizing the location of surface, near surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits and trenches, and for adherence to OSHA regulations during these operations.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of soil samples and the completion of all required paperwork (i.e., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custodies).

5.0 PROCEDURES

5.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they have migrated into the water table, and can establish the amount of contamination sorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can effect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during the sampling operations, particularly noting the location, depth, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. As a result, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers and be analyzed as soon as possible.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. Often this information on soil properties can be obtained from published soil surveys available through the U.S. Geological Surveys and other government or farm agencies. It is the intent of this procedure to present the most commonly employed soil sampling methods used at hazardous waste sites.

5.2 Soil Sample Collection

5.2.1 Procedure for Collecting Volatile Soil Samples

Volatile samples are only collected as grab samples and maintained and handled in as near an undisturbed state as possible. The sample is transferred directly into an approved glass container with a teflon lined cap. The sample must be packed down as much as possible to reduce air space within the sample container to an absolute minimum. Also, a properly filled volatile organics sample container will have no head space.

5.2.2 Procedure for Collecting Non-Volatile Soil Samples

Non-volatile soil samples may be collected as either grab or composite samples. The non-volatile soil sample is thoroughly mixed in a stainless steel or disposable, inert plastic tray, using a stainless steel trowel or other approved tool, then transferred into the appropriate sample container(s). Head space is permitted in a non-volatile soil sample container to allow for sample expansion.

5.2.3 Procedure for Collecting Undisturbed Soil Samples (ASTM D1587-83)

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) will be employed. The following method will be used:

1. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Use of any side-discharge bits is permitted.

3. 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 into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

4. 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're 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 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.

5. Upon removal of the sampling 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. Clean filler must be placed in voids at either end of the tube prior to sealing with wax. Place plastic caps on the ends of the sample tube, tape the caps in place, and dip the ends in wax.

6. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label. Mark the "up" direction on the side of the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms (see SOP SA-6.3). 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 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 need for acquiring an undisturbed sample.

5.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples (most commonly collected to a depth of 6 inches) for subsequent analysis is by use of a stainless steel trowel.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel trowel.
- Real-time air monitoring instrument (e.g., PID, FID, etc.).
- Latex gloves.
- Required Personal Protective Equipment (PPE).
- Required paperwork.
- Required decontamination equipment.
- Required sample container(s).
- Wooden stakes or pin flags.
- Sealable polyethylene bags (i.e., Ziploc baggies).
- Heavy duty cooler.
- Ice (if required) double-bagged in sealable polyethylene bags.
- Chain-of-custody records and custody seals.

When acquiring surface soil samples, the following procedure shall be used:

1. Carefully remove vegetation, roots, twigs, litter, etc., to expose an adequate soil surface area to accommodate sample volume requirements.
2. Using a decontaminated stainless steel trowel, follow the procedure cited in Section 5.2.1 for collecting a volatile soil sample.

3. Thoroughly mix (in-situ) a sufficient amount of soil to fill the remaining sample containers and transfer the sample into those containers utilizing the same stainless steel trowel employed above. Cap and securely tighten all sample containers.

4. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.

5. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.

5.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6-18 inches) can be accomplished with tools such as shovels and stainless steel trowels.

The following equipment is necessary to collect near surface soil samples:

- Clean shovel.
- Plus the equipment listed under Section 5.3 of this procedure.

To obtain near-surface soil samples, the following protocol shall be observed:

1. With a clean shovel, make a series of vertical cuts to the depth required in the soil to form a square approximately 1 foot by 1 foot.

2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel trowel to remove any loose soil.

3. Follow steps 2 through 10 listed under Section 5.3 of this procedure.

5.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of all stainless steel bucket bits (i.e., cylinders 6-1/2" long, and 2-3/4", 3-1/4", and 4" in diameter), a series of extension rods (available in 2', 3', 4' and 5' lengths), and a cross handle. A larger diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then withdrawn. In turn, the larger diameter bit is replaced with a smaller diameter bit, lowered down the hole, and slowly turned into the soil at the completion depth (approximately 6"). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil both from the surface, or to depths in excess of 12 feet. However, the presence of rock layers and the collapse of the borehole normally contribute to its limiting factors.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes).
- Stainless steel mixing bowls.
- Plus the equipment listed under Section 5.3 of this procedure.

To obtain soil samples using a hand auger, the following procedure shall be followed:

1. Attach a properly decontaminated bucket bit to a clean extension rod and further attach the cross handle to the extension rod.

2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).

3. Begin augering (periodically removing accumulated soils from the bucket bit) and add additional rod extensions as necessary. Also, note (in a field notebook or on standardized data sheets) any changes in the color, texture or odor of the soil.

4. After reaching the desired depth, slowly and carefully withdraw the apparatus from the borehole.

5. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is commonly smaller in diameter than the bucket bit employed to initiate the borehole.

6. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.

7. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.

8. Discard the top of the core (approximately 1"), which represents any loose material collected by the bucket bit before penetrating the sample material.

9. Fill volatile sample container(s), using a properly decontaminated stainless steel trowel, with sample material directly from the bucket bit. Refer to Section 5.2.1 of this procedure.

10. Utilizing the above trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl and thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

11. Follow steps 4 through 10 listed under Section 5.3 of this procedure.

5.6 Subsurface Soil Sampling With a Split-Barrel Sampler (ASTM D1586-84)

Split-barrel (split-spoon) samplers consist of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment A). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-lb. or larger casing driver.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (O.D. 2 inches, I.D. 1-3/8 inches, either 20 inches or 26 inches long); Larger O.D. samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-lb. weight, driving head and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Plus equipment listed under Section 5.3 of this procedure.

The following steps shall be followed to obtain split-barrel samples:

1. Remove the drive head and nosepiece, and open the sampler to reveal the soil sample. Immediately scan the sample core with a real-time air monitoring instrument (e.g., OVA, HNU, etc.). Carefully separate the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.

2. Collect the volatile sample from the center of the core where elevated readings occurred. If no elevated readings where encountered the sample material should still be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact). Refer to Section 5.2.1 of this procedure.

3. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl. Thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

4. Follow steps 4 through 10 listed under Section 5.3.3 of this procedure.

5.7 Excavation and Sampling of Test Pits and Trenches

5.7.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise which control the method of excavation. All excavations that are deeper than 4 feet must be stabilized (before entry into the excavation) by bracing the pit sides using wooden or steel support structures. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments. In these cases, substantial air monitoring is required before entry, and appropriate respiratory gear and protective clothing is mandatory. There must be at least two persons present at the immediate site before entry by one of the investigators. The reader shall refer to OSHA regulations 29 CFR 1926, 29 CFR 1910.120, and 29 CFR 1910.134.

Excavations are generally not practical where a depth of more than about 15 feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If data on soils at depths greater than 15 feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

5.7.2 Test Pit and Trench Excavation

These procedures describe the methods for excavating and logging test pits and trenches excavated to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented as described in SOP SA-6.3.

Test pits and trenches may be excavated by hand or by power equipment to permit detailed description of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration.
- The space required for efficient excavation.
- The chemicals of concern.
- The economics and efficiency of available equipment.

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table, which is based on equipment efficiencies, gives a rough guide for design consideration:

Equipment	Typical Widths, in Feet
Trenching machine	2
Backhoe	2-6
Track dozer	10
Track loader	10
Excavator	10
Scraper	20

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous waste materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, field conditions may necessitate revisions to the initial plans. The final depth and construction method shall be determined by the field geologist. The actual layout of each test pit,

temporary staging area and spoils pile will be predicated based on site conditions and wind direction at the time the test pit is made. Prior to excavation, the area can be surveyed by magnetometer or metal detector to identify the presence of underground utilities or drums.

If the depth exceeds 4 feet and people will be entering the pit or trench, Occupational Safety and Health Administration (OSHA) requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be in the hole at all times, and a temporary guardrail must be placed along the surface of the hole before entry. It is advisable to stay out of test pits as much as possible; if possible, the required data or samples shall be gathered without entering the pit. Samples of leachate, groundwater, or sidewall soils can be taken with telescoping poles, etc.

Dewatering may be required to assure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation dry. This is an important consideration for excavations in cohesionless material below the groundwater table. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

5.7.3 Sampling in Test Pits and Trenches

5.7.3.1 General

Test pits and trenches are usually logged as they are excavated. Records of each test pit/trench will be made as described in SOP SA-6.3. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous and shall be avoided unless absolutely necessary. Pits more than 4 feet deep must be shored prior to entry, the "buddy" system must be used, and all applicable Health and Safety and OSHA requirements must be followed.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information would include soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples, which can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

5.7.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks and hand augers, stainless steel trowels.

- Sample container - bucket with locking lid for large samples; appropriate bottleware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.
- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps and right angle adapter for conduit (see Attachment B).

5.7.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 5.7.3.4.

- Excavate trench or pit in several depth increments. After each increment, the operator will wait while the sampler inspects the test pit from grade level to decide if conditions are appropriate for sampling. (Monitoring of volatiles by the SSO will also be used to evaluate the need for sampling.) Practical depth increments range from 2 to 4 feet.

The backhoe operator, who will have the best view of the test pit, will immediately cease digging if:

- Any fluid phase or groundwater seepage is encountered in the test pit.
- Any drums, other potential waste containers, obstructions or utility lines are encountered.
- Distinct changes of material are encountered.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending upon the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Remove loose material to the greatest extent possible with backhoe.
- Secure walls of pit if necessary. (There is seldom any need to enter a pit or trench which would justify the expense of shoring the walls. All observations and samples can generally be taken from the ground surface.)
- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material once it has been deposited on the ground. The sampler or Field Operations Leader directs the backhoe operator to remove material from the selected depth or location within the test pit/trench. The bucket is brought to the surface and moved away from the pit. The sampler and/or SSO then approaches the bucket and monitors its contents with a photoionization (HNU) or flame ionization (OVA) meter. The sample is collected from the center of the bucket or pile and placed in sample containers using a decontaminated stainless steel trowel or spatula.
- If a composite sample is desired, several depths or locations within the pit/trench are selected and a bucket is filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container

shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

- Using the remote sampler shown in Attachment B, samples can be taken at the desired depth from the side wall or bottom of the pit. The face of the pit/trench shall first be scraped (using a long-handled shovel or hoe) to remove the smeared zone that has contacted the backhoe bucket. The sample shall then be collected directly into the sample jar, by scraping with the jar edge, eliminating the need to utilize samplers and minimizing the likelihood of cross-contamination. The sample jar is then capped, removed from the assembly, and packaged for shipment.

- Complete documentation as described in SOP SA-6.3.

5.7.3.4 In-Pit Sampling

Samples can also be obtained by personnel entering the test pit/trench. This is necessary when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soils or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- The project will benefit significantly from the improved quality of the logging and sampling data obtained if personnel enter a pit or trench rather than conduct such operations from the ground surface.

- There is no practical alternative means of obtaining such data.

- The Site Safety Officer determines that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of volatile organics, explosive gases and available oxygen).

- An experienced geotechnical professional determines that the pit/trench is stable or is made stable (by grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements (Reference 1) must be strictly implemented.

If these conditions are satisfied, one person will enter the pit/trench. On potentially hazardous waste sites, this individual will be dressed in safety gear as required by the conditions in the pit, usually Level B. He/she will be affixed to a safety rope and continuously monitored while in the pit.

A second individual will be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations. The individual entering the pit will remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon. As an added precaution, it is advisable to keep the backhoe bucket in the test pit when personnel are working below grade. Such personnel can either stand in or near the bucket while performing sample operations. In the event of a

~~cave-in they can either be lifted clear in the bucket, or at least climb up on the backhoe arm to reach~~ safety.

5.7.3.5 Geotechnical Sampling

In addition to the equipment described in Section 5.7.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., open tube samplers), which can be pushed or driven into the floor of the test pit.
- Suitable driving (i.e., a sledge hammer) or pushing (i.e., the backhoe bucket) equipment which is used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soils in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification, while larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soils using open tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe, rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the sampler when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 5.7.3.4 of this procedure must be followed. The open tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate, because the sample will not have the correct orientation

A sledge hammer or the backhoe may be used to drive or push the sampler or tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry of the test pit, the requirements in Section 5.7.3.4 of this procedure must be followed. Prepare, label, pack and transport the sample in the required manner, as described in SOP SA-6.3.

5.7.4 Backfilling of Trenches and Test Pits

Before backfilling, the onsite crew shall photograph all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL.

If a low permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

5.8 Records

Either a single Sample Log Sheet (see Attachment C-1) or a multiple Sample Log Sheet (see Attachment C-2) must be completed by the site geologist/sampler. All soil sampling locations must be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) and shall be located on a single Sample Log Sheet, site map or field notebook. Surveying may also be necessary, depending on the project requirements. Composite samples must be recorded on the single Sample Log Sheet. Grab samples can be recorded on either the Single or Multiple Sample Log Sheets. However, if the Multiple Sample Log Sheet is used, a detailed map showing all soil sampling locations must be provided with the log sheet and must be referenced in the remarks section of the Multiple Sample Log Sheet

Test pit logs shall contain a sketch of pit conditions (see Attachment D, Test Pit Log Form). In addition, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits and trenches shall be logged by the field geologist in accordance with SOP GH-1.5. Other data to be recorded in the field logbook include the following:

- Name and location of job.
- Date of boring and excavation
- Approximate surface elevation
- Total depth of boring and excavation
- Dimensions of pit.
- Method of sample acquisition
- Type and size of samples.
- Soil and rock descriptions.
- Photographs.
- Groundwater levels.
- Organic gas or methane levels.
- Other pertinent information, such as waste material encountered.

6.0 REFERENCES

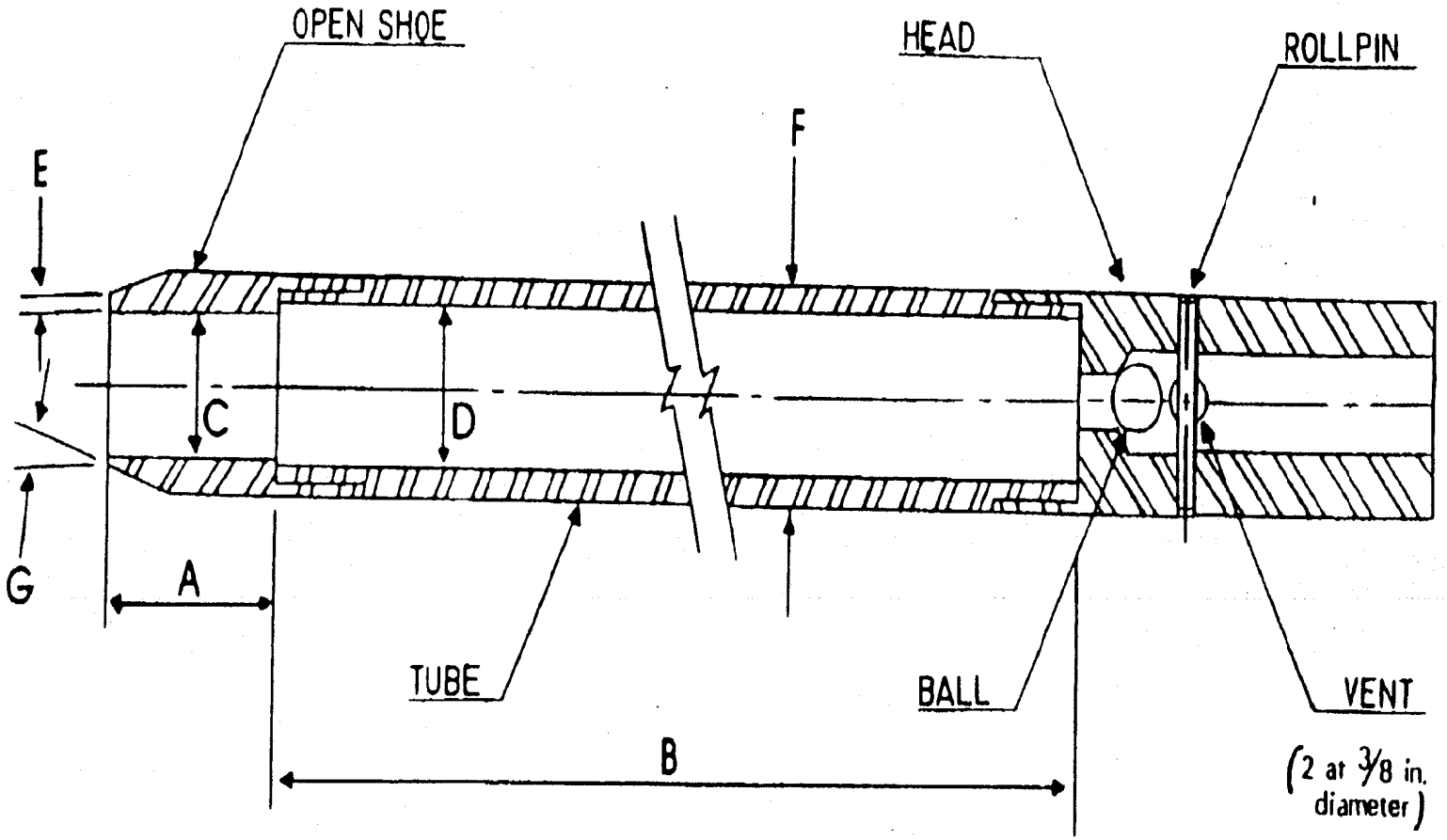
American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

NUS Corporation, 1986. Hazardous Material Handling Training Manual.

NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, 1979. Excavation, Trenching and Shoring 29 CFR 1926.650-653.

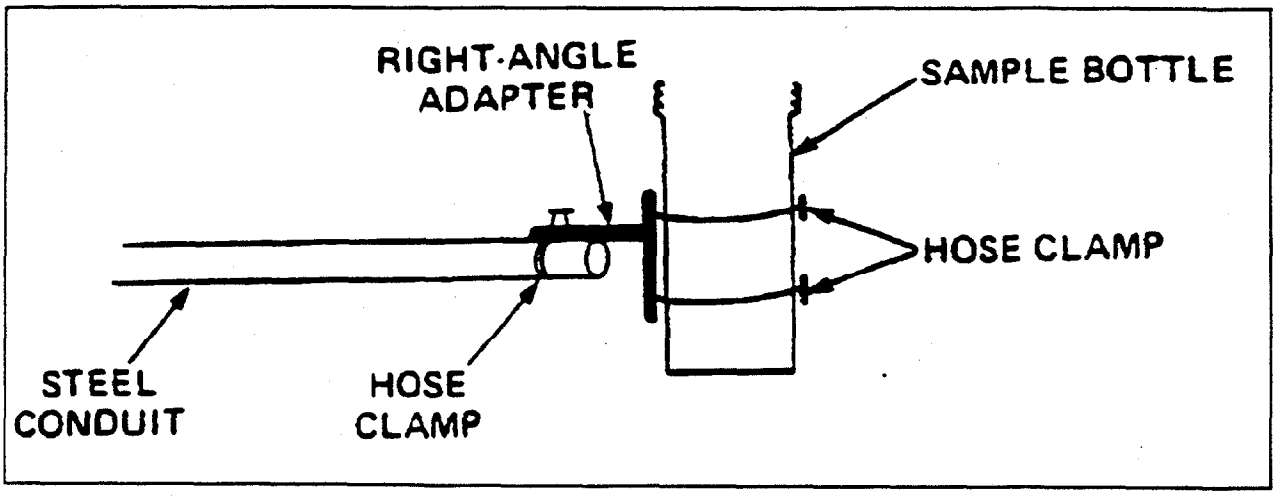
ATTACHMENT A
SPLIT-SPOON SAMPLER



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

ATTACHMENT B
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING



ATTACHMENT C-1
SINGLE SAMPLE LOG SHEET (SOIL)

SINGLE SAMPLE LOG SHEET

Page ____ of ____

Project Site Name: _____

Project No.: _____

- ☐ Surface Soil
- ☐ Subsurface Soil
- ☐ Sediment
- ☐ Other _____
- ☐ QA Sample Type: _____

Sample ID No.: _____

Sample Location: _____

Sampled By: _____

C.O.C. No.: _____

Sample Method:	Composite Sample Data		
	Sample	Time	Color/Description
Depth Sampled:			
Sample Date and Time:			
Type of Sample			
☐ Grab			
☐ Composite			
☐ Grab-Composite	Grab Sample Data		
☐ High Concentration	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)	
☐ Low Concentration			

Analysis	Container Requirements	Collected (✓)	Map:

Observations/Notes:

Circle If Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

ATTACHMENT C-2
MULTIPLE SAMPLE LOG SHEET (SOIL)

Brown & Root Environmental

MULTIPLE SAMPLE LOG SHEET

PAGE ___ OF ___

[ ] SURFACE SOIL
[ ] SUBSURFACE SOIL
[ ] SEDIMENT
[ ] LAGOON/POND
[ ] OTHER

SAMPLER(S) SIGNATURE _____

PROJECT NAME: _____

PROJECT NUMBER: _____

AREA DESIGNATION _____

Sample No.	SAMPLE METHOD	DEPTH (FT)	DATE	TIME	SAMPLED BY	CONCENTRATION (L)LOW (H)HIGH	(G)GRAB (C)COMPOSITE	ANALYSES							No. OF CONT. TOTAL	SOIL DESCRIPTION

REMARKS:

LAB:

COC NO:

ACAD: C:\FORMS\SAMPLOG.DWG 02/17/95 TD

ATTACHMENT D
TEST PIT LOG

TEST PIT LOG

Brown & Root Environmental

PROJECT: _____ TEST PIT NO.:

PROJECT NO _____ DATE: _____

LOCATION: _____

FIELD GEOLOGIST: _____

DEPTH (ft.)	LITHOLOGY CHANGE (Good/Poor)	MATERIAL DESCRIPTION (Soil Density / Consistency, Color)	USCS	REMARKS

Test Pit Cross Section and / or Plan View

REMARKS _____

PHOTO LOG _____ TEST PIT _____

PAGE ____ OF ____

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

2.0 SCOPE

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 off site for chemical analysis.
- Provides instruction for sample packaging and shipping in accordance with current U.S. Department of Transportation (DOT) regulations.

3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173.

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (~~y~~261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (~~y~~261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

ORM - Other regulated material (see DOT 49 CFR 173.144).

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H_2SO_4
- Nitric Acid - HNO_3
- Sodium Hydroxide - NaOH

Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - $Na_2S_2O_3$

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent. Thus, a one-molar solution of HCl, containing 1 gram-atom of H, is "one normal," whereas a one-molar solution of H_2SO_4, containing 2 gram-atoms of H, is "two normal."

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

4.0 RESPONSIBILITIES

Field Operations Leader - Directly responsible for the bottling, preservation, labeling, packaging, shipping, and custody of samples up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the common carrier.

5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

5.1 Sample Containers

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, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of bottle orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

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 a missing Teflon liner (if required for the container), shall be discarded.

5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although 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 (certain biological samples only).

5.2.1 Overview

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 be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. 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 samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO_3, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas 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.

5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H_2SO_4)	1 part concentrated H_2SO_4: 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO_3)	Undiluted concentrated HNO_3	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample (assuming that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required). Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.

- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).

- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

  If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

  Continue with proper base preservation of the sample as described, generally, above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

  The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

  The sample pH is then raised to 9 using the NaOH preservative.

- To test of sodium thiosulfate must be added to remove residual chlorine from a sample, test the sample for residual chlorine using a field test kit especially made for this purpose.

  If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

  Continue with proper acidification of the sample as described, generally, above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory <u>before</u> sampling begins.

5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated silicon tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).

- To perform filtration, thread the silicon tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration.

- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

5.4 Sample Packaging and Shipping

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. 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 transport and laboratory personnel receiving the samples (special precautions are used by the shipper and at laboratories when hazardous materials are received.)

Detailed procedures for packaging environmental and hazardous material samples are outlined in the remainder of this section.

5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place sample container, properly identified and with lid securely fastened in a plastic bag (e.g. Ziploc baggie), and seal the bag.

- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic (e.g. "garbage" bag).

- Pack with enough noncombustible, absorbent, cushioning materials such as vermiculite (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

- If cooling is required (see Attachments A and B), double-bag ice in Ziploc baggies and place around container shoulders, and on top of absorbent packing material (minimum of 8 pounds of ice for a medium-size cooler).

- Seal (i.e., tape or tie top in knot) large liner bag.

- The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment.

- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

5.4.2 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.

5.4.2.1 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 it is listed) in the DOT Hazardous Materials Table, 49 CFR 172.101. (DOT Guide for shippers can be found in Attachment D of this document.)

To determine the proper shipping name, use the following steps to help locate the shipping name on the Hazardous Materials Table, DOT 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 listed as 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 . . .

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 use the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s, or Oxidizer, n.o.s.

5.4.2.2 Unknown Substances

For samples of hazardous substances of unknown content, select the appropriate transportation category according to the DOT hazardous materials classification of a material having more than one hazard. This procedure is outlined in DOT Regulation 49 CFR 173.2a. (This can be found in Attachment C of this SOP.)

The correct shipping classification for an unknown sample is selected through a process of elimination, as outlined in DOT Regulation 49 CFR 172.101(c)(11). By using the provisions in this paragraph, the proper shipping name and description will be determined. A step-by-step guide is provided by the Department of Transportation (DOT) and can be found in Attachment D of this SOP.

5.4.3 Packaging and Shipping of Samples Classified as Flammable Liquid (or Solid)

5.4.3.1 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. Containerize sample as required (see Attachments A and B). To prevent leakage, fill container no more than 90 percent full. Seal lid with teflon tape or wire.

2. Complete sample label and attach securely to sample container.

3. Seal container and place in 2-mil-thick (or thicker) polyethylene bag (e.g., Ziploc baggie), one sample per bag. Position sample identification label so that it can be read through bag. Seal bag.

4. For soil jars, place sealed bag inside metal can (available from laboratory or laboratory supplier) 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 5.3.4.2, below. Single 1-gallon bottles do not need to be placed in metal cans.

5. Place one or more metal cans (or a single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans (or bottle) with noncombustible, absorbent cushioning materials for stability during transport. The absorbent material should be able to absorb the entire contents of the container. Mark container as indicated in Paragraph 2 below.

5.4.3.2 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.

- Proper shipping name from the hazardous materials table (DOT Regulation CFR 49 172.101). Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325." This will include packing group (see Section 5.3.4.2, No. 2.)

Not otherwise specified (n.o.s) is not used if the flammable liquid (or solid) is identified. If identified, 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. Determine packing group. The packing group is part of the proper shipping name and must be included on the shipping papers in the description section.

   I. Most Hazardous
   II. Medium Hazard
   III. Least Hazardous

   The packing group will be listed in the hazardous materials table, column 5.

3. 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 DOT label such as: "Flammable Liquid" (or "Flammable Solid"). "Dangerous When Wet" label shall be used if the Flammable 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.

5.4.3.3 Shipping Papers

1. Use abbreviations only where specified. Complete the carrier-provided bill of lading and sign certification statement. Provide the following information in the order listed (one form may be used for more than one exterior container):

   - Proper shipping name. (Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325 Packing Group I, II, III").
   - "Limited Quantity" (or "Ltd. Qty."). (See No. 3, below.)
   - "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; use custody seals.

3. "Limited Quantity" means the maximum amount of a hazardous material for which there is a specific labeling or packaging exception (DOT CFR 49 171.8). This may mean that packages are exempted from labeling requirements. To determine if your sample meets the Limited Quantity Exception, refer to DOT Regulation CFR 49 Subpart C 173.50 through 173.156. First, determine the proper classification and shipping name for the material; then refer to the exception requirements for that particular class of material beginning with 173.50.

   Example: "Flammable Liquid n.o.s. UN1993 Packing Group 1." The outer package can weigh no more than 66 pounds gross weight. The inner package or container can weigh no more than 0.1 gallon net capacity for each container.

   To determine whether the material can be shipped as a "Limited Quantity," you must check the specific requirement for that class of material.

5.4.3.4 Transportation

1. The majority of unknown hazardous substance samples will be classified as flammable liquids. The samples will be transported by rented or common carrier truck, railroad, or express overnight package services. Do not transport samples on any passenger-carrying air transport system, even if the system has cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that carry only cargo. If unsure of what mode of transportation to use, consult the FOL or Project Manager.[1]

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 followed.

3. Use the hazardous materials shipping check list (Attachment E) as a guidance to ensure that all sample-handling requirements are satisfied.

4. In some cases, various materials may react if they break during shipment. To determine if you are shipping such materials, refer to the DOT compatibility chart in Attachment F.

5.5 Shipment of Lithium Batteries

Monitoring well data are analyzed using either the Hermit SE 1000 or the Hermit SE 2000 environmental data logger. These instruments are powered by lithium batteries. The Department of Transportation has determined that lithium batteries are a hazardous material and are to be shipped using the following information:

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[1] Note: If you are unsure as how to ship the sample (hazardous or environmental sample), contact the FOL or Project Manager so that a decision can be made as to the proper shipping practices. The DOT penalties for improper shipment of a hazardous material are stringent and may include a prison term for intentional violations.

- Product Designation
  - Hermit SE 1000
  - Hermit SE 2000

- DOT Proper Shipping Name
  - Lithium batteries, contained in equipment, UN3091

- Classification or Division
  - Class 9

Shipment of equipment containing lithium batteries must be accompanied by shipping papers completed as indicated in Attachment G. The instrument will be shipped by Federal Express as a Hazardous Material. Place the instrument in the same container in which it was received. This container or case is a DOT-approved shipping container. For Federal Express procedures to ship hazardous materials, call 1-800-238-5355, extension 922-1666. In most cases, the return shipping papers and DOT labels will be shipped to you from the company warehouse or the vendor. An example of the types of labels used for shipment and the wording are shown in Attachment G. These labels will be attached to the outside container with the following wording:

- Lithium Batteries Contained in Equipment
  - UN-3091
  - Shipped Under CA-9206009

6.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. APHA, Washington, D.C.

U.S. Department of Transportation, 1993. Hazardous Materials Regulations, 49 CFR 171-177.

U.S. EPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

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

ATTACHMENT A

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration			Container[1]	Sample Size	Preservation[2]	Holding Time[2]
WATER						
Organics (GC&GC/MS)	VOC	Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to ≤ 2	14 days[8]
	Extractables (Low SVOCs and pesticide/PCBs)		Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables (Medium SVOCs and pesticide/PCBs)		Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals	Low	High-density polyethylene	1 L	HNO_3 to pH ≤2	6 months (Hg-28 days)
		Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide	Low	High-density polyethylene	1 L	NaOH to pH>12	14 days
	Cyanide	Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	14 days
SOIL						
Organics (GC&GC/MS)	VOC		Wide-mouth glass with teflon liner	2 x 4 oz.	Cool to 4°C	14 days
	Extractables (Low SVOCs and pesticides/PCBs)		Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables (Medium SVOCs and pesticides/PCBs)		Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium		Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/ Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All		Wide-mouth glass	4 oz.	None	7 days until extraction; 40 days after extraction
TCLP	All		Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction
AIR						
Volatile Organics	Low/Medium		Charcoal tube – 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended

(1) All glass containers should have Teflon cap liners or septa.
(2) See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

ATTACHMENT B

ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
INORGANIC TESTS:			
Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C; NaOH to pH 12; 0.6 g ascorbic acid(5)	14 days(6)
Fluoride	P	None required	28 days
Hardness	P, G	HNO_3 to pH 2; H_2SO_4 to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H_2SO_4 to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE TWO

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
INORGANIC TESTS (Cont'd):			
Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours
METALS:(7)			
Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	P, G	HNO_3 to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO_3 to pH 2	6 months
ORGANIC TESTS:(8)			
Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$(5) HCl to pH 2 (9)	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$(5) adjust pH to 4-5 (10)	14 days
Phenols(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction
Benzidines(11), (12)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction(13)
Phthalate esters(11)	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitrosamines(11), (14)	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction
PCBs(11)	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5); store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs)(11),(14)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5); store in dark	7 days until extraction; 40 days after extraction
Haloethers(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF)(11)	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$(5)	7 days until extraction; 40 days after extraction

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE THREE

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
RADIOLOGICAL TESTS:			
1-5 Alpha, beta and radium	P, G	HNO_3 to pH 2	6 months

(1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
(2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
(3) When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
(4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer periods, and has received a variance from the Regional Administrator.
(5) Should only be used in the presence of residual chlorine.
(6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments are made to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
(7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
(8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
(9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
(10) The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
(11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
(12) If 1,2-diphenylthydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.
(13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
(14) For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
(15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

ATTACHMENT C

DOT HAZARDOUS MATERIAL CLASSIFICATION
(49 CFR 173.2a)

1. Radioactive material (except a limited quantity)
2. Division 2.3, Poisonous Gases
3. Division 2.1, Flammable Gas
4. Division 2.2, Nonflammable gas
5. Division 6.1, Poisonous Liquids, Packing Group 1 (poison by inhalation only)
6. Division 4.2, Pyrophoric Material
7. Division 4.1, Self-Reactive Material
8. Class 3, Flammable Liquids*
9. Class 8, Corrosive Material
10. Division 4.1, Flammable Solid*
11. Division 4.2, Spontaneously Combustible Materials*
12. Division 4.3, Dangerous When Wet Materials*
13. Division 5.1, Oxidizers*
14. Division 6.1, Poisonous Liquids or Solids (other than Packing Group 1)*
15. Combustible liquid
16. Class 9, Miscellaneous Hazardous Materials

* If a material has or meets the criteria for more than one hazard class, use the precedence of hazardous table on the following page for Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1. The following table ranks those materials that meet the definition of Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1.

ATTACHMENT C (Continued)

PRECEDENCE OF HAZARD TABLE

(Hazard Class and Packing Group)

Class	Packing Group	4.2	4.3	5.1 I[a]	5.1 II[a]	5.1 III[a]	6.1 I (Dermal)	6.1 I (Oral)	6.1 II	6.1 III	8 I (Liquid)	8 I (Solid)	8 II (Liquid)	8 II (Solid)	8 III (Liquid)	8 III (Solid)
3	I						3	3	3	3	3	[c]	3	[c]	3	[c]
3	II						3	3	3	3	8	[c]	3	[c]	3	[c]
3	III						6.1	6.1	6.1	3[d]	8	[c]	8	[c]	3	[c]
4.1	II[b]	4.2	4.3	5.1	4.1	4.1	6.1	6.1	4.1	4.1	[c]	8	[c]	4.1	[c]	4.1
4.1	III[b]	4.2	4.3	5.1	4.1	4.1	6.1	6.1	6.1	4.1	[c]	8	[c]	8	[c]	4.1
4.2	II		4.3	5.1	4.2	4.2	6.1	6.1	4.2	4.2	[c]	8	[c]	4.2	[c]	4.2
4.2	III		4.3	5.1	4.2	4.2	6.1	6.1	6.1	4.2	[c]	8	[c]	8	[c]	4.2
4.3	I			5.1	4.3	4.3	6.1	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
4.3	II			5.1	4.3	4.3	6.1	4.3	4.3	4.3	8	8	8	4.3	4.3	4.3
4.3	III			5.1	4.3	4.3	6.1	6.1	6.1	4.3	8	8	8	8	4.3	4.3
5.1	I[a]						5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
5.1	II[a]						6.1	5.1	5.1	5.1	8	8	8	5.1	5.1	5.1
5.1	III[a]						6.1	6.1	6.1	5.1	8	8	8	8	5.1	5.1
6.1	I, Dermal										8	6.1	6.1	6.1	6.1	6.1
6.1	I, Oral										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Inhalation										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Dermal										8	6.1	8	6.1	6.1	6.1
6.1	II, Oral										8	8	8	6.1	6.1	6.1
6.1	III										8	8	8	8	8	8

(a) There are at present no established criteria for determining Packing Groups for liquids in Division 5.1. At present, the degree of hazard is to be assessed by analogy with listed substances, allocating the substances to Packing Group I, Great; Group II, Medium; or Group III, Minor Danger.

(b) *Substances of Division 4.1 other than self-reactive substances.*

(c) Denotes an impossible combination.

(d) For pesticides only, where a material has the hazards of Class 3, Packing Group III, and Division 6.1, Packing Group III, the primary hazard is Division 6.1, Packing Group III.

ATTACHMENT D

GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

USE OF GUIDE - This guide is presented as an aid to shippers of hazardous materials. It does not contain or refer to all of the DOT requirements for shipping hazardous materials. For specific details, refer to all of the DOT requirements for shipping hazardous materials, as provided in the Code of Federal Regulations (CFR), Title 49, Transportation, Parts 100-199.

The following is offered as a step-by-step procedure to aid in compliance with the applicable DOT regulations.

STEP 1 - DETERMINE THE PROPER SHIPPING NAME. The shipper must determine the proper shipping name of the materials as listed in the Hazardous Materials Table, 49 CFR 172.101, Column (2).

STEP 2 - DETERMINE THE HAZARD CLASS OR CLASSES.

a. Refer to the Table, 49 CFR 172.101, Column (3), and locate the hazard class of the material.
b. If more than one class is shown for the proper shipping name, determine the proper class by definition.
c. If the materials have more than one hazard, classify the material based on the order of hazards in 49 CFR 173.2.

STEP 3 - SELECT THE PROPER IDENTIFICATION NUMBERS.

a. Refer to the Table, 49 CFR 172.101, Column (3a), and select the Identification Number (ID) that corresponds to the proper shipping name and hazard class.
b. Enter the ID number(s) on the shipping papers and display them, as required, on packagings, placards and/or orange panels.

STEP 4 - DETERMINE THE MODE(S) OF TRANSPORT TO ULTIMATE DESTINATION.

a. As a shipper, you must assure yourself that the shipment complies with various modal requirements.
b. The modal requirements may affect the following: (1) Packaging; (2) Quantity per Package; (3) Marking; (4) Labeling; (5) Shipping Papers: and (6) Certification.

STEP 5 - SELECT THE PROPER LABEL(S) AND APPLY AS REQUIRED.

a. Refer to the Table, 49 CFR 172.101, Column (4) for required labels.
b. For details on labeling refer to (1) Additional Labels, 49 CFR 172.402; (2) Placement of Labels, 49 CFR 172.406; (3) Packagings (Mixed or Consolidated), 49 CFR 172.404(a) and (h); (4) Packages Containing Samples, 49 CFR 172.402(h); (5) Radioactive Materials, 49 CFR 172.403; and (6) Authorized Label Modifications, 49 CFR 172.405.

STEP 6 - DETERMINE AND SELECT THE PROPER PACKAGES.

a. Refer to the Table, 49 CFR 172.101, Column (5a) for exceptions and Column (5b) for specification packagings. Consider the following when selecting an authorized package: Quantity per Package; Cushioning Material, if required; Proper Closure and Reinforcement; Proper Pressure; Outage; etc., as required.
b. If packaged by a prior shipper, make sure the packaging is correct and in proper condition for transportation.

ATTACHMENT D (Continued)
GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

STEP 7 - MARK THE PACKAGING (INCLUDING OVERPACKS).

a. Apply the required markings (49 CFR 172.300); Proper shipping name and ID number, when required (49 CFR 172.301); Name and address of Consignee or Consignor (49 CFR 172.306).
b. For details and other required markings, see 49 CFR 172.300 through 172.338.

STEP 8 - PREPARE THE SHIPPING PAPERS.

a. The basic requirements for preparing shipping papers include Proper Shipping Name; Hazard Class; ID Number; Total Quantity; Shipper's Certification; and Emergency Response Telephone Number.
b. Make all entries on the shipping papers using the information required and in proper sequence (49 CFR 172.202).

STEP 9 - CERTIFICATION.

a. Each shipper must certify by printing (manually or mechanically) on the shipping papers that the materials being offered for shipment are properly classified, described, packaged, marked and labeled, and in proper condition for transportation according to the applicable DOT Regulations (49 CFR 172.202).

STEP 10 - LOADING, BLOCKING, AND BRACING. When hazardous materials are loaded into the transport vehicle or freight container, each package must be loaded, blocked, and braced in accordance with the requirements for mode of transport.

a. If the shipper loads the freight container or transport vehicle, the shipper is responsible for the proper loading, blocking, and bracing of the materials.
b. If the carrier does the loading, the carrier is responsible.

STEP 11 - DETERMINE THE PROPER PLACARD(S). Each person who offers hazardous materials for transportation must determine that the placarding requirements have been met.

a. For Highway, unless the vehicle is already correctly placarded, the shipper must provide the required placard(s) and required ID number(s) (49 CFR 172.506).
b. For Rail, if loaded by the shipper, the shipper must placard the rail car if placards are required (49 CFR 172.508).
c. For Air and Water shipments, the shipper has the responsibility to apply the proper placards.

STEP 12 - HAZARDOUS WASTE/HAZARDOUS SUBSTANCE.

a. If the material is classed as a hazardous waste or hazardous substance, most of the above steps will be applicable.
b. Pertinent Environmental Protection Agency regulations are found in the Code of Federal Regulations, Title 40, Part 262.

As a final check and before offering the shipment for transportation, visually inspect your shipment. The shipper should ensure that emergency response information is on the vehicle for transportation of hazardous materials.

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Revised March 1995.

ATTACHMENT E

HAZARDOUS MATERIALS SHIPPING CHECK LIST

PACKAGING

1. Check DOT 173.24 for appropriate type of package for hazardous substance.
2. Check for container integrity, especially the closure.
3. Check for sufficient absorbent material in package.
4. Check for sample tags and log sheets for each sample and for chain-of-custody record.

SHIPPING PAPERS

1. Check that entries contain only approved DOT abbreviations.
2. Check that entries are in English.
3. Check that hazardous material entries are specially marked to differentiate them from any nonhazardous materials being sent using same shipping paper.
4. Be careful that all hazardous classes are shown for multiclass materials.
5. Check total amounts by weight, quantity, or other measures used.
6. Check that any limited-quantity exemptions are so designated on the shipping paper.
7. Check that certification is signed by shipper.
8. Make certain driver signs for shipment.

RCRA MANIFEST

1. Check that approved state/federal manifests are prepared.
2. Check that transporter has the following: valid EPA identification number, valid driver's license, valid vehicle registration, insurance protection, and proper DOT labels for materials being shipped.
3. Check that destination address is correct.
4. Check that driver knows where shipment is going.
5. Check that the driver is aware of emergency procedures for spills and accidents.
6. Make certain driver signs for shipment.
7. Make certain one copy of executed manifest and shipping document is retained by shipper.

ATTACHMENT F

DOT SEGREGATION AND SEPARATION CHART

Class or Division	Notes	1.1-1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3 gas Zone A*	2.3 gas Zone B*	3	4.1	4.2	4.3	5.1	5.2	6.1 liquids PG-I Zone A*	7	8 liquids only
Explosives . . . . . 1.1 and 1.2	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives 1.3		*	*	*	*	*	X		X	X	X		X	X	X	X	X		X
Explosives 1.4		*	*	*	*	*	O		O	O	O		O				O		O
Very insensitive explosives 1.5	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Extremely insensitive explosives 1.6		*	*	*	*	*													
Flammable gases 2.1		X	X	O	X				X	O							O	O	
Non-toxic, non-flammable gases 2 2		X			X														
Poisonous gas - Zone A** 2 3		X	X	O	X		X				X	X	X	X	X	X			X
Poisonous gas - Zone B** 2 3		X	X	O	X		O				O	O	O	O	O	O			O
Flammable liquids 3		X	X	O	X				X	O					O		X		
Flammable solids 4 1		X			X				X	O							X		O
Spontaneously combustible materials 4 2		X	X	O	X				X	O							X		X
Dangerous-when-wet materials 4.3		X	X		X				X	O							X		O
Oxidizers 5.1	A	X	X		X				X	O	O						X		O
Organic peroxides 5.2		X	X		X				X	O							X		O
Poisonous liquids PG I - Zone A** . . 6.1		X	X	O	X		O				X	X	X	X	X	X			X
Radioactive materials 7		X			X		O												
Corrosive liquids 8		X	X	O	X				X	O		O	X	O	O	O	X		

No entry means that the materials are compatible (have no restrictions).

X These materials may not be loaded, transported, or stored together in the same vehicle or facility.
O The materials may not be loaded, transported, or stored together in the same vehicle or facility unless they are separated for 4 feet on all sides.
* Check the explosives compatibility chart in 49 CFR 179.848(f).
A Ammonium nitrate fertilizers may be stored with Division 1.1 materials.
** Denotes inhalation hazardous for poisons; consult field team leader or project manager if you encounter a material in this class before shipment.

ATTACHMENT G
LITHIUM BATTERY SHIPPING PAPERS

3224637861

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non applicable)*

[redacted] | CARGO AIRCRAFT ONLY

Airport of Departure:

Airport of Destination: 19CYS

Shipment type: *(delete non-applicable)*

NON-RADIOACTIVE | [redacted]

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification						
Proper Shipping Name	Class or Division	UN or ID No.	Subsidiary Risk	Quantity and type of packing	Packing Inst.	Authorization
LITHIUM BATTERIES CONTAINED IN EQUIPMENT	9	UN3091		1 PLASTIC BOX X 55 GRAMS	912 II	PER CA-9206009

Additional Handling Information

1 HERMIT SERIES DATALOGGER X 55 GRAMS (11 GRAMS/CELL)

I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and are in all respects in the proper condition for transport by air according to the applicable International and National Government Regulations.

Name/Title of Signatory

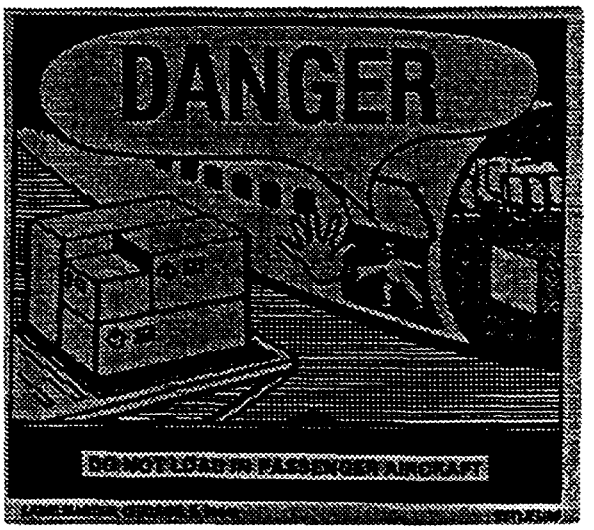
Place and Date

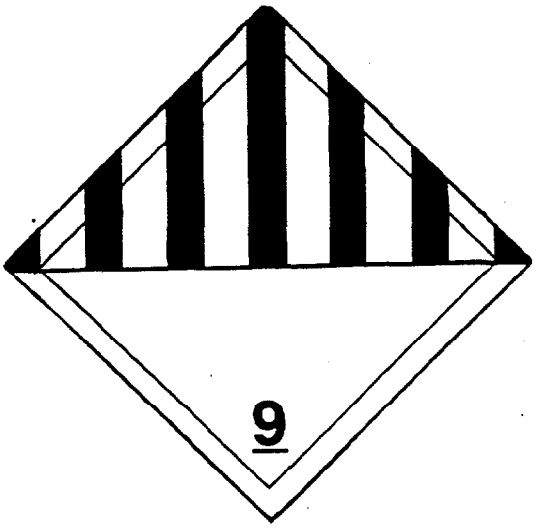
Signature *(see warning above)*

Emergency Telephone Number (Required for US Origin or Destination Shipments)
800-535-5053

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

ATTACHMENT G (CONTINUED)
LITHIUM BATTERY SHIPPING PAPERS





LITHIUM BATTERIES CONTAINED IN EQUIPMENT.
UN-3091.
SHIPPED UNDER CA-9206009

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting Brown & Root Environmental field activities.

2.0 SCOPE

Documents presented within this procedure (or equivalents) shall be used for all Brown & Root Environmental field activities, as applicable. Other or additional documents may be required by specific client contracts.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for obtaining hardbound, controlled-distribution logbooks (from the appropriate source), as needed. In addition, the Project Manager is responsible for placing all forms used in site activities (i.e., records, field reports, and upon the completion of field work, the site logbook) in the project's central file.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate forms and field reports illustrated in this guideline (and any additional forms required by the contract) are correctly used, accurately filled out, and completed in the required time-frame.

5.0 PROCEDURES

5.1 Site Logbook

5.1.1 General

The site logbook is a hard-bound, paginated controlled-distribution record book in which all major onsite activities are documented. At a minimum, the following activities/events shall be recorded (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start or completion of borehole/trench/monitoring well installation or sampling activities
- Daily onsite activities performed each day
- Sample pickup information
- Health and Safety issues (level of protection observed, etc.)
- Weather conditions

A site logbook shall be maintained for each project. The site logbook shall be initiated at the start of the first onsite activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day that onsite activities take place which involve Brown & Root Environmental or subcontractor personnel. Upon completion of the fieldwork, the site logbook must become part of the project's central file.

The following information must be recorded on the cover of each site logbook:

- Project name
- Brown & Root Environmental project number
- Sequential book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks (see Section 5.2), but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). An example of a typical site logbook entry is shown in Attachment A.

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 site notebook in which the measurements are recorded (see Attachment A).

All logbook, notebook, and log sheet entries shall be made in indelible ink (black pen is preferred). 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 pages used must be signed and dated. The site logbook must also be signed by the Field Operations Leader at the end of each day.

5.1.2 Photographs

When movies, slides, or photographs are taken of a site or any monitoring location, they must be numbered sequentially to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be 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 must be compiled to account for routine film processing. Once processed, the slides of photographic prints shall be consecutively numbered and labeled according to the logbook descriptions. The site photographs and associated negatives must be docketed into the project's central file.

5.2 Site Notebooks

Key field team personnel may maintain a separate dedicated notebook to document the pertinent field activities conducted directly under their supervision. For example, on large projects with multiple investigative sites and varying operating conditions, the Health and Safety Officer may elect to maintain a separate site notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a site notebook.

5.3 Sample Forms

A summary of the forms illustrated in this procedure is shown as the listing of Attachments in the Table of Contents for this SOP. Forms may be altered or revised for project-specific needs contingent upon client approval. Care must be taken to ensure that all essential information can be documented. Guidelines for completing these forms can be found in the related sampling SOP.

5.3.1 Sample Collection, Labeling, Shipment and Request for Analysis

5.3.1.1 Sample Log Sheet

Sample Log Sheets are used to record specified types of data while sampling. Attachments B-1 to B-4 are examples of Sample Log Sheets. The data recorded on these sheets are useful in describing the waste source and sample as well as pointing out any problems encountered during sampling. A log sheet must be completed for each sample obtained, including field quality control (QC) samples.

5.3.1.2 Sample Label

A typical sample label is illustrated in Attachment B-5. Adhesive labels must be completed and applied to every sample container. Sample labels can usually be obtained from the appropriate Program source or are supplied from the laboratory subcontractor.

5.3.1.3 Chain-of-Custody Record Form

The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site. One part of the completed COC form is retained by the field crew while the other two or three portions are sent to the laboratory. The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment. An example of a Chain-of-Custody Record form is provided as Attachment B-6. A supply of these forms are purchased and stocked by the field department of the various Brown & Root Environmental offices. Alternately, COC forms supplied by the laboratory may be used. Once the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed COC form (any discrepancies between the sample labels and COC form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the Brown & Root Environmental Project Manager). The COC form is signed and one of the remaining two parts are retained by the laboratory while the last part becomes part of the samples' corresponding analytical data package. Internal laboratory chain-of-custody procedures are documented in the Laboratory Quality Assurance Plan (LQAP).

5.3.1.4 Chain-of-Custody Seal

Attachment B-7 is an example of a custody seal. The Custody seal is also an adhesive-backed label. It is part of a chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field and sealed in coolers for transit to the laboratory. The COC seals are signed and dated by the samplers and affixed across the opening edges of each cooler containing environmental samples. COC seals may be available from the laboratory; these seals may also be purchased from a supplier.

5.3.2 Geohydrological and Geotechnical Forms

5.3.2.1 Groundwater Level Measurement Sheet

A groundwater level measurement sheet, shown in Attachment C-1 must be filled out for each round of water level measurements made at a site.

5.3.2.2 Data Sheet for Pumping Test

During the performance of a pumping test (or an in-situ hydraulic conductivity test), a large amount of data must be recorded, often within a short time period. The pumping test data sheet (Attachment C-2) facilitates this task by standardizing the data collection format, and allowing the time interval for collection to be laid out in advance.

5.3.2.3 Packer Test Report Form

A packer test report form shown in Attachment C-3 must be completed for each well upon which a packer test is conducted following well installation.

5.3.2.4 Summary Log of Boring

During the progress of each boring, a log of the materials encountered, operation and driving of casing, and location of samples must be kept. The Summary Log of Boring (Attachment C-4) is used for this purpose and must be completed for each soil boring performed. In addition, if volatile organics are monitored on cores, samples or cuttings from the borehole (using HNU or OVA detectors), these results must be entered on the boring log (under the "Remarks" column) at the appropriate depth. The "Remarks" column can also be used to subsequently enter the laboratory sample number and the concentration of a few key analytical results. This feature allows direct comparison of contaminant concentrations with soil characteristics.

5.3.2.5 Monitoring Well Construction Details Form

A Monitoring Well Construction Details Form must be completed for every monitoring well piezometer or temporary well point installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter pack, annular seal and grout characteristics, and surface seal characteristics. This information is important in evaluating the performance of the monitoring well, particularly in areas where water levels show temporal variation, or where there are multiple (immiscible) phases of contaminants. Depending on the type of monitoring well (in overburden or bedrock), different forms are used (see Attachments C-5 through C-9). Similar forms are used for flush-mount well completions. The Monitoring Well Construction Details Form is not a controlled document.

5.3.2.6 Test Pit Log

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log (Attachment C-10) must be filled out by the responsible field geologist or sampling technician.

5.3.3 Equipment Calibration and Maintenance Form

The calibration or standardization of monitoring, measuring or test equipment is necessary to assure the proper operation and response of the equipment, to document the accuracy, precision or sensitivity of the measurement, and determine if correction should be applied to the readings. Some items of

equipment require frequent calibration, others infrequent. Some are calibrated by the manufacturer, others by the user.

Each instrument requiring calibration has its own Equipment Calibration Log (Attachment D) which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device used in the field; entries must be made for each day the equipment is used.

5.4 Field Reports

The primary means of recording onsite activities is the site logbook. Other field notebooks may also be maintained. These logbooks and notebooks (and supporting forms) contain detailed information required for data interpretation or documentation, but are not easily useful for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain onsite for extended periods of time and are thus not accessible for timely review by project management.

5.4.1 Weekly Status Reports

To facilitate timely review by project management, Xeroxed copies of logbook/notebook entries may be made for internal use. To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

It should be noted that in addition to the summaries described herein, other summary reports may also be contractually required.

5.4.2 Daily Activities Report

5.4.2.1 Description

The Daily Activities Report (DAR) documents the activities and progress for each day's field work. This report must be filled out on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring which involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors (Attachment E is an example of a Daily Activities Report).

5.4.2.2 Responsibilities

It is the responsibility of the rig geologist to complete the DAR and obtain the driller's signature acknowledging that the times and quantities of material entered are correct.

5.4.2.3 Submittal and Approval

At the end of the shift, the rig geologist must submit the Daily Activities Report to the Field Operations Leader (FOL) for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The DAR reports are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the Project Manager.

6.0 ATTACHMENTS

Attachment A	TYPICAL SITE LOGBOOK ENTRY
Attachment B-1	EXAMPLE GROUNDWATER SAMPLE LOG SHEET
Attachment B-2	EXAMPLE SURFACE WATER SAMPLE LOG SHEET
Attachment B-3	EXAMPLE SOIL/SEDIMENT SAMPLE LOG SHEET
Attachment B-4	CONTAINER SAMPLE LOG SHEET FORM
Attachment B-5	SAMPLE LABEL
Attachment B-6	CHAIN-OF-CUSTODY RECORD FORM
Attachment B-7	CHAIN-OF-CUSTODY SEAL
Attachment C-1	EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET
Attachment C-2	EXAMPLE PUMPING TEST DATA SHEET
Attachment C-3	PACKER TEST REPORT FORM
Attachment C-4	EXAMPLE BORING LOG
Attachment C-5	EXAMPLE OVERBURDEN MONITORING WELL SHEET
Attachment C-5A	EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)
Attachment C-6	EXAMPLE CONFINING LAYER MONITORING WELL SHEET
Attachment C-7	EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL
Attachment C-8	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK
Attachment C-8A	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK (FLUSHMOUNT)
Attachment C-9	EXAMPLE TEST PIT LOG
Attachment D	EXAMPLE EQUIPMENT CALIBRATION LOG
Attachment E	EXAMPLE DAILY ACTIVITIES RECORD
Attachment F	FIELD TRIP SUMMARY REPORT

ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL:

BROWN & ROOT ENV.	DRILLER	EPA
_____	_____	_____
_____	_____	_____
_____	_____	_____

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

ACTIVITIES:

1. Steam jenney 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 off site, gate locked.

_____
Field Operations Leader

ATTACHMENT B-1
EXAMPLE GROUNDWATER SAMPLE LOG SHEET

GROUNDWATER
SAMPLE LOG SHEET

Page ____ of ____

Project Site Name: _____

Project No.: _____

☐ Domestic Well Data
☐ Monitoring Well Data
☐ Other Well Type: _____
☐ QA Sample Type: _____

Sample ID No.: _____

Sample Location: _____

Sampled By: _____

C.O.C. No.: _____

Sampling Data

Date: / Time: / Method:	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD

Purge Data

Date: / Method:	Volume	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD
	Initial							
Monitor Reading (ppm):	1							
Well Casing Dia. & Material Type:	2							
	3							
Total Well Depth (TD):	4							
Static Water Level (WL):	5							
TD-WL (ft.) =								
One Casing Volume: (gal/L)								
Start Purge (hrs.):								
End Purge (hrs.):								
Total Purge Time (min):								
Total Amount Purged (gal/L):								

Analysis	Preservative	Container Requirements	Collected (✓)

Observations/Notes:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

TBD: To Be Determined

ATTACHMENT B-2
EXAMPLE SURFACE WATER SAMPLING LOG SHEET

SURFACE WATER SAMPLING LOG SHEET

Page ____ of ____

Project Site Name: _____ Sample ID No.: _____

Project No.: _____ Sample Location: _____

☐ Spring ☐ Pond Sampled By: _____

☐ Stream ☐ Lake

☐ Other _____

☐ QA Sample Type: _____ C.O.C. No.: _____

Sample Data		
Date and Time	Method	Depth

pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD

Analysis	Preservative	Container Requirements	Collected (✓)

Observations/Notes:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No.:	

TBD: To Be Determined

ATTACHMENT B-3
EXAMPLE SOIL/SEDIMENT SINGLE SAMPLE LOG SHEET

SOIL/SEDIMENT
SINGLE SAMPLE LOG SHEET

Page ____ of ____

Project Site Name: _____

Project No.: _____

- ☐ Surface Soil
- ☐ Subsurface Soil
- ☐ Sediment
- ☐ Other _____
- ☐ QA Sample Type: _____

Sample ID No.: _____

Sample Location: _____

Sampled By: _____

C.O.C. No.: _____

Sample Method:	Composite Sample Data		
	Sample	Time	Color/Description
Depth Sampled:			
Sample Date and Time:			
Type of Sample			
☐ Grab			
☐ Composite			
☐ Grab-Composite	Field Sample Data		
☐ High Concentration	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)	
☐ Low Concentration			

Analysis	Container Requirements	Collected (✓)	Map:

Observations/Notes:

Circle If Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

ATTACHMENT B-4
CONTAINER SAMPLE LOG SHEET FORM

Brown & Root Environmental

Page ___ of _

☐ Container Data

Case #: _____

By: _____

Project Site Name: _____ Project Site No. _____

Brown & Root Env. Source No. _____ Source Location: _____

Container Source	Container Description
☐ Drum ☐ Bung Top ☐ Lever Lock ☐ Bolted Ring ☐ Other _____ _____ ☐ Bag/Sack ☐ Tank ☐ Other _____ _____	Color: _____ Condition: _____ Markings: _____ Vol. of Contents: _____ Other: _____

Disposition of Sample	Sample Description	Layer 1	Layer 2	Layer 3
☐ Container Sampled ☐ Container opened but not sampled. Reason: _____ _____ ☐ Container not opened. Reason: _____ _____	Phase	☐Sol. ☐Liq.	☐Sol. ☐Liq.	☐Sol. ☐Liq.
	Color	_____	_____	_____
	Viscosity	☐L ☐M ☐H	☐L ☐M ☐H	☐L ☐M ☐H
	% of Total Volume	_____	_____	_____
	Other	_____	_____	_____

Monitor Reading:	Type of Sample	
Sample Method:	☐ Low Concentration ☐ High Concentration	☐ Grab ☐ Composite ☐ Grab-composite

		Organic	Inorganic
Sample Date & Time:	Sample Identification		
Sampled by:			
Signature(s):			
	Date Shipped		
Analysis:	Time Shipped		
	Lab		
	Volume		

ATTACHMENT B-5

SAMPLE LABEL

Brown & Root Environmental PROJECT: _____

STATION LOCATION: _____

DATE: ____/____/____ TIME: _____ hrs.

MEDIA: WATER ☐ SOIL ☐ SEDIMENT ☐ _____ ☐

CONCENTRATION: LOW ☐ MEDIUM ☐ HIGH ☐

TYPE: GRAB ☐ COMPOSITE ☐

ANALYSIS	PRESERVATION
VOA ☐ BNAs ☐	Cool to 4°C ☐
PCBs ☐ PESTICIDES ☐	HNO_3 to pH < 2 ☐
METALS: TOTAL ☐ DISSOLVED ☐	NaOH to pH > 12 ☐
CYANIDE ☐	
_____ ☐	_____ ☐

Sampled by: _____

Remarks:

ATTACHMENT B-6

CHAIN-OF-CUSTODY RECORD FORM
(Original is 8.5 x 11")

PROJECT NO.	PROJECT NAME	NO. OF CONTAINERS	REMARKS
SAMPLERS: *(Signature)*			

STA NO.	DATE	TIME			STATION LOCATION								

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks:	

ATTACHMENT B-7

CHAIN-OF-CUSTODY SEAL

CUSTODY SEAL	**CUSTODY SEAL**
Date	**Date**
Signature	**Signature**

ATTACHMENT C-1
EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET

GROUNDWATER LEVEL MEASUREMENT SHEET

Page ___ of ___

PROJECT NAME: _____ LOCATION: _____
PROJECT NUMBER: _____ MEASURING DEVICE: _____
PERSONNEL: _____ ADJUSTMENT FACTOR: _____
DATE: _____ REMARKS: _____
WEATHER CONDITIONS: _____

Well or Piezometer Number	Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Groundwater Elevation (Feet)*	Comments

*Measurements to nearest 0.01 foot.

Signature(s): _____

ATTACHMENT C-2
EXAMPLE PUMPING TEST DATA SHEET

PUMPING TEST DATA SHEET

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
PUMPING TEST: [ ]
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DATE(s): _____
STATIC H_2O LEVEL (ft) (SO) _____

PUMPING WELL NUMBER: _____
MEASURED WELL NUMBER: _____
STEP DRAW DOWN TEST [ ]
MONITORING POINT: _____
DEPTH CORRECTION (ft) _____
PUMP SETTING (Ft. below monitoring point): _____
DISTANCE FROM PUMPING WELL (ft) (r): _____

PUMPING TEST PERFORMED BY: _____
REMARKS: _____

MILITARY TIME	ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	CORRECTION (Ft.)	DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	PUMPING RATE (GPM)	REMARKS

SIGNATURE(s): _____

ATTACHMENT C-3

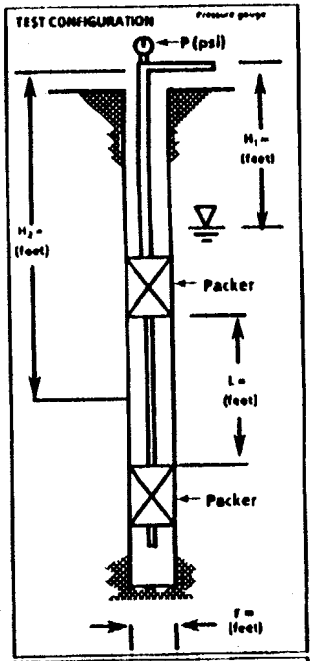
PACKER TEST REPORT FORM

PROJECT: _____ PROJECT NO.: _____ TEST NO: _____ PAGE ____ OF ____

BORING NO.: _____ CASING DEPTH: _____ CONTRACTOR: _____ STATIC WATER LEVEL _____

TEST INTERVAL: _____ BY: _____ CHECKED: _____ PACKER PRESSURE _____

Flow Test					Calculated Results							
Pressure, p (psi)	Elapsed Time (min)	Flow Reading	Δ Flow, ΔQ (ft³)	Δ Flow, ΔQ (gal)	Flow Rate Q (gal/min)	H_1* (ft)	Hp(ft) = 2.31 (psi)	H_2* (ft)	H = Hp + (H1 or H2)	Cp	K (ft/yr) = 0.5 Q/H	K (cm/sec) = 9.67 x 10⁻⁶ K (ft/yr)



Length of Test Section in Feet, L	Cp (Drilling Bit Size)			
	EX (1.5")	AX (1.875")	BX (2.37")	NX (3")
1	31,000	28,500	25,000	22,000
2	19,000	18,100	16,000	15,500
5	9,000	9,000	8,000	8,000
8	6,000	6,000	6,100	5,000
10	5,700	5,000	5,000	4,900
15	4,100	3,900	3,800	3,600
20	3,200	3,100	3,000	2,900

$CP = (1/(2 \pi L)) \ln(L/r)$ (70.3 L/S)
7.48 Gallons = 1 Ft³
1 psi = 2.31 ft head

* H_1 is used when the test length is below the water table.
H_2 is used when the test length is above the water table.

Remarks _____

ATTACHMENT C-4
EXAMPLE BORING LOG

BORING LOG Page___ of___

PROJECT NAME: _____ BORING NUMBER: _____
PROJECT NUMBER: _____ DATE : _____
DRILLING COMPANY: _____ GEOLOGIST: _____
WATER LEVEL DATA: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows/ 6" or RQD (%)	Sample Recovery/ Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density, Consistency or Rock Hardness	Color	Material Classification	* USCS	Remarks	PID or FID Reading (ppm)

*When rock coring enter rock brokeness.

CONVERTED TO WELL : ___ Yes ___ No; WELL I.D.#: _____
REMARKS: _____

Signature(s): _____

LEGEND

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)

COARSE GRAINED SOILS — More Than Half of Material is LARGER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)			GROUP SYMBOL	TYPICAL NAMES
GRAVELS (50%(+)>1/4"Ø)	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel sand mixtures, little or no fines.
	GRAVELS W/FINES (High % Fines)	Non plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand silt mixtures.
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel sand clay mixtures.
SANDS 50%(+)<1/4"(Ø)	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines
		Predominantly one size or a range of sizes with some intermediate sizes missing	SP	Poorly graded sands, gravelly sands little or no fines
	SANDS W/FINES (High % Fines)	Non plastic fines (for identification procedures, see ML)	SM	Silty sands, poorly graded sand silt mixtures
		Plastic fines (for identification procedures, see CL)	SC	Clayey sands, poorly graded sand clay mixtures

FINE-GRAINED SOILS — More Than Half of Material is SMALLER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)	Identification Procedures on Fraction Smaller Than No. 40 Sieve Size				GROUP SYMBOL	TYPICAL NAMES
		DRY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)		
SILTS AND CLAYS Liquid Limit <50		None to Slight	Quick to Slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
		Medium to High	None to Very Slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
SILTS AND CLAYS Liquid Limit >50		Slight to Medium	Slow to None	Slight to Medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		High to Very High	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Medium to High	None to very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.				Pt	Peat and other organic soils

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW GC, well graded gravel-sand mixture with clay binder.
All sieve sizes on this chart are U.S. Standard

DENSITY OF GRANULAR SOILS

DESIGNATION	STANDARD PENETRATION RESISTANCE BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNC COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily pentrated 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.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)

Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects
Soft	Easily Gouged	Crushes when pressed with hammer
Medium Soft	Can be Gouged	Breaks (one blow); crumbly edges
Medium Hard	Can be scratched	Breaks (one blow); sharp edges
Hard	Cannot be scratched	Breaks conchoidally (several blows); sharp edges

ROCK BROKENESS

Descriptive Terms	Abbreviation	Spacing
Very Broken	(V. Br.)	0-2"
Broken	(Br.)	2"-1'
Blocky	(Bl.)	1'-3"
Massive	(M.)	3'-10'

LEGEND:

SOIL SAMPLES - TYPES

S-2" Split-Barrel Sample

ST-3" O.D. Undisturbed Sample

O - Other Samples, Specify in Remarks

ROCK SAMPLES - TYPES

X HX (Conventional) Core (-2-1/8" O.D.)

Q-NQ (Wireline) Core (-1-7/8" O.D.)

Z - Other Core Sizes, Specify in Remarks

WATER LEVELS

12/18 ▼ 12.6' Initial Level w/Date & Depth

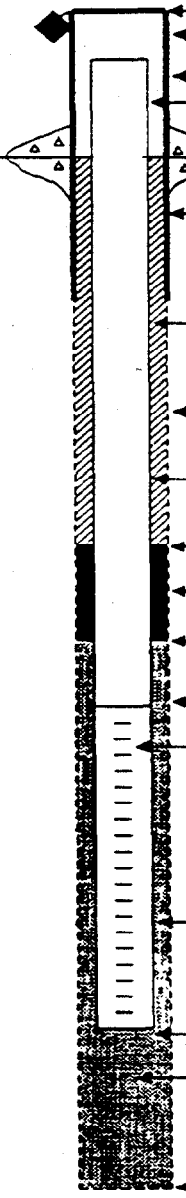
12/18 ▼ 12.6' Stabilized Level w/Date & Depth

ATTACHMENT C-5
EXAMPLE OVERBURDEN MONITORING WELL SHEET

BORING NO.: _____

OVERBURDEN
MONITORING WELL SHEET

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



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: _____ / _____

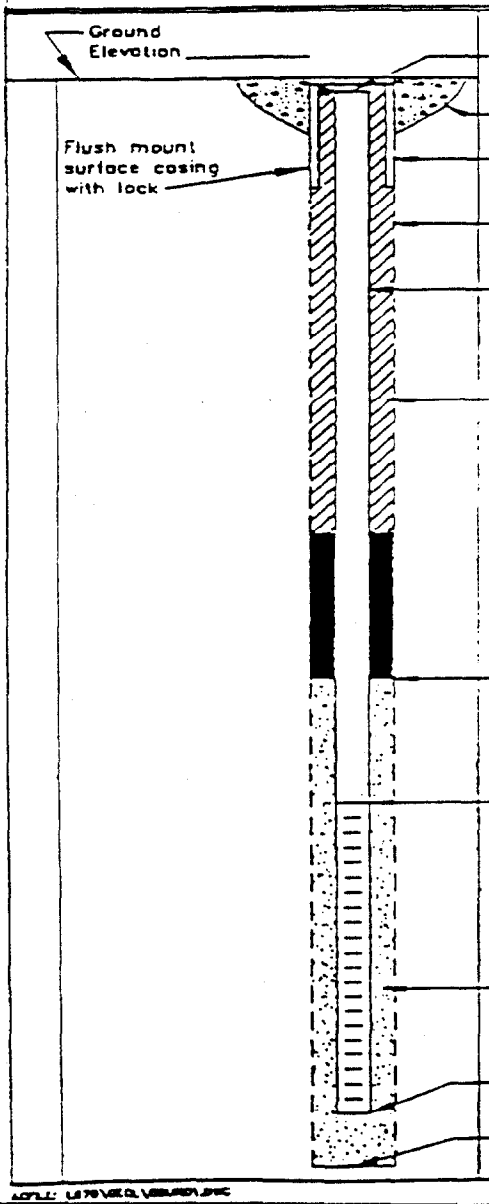
ATTACHMENT C-5A
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)

BORING NO.: _____

MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

_____

DEPTH/ELEVATION TOP OF SAND: _____ / _____

DEPTH/ELEVATION TOP OF SCREEN: _____ / _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____

DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____

DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____

BACKFILL MATERIAL BELOW SAND: _____

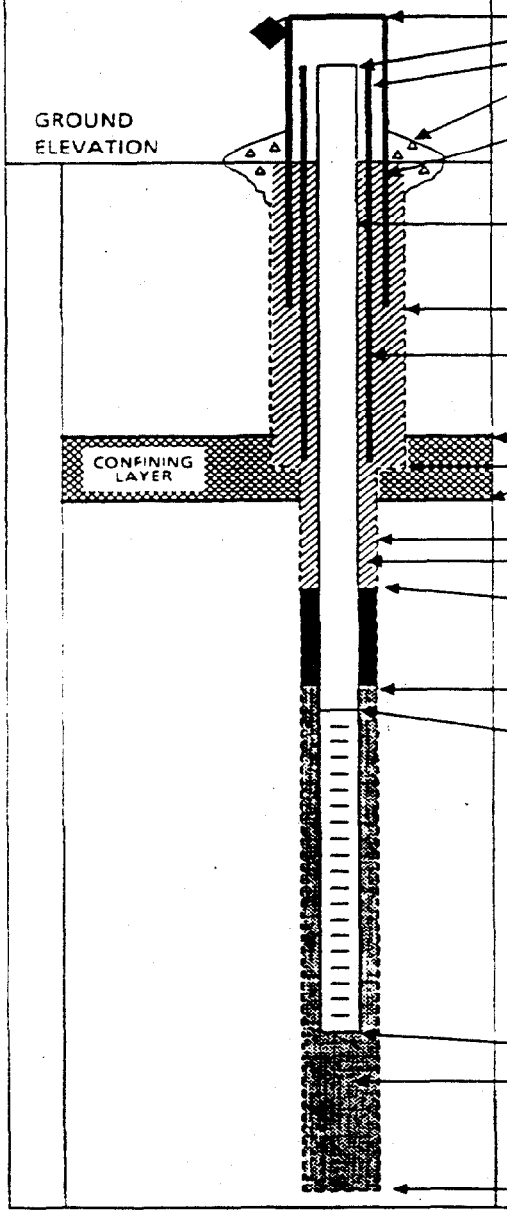
ATTACHMENT C-6
EXAMPLE CONFINING LAYER MONITORING WELL SHEET

BORING NO.: _____

CONFINING LAYER
MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING : _____
ELEVATION OF TOP OF RISER PIPE: _____
ELEVATION TOP OF PERM. CASING: _____
TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

RISER PIPE I.D. _____
TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____

PERM. CASING I.D. _____
TYPE OF CASING & BACKFILL: _____

ELEVATION / DEPTH TOP CONFINING LAYER: _____
ELEVATION / DEPTH BOTTOM OF CASING: _____
ELEVATION / DEPTH BOT. CONFINING LAYER: _____

BOREHOLE DIA. BELOW CASING: _____
TYPE OF BACKFILL: _____

ELEVATION / DEPTH TOP OF SEAL: _____
TYPE OF SEAL: _____

DEPTH TOP OF SAND PACK: _____

ELEVATION/DEPTH TOP OF SCREEN: _____
TYPE 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: _____

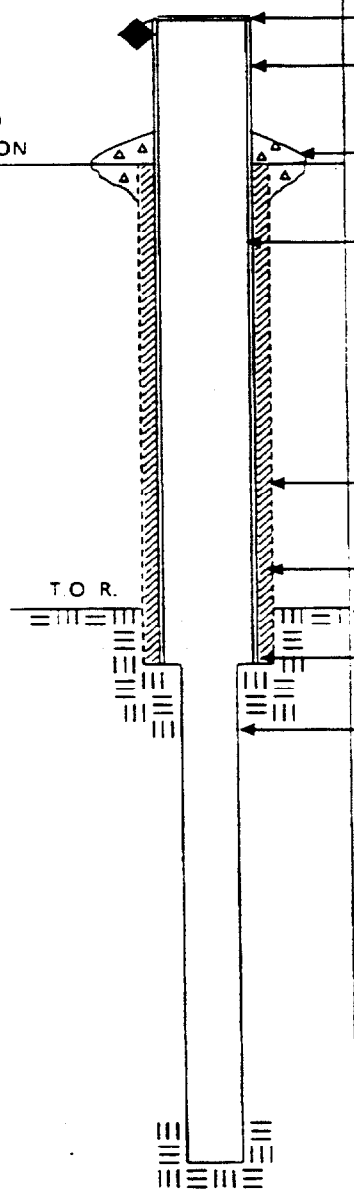
ATTACHMENT C-7
EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
OPEN HOLE WELL

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF CASING: _____

STICK UP OF CASING ABOVE GROUND SURFACE: _____

TYPE OF SURFACE SEAL: _____

I.D. OF CASING: _____
TYPE OF CASING: _____

TEMP. / PERM.: _____

DIAMETER OF HOLE: _____

TYPE OF CASING SEAL: _____

DEPTH TO TOP OF ROCK: _____

DEPTH TO BOTTOM CASING: _____

DIAMETER OF HOLE IN BEDROCK: _____

DESCRIBE IF CORE / REAMED WITH BIT:

_____

DESCRIBE JOINTS IN BEDROCK AND DEPTH:

_____

ELEVATION / DEPTH OF HOLE: _____ / _____

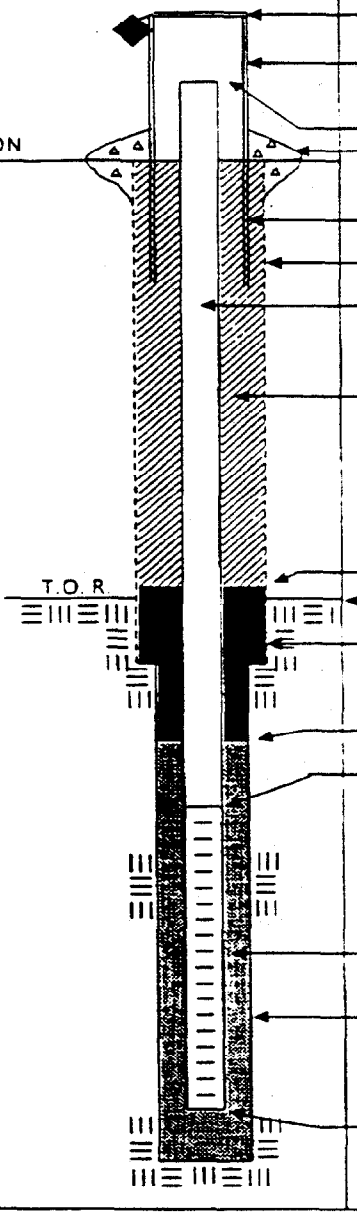
ATTACHMENT C-8
EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING: _____

STICK UP OF CASING ABOVE GROUND SURFACE: _____

ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____

DIAMETER OF HOLE: _____

RISER PIPE I.D.: _____

TYPE OF RISER PIPE: _____

TYPE OF BACKFILL: _____

ELEVATION / DEPTH TOP OF SEAL: ____/____

ELEVATION / DEPTH TOP OF BEDROCK: ____/____

TYPE OF SEAL _____

ELEVATION / DEPTH TOP OF SAND: ____/____

ELEVATION / DEPTH TOP OF SCREEN: ____/____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

I.D. SCREEN: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK:

CORE / REAM: _____

ELEVATION / DEPTH BOTTOM SCREEN: ____/____

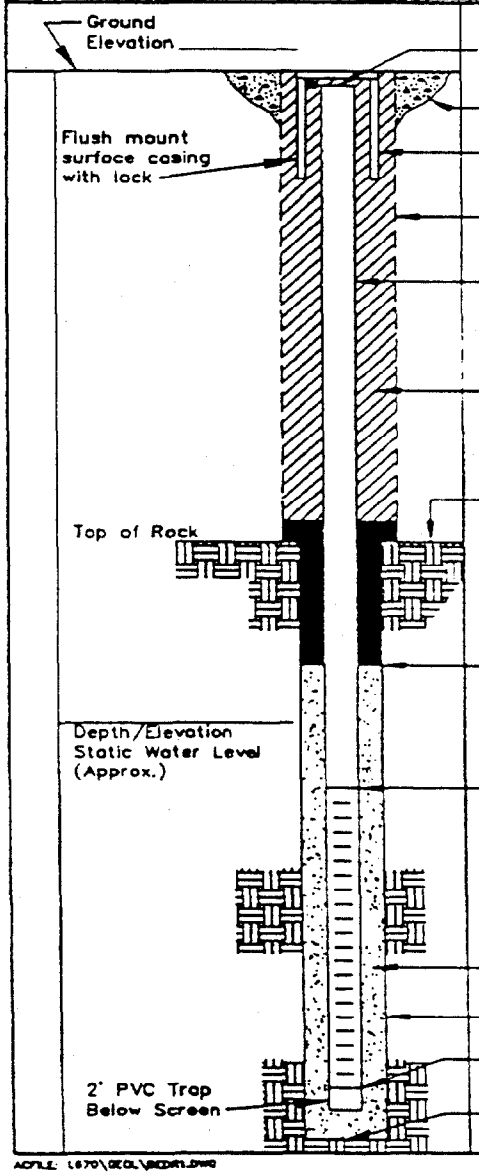
ELEVATION / DEPTH BOTTOM OF HOLE: ____/____

ATTACHMENT C-8A
EXAMPLE BEDROCK MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK (FLUSHMOUNT)

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

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



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

_____

DEPTH/ELEVATION TOP OF BEDROCK: _____ / _____

DEPTH/ELEVATION TOP OF SAND: _____ / _____

DEPTH/ELEVATION TOP OF SCREEN: _____ / _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____

DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____

DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____

BACKFILL MATERIAL BELOW SAND: _____

ACFILE: L679\GEOL\BEDRK1.DWG

ATTACHMENT C-9
EXAMPLE TEST PIT LOG

TEST PIT LOG

Brown & Root Environmental

PROJECT: _____ TEST PIT NO.:

PROJECT NO _____ DATE: _____

LOCATION: _____

FIELD GEOLOGIST: _____

DEPTH (ft.)	LITHOLOGY CHANGE (Depth, ft.)	MATERIAL DESCRIPTION (Soil Density / Consistency, Color)	USCS	REMARKS

Test Pit Cross Section and / or Plan View

REMARKS _____

PHOTO LOG _____ TEST PIT _____

PAGE ____ OF ____

ATTACHMENT D
EXAMPLE EQUIPMENT CALIBRATION LOG

Brown & Root Environmental

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME / MODEL : _____

JOB NAME : _____

MANUFACTURER : _____

JOB NUMBER : _____

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

ATTACHMENT E
EXAMPLE DAILY ACTIVITIES RECORD

Brown & Root Environmental

DAILY ACTIVITIES RECORD

PROJECT _____ LOCATION _____
CLIENT _____ ARRIVAL TIME _____ JOB NO. _____
DATE _____ DEPARTURE TIME _____
CONTRACTOR _____ DRILLER _____
BORING NO. _____ HNUS REPRESENTATIVE _____

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS _____

APPROVED BY:

_____ _____
HNUS FIELD REPRESENTATIVE DRILLER OR REPRESENTATIVE

ATTACHMENT F
FIELD TRIP SUMMARY REPORT
PAGE 1 OF 2

SUNDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

MONDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

TUESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

WEDNESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

ATTACHMENT F
PAGE 2 OF 2
FIELD TRIP SUMMARY REPORT

THURSDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

FRIDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

SATURDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

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1.0 PURPOSE

The purpose of this procedure is to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

5.0 PROCEDURES

To ensure that analytical chemical results reflect actual contaminant concentrations present at sampling locations, the various drilling equipment and chemical sampling and analytical equipment used to acquire the environment sample must be properly decontaminated. Decontamination minimizes the potential for cross-contamination between sampling locations, and the transfer of contamination offsite.

5.1 Drilling Equipment

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 samples. 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. Where the drilling rig is set to perform multiple borings at a single area of concern, the steam-cleaning of the drilling rig itself may be waived with proper approval. Downhole equipment, however, must always be steam-cleaned between borings. Where PVC well casings are to be installed, decontamination is not required if the manufacturer provides these casings in factory-sealed, protective, plastic sleeves (so long as the protective packaging is not compromised until immediately before use.

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-ground tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases 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. Alternately, a lined sloped pad with a collection pump installed at the lower end may be permissible. The location of the steam cleaning area shall be onsite in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating drilling 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.

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, as practicable. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

5.2 Sampling Equipment

5.2.1 Bailers and Bailing Line

The potential for cross-contamination between sampling points through the use of a common bailer or its attached line is high unless strict procedures for decontamination are followed. For this reason, it is preferable 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 must be followed.

Before the initial sampling and after each successive sampling point, the bailer must be decontaminated. The following steps are to be performed when sampling for organic contaminants. Note: contract-specific requirements may permit alternative procedures.

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush (may be required if the sample point is heavily contaminated with heavy or extremely viscous compounds)
- Potable water rinse
- Rinse with 10 percent nitric acid solution*
- Deionized water rinse

---

* 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.

- Acetone or methanol rinse (in some EPA Regions, isopropanol is used instead)
- Hexane rinse**
- Copious distilled/Deionized water rinse
- Air dry

If sampling for volatile organic compounds (VOCs) only, the nitric acid, acetone, methanol, and hexane rinses may be omitted. Only reagent grade or purer solvents are to be used for decontamination. When isopropanol is used, the bailer must be thoroughly dry before using to acquire the next sample.

In general, specially purchased pre-cleaned disposable sampling equipment is not decontaminated (nor is an equipment rinsate blank collected) so long as the supplier has provided certification of cleanliness. If decontamination is performed on several bailers at once (i.e., in batches), bailers not immediately used may be completely wrapped in aluminum foil (shiny-side toward equipment) and stored for future use. When batch decontamination is performed, one equipment rinsate is generally collected from one of the bailers belonging to the batch before it is used for sampling.

It is recommended that clean, dedicated braided nylon or polypropylene line be employed with each bailer use.

5.2.2 Sampling Pumps

Most sampling pumps are 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 prior to initial use and after each use.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except that the 10 percent nitric acid solution is omitted. Each of the liquid factions 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. For peristaltic pumps, the tubing is replaced rather than cleaned.

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 (especially phthalate esters) into the water being sampled or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (listed in order of preference). Whenever possible, dedicated hoses should be used. It is preferable that these types of pumps not be used for sampling, only for purging.

5.2.3 Filtering Equipment

On occasion, the sampling plan may require acquisition of filtered groundwater samples. Field-filtering is addressed in SOP SA-6.1 and should be conducted as soon after sample acquisition as possible. 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 or replaced before each use.

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

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.)

5.2.4 Other Sampling Equipment

Field tools such as trowels and mixing bowls are to be decontaminated in the same manner as described above.

5.3 Field Analytical Equipment

5.3.1 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 (unless otherwise directed by manufacturer)
- 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.

5.3.2 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 (e.g., dissolved oxygen probes). 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 is self-cleaning when exposure to uncontaminated air is allowed and the housing can be wiped clean with paper-towels or cloth wetted with alcohol.

5.4 Waste Handling

For the purposes of these procedures, contaminated materials are defined as any byproducts of field activities that are suspected or known to be contaminated with hazardous substances. These byproducts include such materials as decontamination solutions, disposable equipment, drilling muds, well-development fluids, and spill-contaminated materials and Personal Protection Equipment (PPE).

The procedures for obtaining permits for investigations of sites containing hazardous substances are not clearly defined at present. In the absence of a clear directive to the contrary by the EPA and the states, it must be assumed that hazardous wastes generated during field activities will require compliance with Federal agency requirements for generation, storage, transportation, or disposal. In addition, there may be state regulations that govern the disposal action. This procedure exclusively describes the technical methods used to control contaminated materials.

The plan documents for site activities must include a description of control procedures for contaminated materials. This planning strategy must assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spoils. Handling and disposing of potentially hazardous materials can be dangerous and expensive. Until sample analysis is complete, it is assumed that all produced materials are suspected of contamination from hazardous chemicals and require containment.

5.5 Sources of Contaminated Materials and Containment Methods

5.5.1 Decontamination Solutions

All waste decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. Larger equipment such as backhoes and tractors must be decontaminated in an area provided with an impermeable liner and a liquid collection system. A decontamination area for large equipment could consist of a bermed concrete pad with a floor drain leading to a buried holding tank.

5.5.2 Disposable Equipment

Disposable equipment that could become contaminated during use typically includes PPE, rubber gloves, boots, broken sample containers, and cleaning-wipes. These items are small and can easily be contained in 55-gallon drums with lids. These containers should be closed at the end of each work day and upon project completion to provide secure containment until disposed.

5.5.3 Drilling Muds and Well-Development Fluids

Drilling muds and well-development fluids are materials that may be used in groundwater monitoring well installations. Their proper use could result in the surface accumulation of contaminated liquids and muds that require containment. The volumes of drilling muds and well-development fluids used depend on well diameter and depth, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes (or number) of containment structures required. Since guesswork is involved, it is recommended that an slight excess of the estimated amount of containers required will be available.

Drilling muds are mixed and stored in what is commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling mud is withdrawn and pumped through hoses, down the drill pipe to the bit, and back up the hole to the settling section of the mud pit. In the settling section, the mud's velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the mud/fluid.

The mud pit may be either portable above-ground tanks commonly made of steel (which is preferred) or stationary in-ground pits as depicted in Attachment A. The above-ground tanks have a major advantage over the in-ground pits because the above-ground tanks isolate the natural soils from the

contaminated fluids within the drilling system. These tanks are also portable and can usually be cleaned easily.

As the well is drilled, the cuttings that accumulate in the settling section must be removed. This is best done by shoveling them into drums or other similar containers. When the drilling is complete, the contents of the above-ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and made available for its next use.

If in-ground pits are used, they should not extend into the natural water table. They should also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the lining material used would have to be nonreactive with the wastes. An advantage of the in-ground pits is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the above-ground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage should be such that any excess fluid could be controlled within the immediate area of the drill site.

The containment procedure for well-development fluids is similar to that for drilling muds. The volume and weight of contaminated fluid will be determined by the method used for development. When a new well is pumped or bailed to produce clear water, substantially less volume and weight of fluid result than when backwashing or high-velocity jetting is used.

5.5.4 Spill-Contaminated Materials

A spill is always possible when containers of liquids are opened or moved. Contaminated sorbents and soils resulting from spills must be contained. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

5.6 Disposal of Contaminated Materials

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, landfilling, treatment, and so on. The problem centers around the assignment of responsibility for disposal. The responsibility must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his acceptance of the disposal obligation. In instances where a responsible party cannot be identified, this responsibility may fall on the public agency or private organization investigating the site.

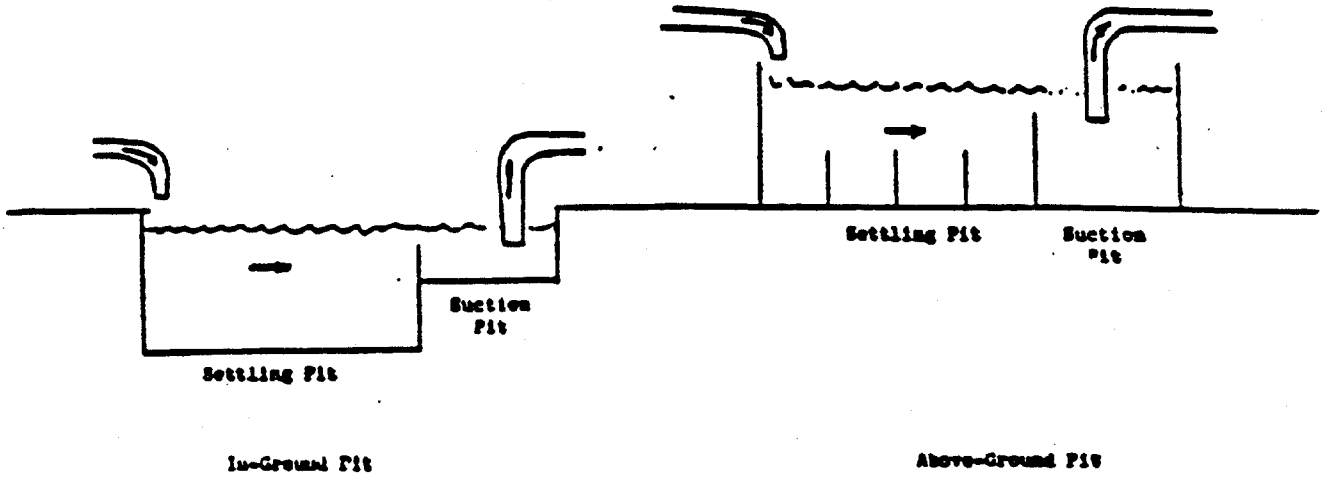
Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered so that proper storage is provided. If onsite storage is expected, then the containment structures should be specifically designed for that purpose.

6.0 REFERENCES

Brown & Root Environmental: Standard Operating Procedure No. 4.33, Control of Contaminated Material.

ATTACHMENT A

TWO TYPES OF MUD PITS USED IN WELL DRILLING



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1.0 PURPOSE

To establish procedures for the use, maintenance, and calibration of the Photovac 2020 Photoionization Air Monitor.

2.0 SCOPE

Applies to each usage of the Photovac 2020 Photoionization Air Monitor by Brown & Root Environmental personnel.

3.0 GLOSSARY

Electron volt (eV) - A unit of energy equal to the energy acquired by an electron when it passes through a potential difference of 1 volt in a vacuum. It is equal to $1.602192 \pm 0.000007 \times 10^{-19}$ volts.

Intrinsically Safe (I.S.) - Based on wiring, configuration, design, operation, gasketing, construction, this instrument may be employed within locations in which flammable gases and/or vapors may exist.

Ionization Potential (I.P.) - The energy required to remove an electron from a molecule yielding a positively charged ion and a negatively charged free electron. The instrument measures this energy level.

Photoionization Detector (PID) - Photoionization detector employed as general reference to air monitors of this type. PIDs detection method employs ultraviolet (UV) radiation as an energy source. As air and contaminant are drawn through the ionization chamber the UV light source causes the contaminant with ionization potentials equal to or less than the UV source to break into positive and negatively charge ions. The created ions are subjected to an electrostatic field. The voltage difference is measured in proportion to the calibration reference and the concentration of the contaminant.

Ultraviolet Radiation (UV) - Ultraviolet radiation is the energy source employed by the instrument to ionize collected sample gas streams. The UV lamp source is required to be equal to or greater than the ionization potential of the substance drawn through the instrument in order to create separate ionized species.

4.0 RESPONSIBILITIES

Health and Safety Manager (HSM) - The HSM shall ensure that the user has been appropriately trained and certified in the usage of the Photovac 2020 instrument.

Equipment Manager - The Equipment Manager shall ensure all air monitoring instrumentation slated for field activities has been operationally checked out, fully charged, and calibrated prior to issuing any instrument for field service. Maintenance deficiencies identified by the Equipment Manager will require those instruments to be pulled from service until repairs can be facilitated.

Field Operations Leader (FOL)/Field Team Leader (FTL) - The FOL/FTL shall ensure all field team members employing the monitoring instruments as part of their assigned duties are adequately trained in the operation and limitations of this instrument. The FOL/FTL shall ensure that the air monitoring instruments are employed as directed by site guidance documents (i.e., Work Plan, Health and Safety Plan, etc.). Additionally, the FOL/FTL shall ensure that the appropriate documentation and recordkeeping requirements are fulfilled including Documentation of Calibration and Direct Reading Instrument Response Data Sheets for air monitoring activities.

Health and Safety Officer (HSO) - The HSO is responsible for determining air monitoring requirements for the site activities, and providing direction for air monitoring during specific site activities. This identification of types of air monitoring and direction for use are indicated within the Site-Specific Health and Safety Plan (HASP).

Site Safety Officer (SSO) - The SSO shall ensure the instruments identified are employed in the manner directed by the HSO, and that any action levels specified are observed for the application of engineering controls, personal protective equipment (PPE) use, and administrative controls. Additionally, he/she shall ensure the instruments are properly maintained and calibrated prior to use in the field. The SSO, during specific air monitoring applications including STEL and TWA mode measurements, will be responsible for the operation and application of this specialty air monitoring device.

5.0 PROCEDURES

5.1 Principle of Operation

The Photovac portable photoionizer detects the concentration of many organic (and a few inorganic). The basis for detection of this instrument is the ionization of components of captured gaseous streams. The incoming gas molecules are subjected to ultraviolet (UV) radiation, which is energetic enough to ionize many gaseous compounds. Molecules are transformed into charged-ion pairs, creating a current between two electrodes. Each molecule has a characteristic ionization potential, which is the energy required to remove an electron from the molecule, yielding a positively-charged ion and the free electron. The instrument measures this energy level.

This instrument measures the concentration of airborne photoionizable gases and vapors and automatically displays and records these concentrations. It does not distinguish between individual substances. Readings displayed represent the total concentration of all photoionizable chemicals present in the sample. This instrument is factory set to display concentration in units of ppm or mg/m^3.

The 2020 instrument is easy to operate The meter display updates itself once per second. Concentrations are directly displayed on the readout.

2020 also performs short-term exposure limit (STEL), time-weighted average (TWA) and PEAK calculations. You can view any of these results, but only one mode may be viewed at a time.

2020 has 6 keys for alphanumeric entry and for accessing multiple functions. The keys are used to set up and calibrate 2020. They allow you to manipulate the concentration data in various ways.

All information entered with the keys and stored in 2020's memory is retained when the instrument is switched off. The clock and calendar continue to operate and do not need to be set each time 2020 is turned on.

5.1.1 Displays

The 2020 has a meter display for reporting detected concentration, and a display used to display status information and guide you through configuration options. All functions of the 2020 will be controlled or reported using one of these displays.

5.1.1.1 Meter Display

The meter display is a 4-digit display. It will always be used for reporting detected concentration. When the detector and pump are off, the meter display will be blank.

In order to accommodate the range of concentrations 2020 can detect, the meter reading will be reported using one of 2 resolutions. A resolution of 0.1 will be used for concentrations below 100 ppm, and a resolution of 1 will be used for concentrations above 100 ppm.

5.1.1.2 Status Display

The status display is a 2 line by 16 character display. The top line is used to display status information and prompts you for information. The bottom line is used for soft key names. Up to 3 names can be displayed for the 3 soft keys. If a name does not appear for a soft key, then the soft key has no associated function.

5.1.2 Keys

5.1.2.1 Fixed Keys

The three round keys below the soft keys each have a fixed function. The first key is the ON/OFF key, the middle key is the EXIT key, and the last key is the ENTER key.

The ON/OFF key is used to both turn power on to the 2020 as well as turn the power off. To turn on 2020, press the ON/OFF key. To turn the power off, press the ON/OFF key and hold it down for 2 seconds, and then release it. This is done to prevent accidental power off.

The EXIT key provides a way of returning to the default display. In the functional map, the soft keys allow you to advance and the EXIT key provides a way to go back. If you are at the initial entry of the menu, EXIT will return you to the default display.

The ENTER key has a context sensitive function. When you are operating or navigating through the function map, the ENTER key is used to exit the functions and return you to the default display. When entering data such as a name, number, date, or time, ENTER is used to confirm the entry.

5.1.2.2 Soft Keys

The three soft keys on 2020 are located directly below the status display. Each key has varying functions for configuring 2020, editing the data logger, and controlling the display. Since only three soft keys are available, each function is broken down into a path

5.1.2.3 Entering Text With the Soft Keys

For all information that you must enter, the left, center, and right soft keys correspond to the up, down, and right arrow.

The up and down arrows are used to change the character highlighted by the cursor. The right arrow is used to advance the cursor to the next character on the right. When the cursor is advanced past the right most character, it wraps around to the first character again. To accept the changes, press the ENTER key. To ignore the change, press EXIT.

Formatting characters, such as the colon (:) in the time, the decimal (.) in a concentration, and the slash (/) in the date are skipped when advancing the cursor.

All inputs are an 8 character input, which is displayed on the right side of the top line of the status display. The prompt, describing the input, occupies the left half of the top line. The soft keys are defined on the bottom line of the status display.

5.2 Default Display

The meter display shows the detected concentration. The resolution of the display changes with the magnitude of the reading. A reading of 0 to 99.9 will be displayed with a resolution of 0.1 ppm or mg/m^3. A reading greater than 99.9 will be shown with a resolution of 1 ppm or mg/m^3. The meter will display concentrations up to 2000 ppm or 2(XX) mg/m^3.

The status display is used to display the instrument status, date, time, units, and active soft keys.

The default display provides the following information: instrument status, current detected concentration, time, date, and measurement units. The status display toggles between showing time and units and then the date.

When the display mode is MAX, the date and time correspond to the date and time the MAX concentration was recorded. In TWA mode, the time represents the number of hours and minutes during which the TWA has been accumulating. For PEAK and STEL monitoring, the date and time correspond to the current date and time.

5.3 Monitoring

5.3.1 Instrument Status

The instrument status is shown on the left of the first line of the status display and on the Table and Graph outputs. Each status has a priority assigned to it. If more than one status is in effect, then the status with the highest priority is displayed until the condition is corrected or until the option is turned off.

5.3.2 Alarms

While operating the instrument, any one of three alarm conditions can occur. To accurately identify the source of the alarm, each type of alarm has been given a unique status.

In addition to the status, 2020 also has an audible alarm and a visual alarm LED. To conserve power, the 2020 alternates between these two alarm indicators, rather than operating both concurrently. Different alarms are identified by the frequency at which the 2020 alternates as follows: PEAK alarm-5 times per second; STEL alarm-2.5 times per second; and TWA alarm-1.25 times per second.

The left soft key is used for acknowledging alarms, and is named "Ack." If no alarm exists, then the "Ack" key is not shown. To clear the alarm, press the "Ack" key. Once acknowledged, the alarm indicators are cleared. The alarm status will remain until the alarm condition clears.

2020 updates the peak concentration once every second. Following every update, the peak concentration is compared to the peak alarm level, and if exceeded, an alarm is triggered.

If 15 minute average exceeds the selected STEL, a STEL alarm is generated.

The TWA alarm is generated when the current average of concentration, since the TWA was last cleared, has exceeded the TWA exposure limit.

During calibration, all alarms are disabled. Once the calibration is complete the alarms are re-enabled.

5.4 STEL, TWA, MAX, and PEAK Operation

The 2020's meter display can be configured to show one of four values: STEL, TWA, PEAK, and MAX.

5.4.1 Short-term Exposure Limit (STEL) Mode

The Short-term Exposure Limit (STEL) mode displays the concentration as a 15 minute moving average. 2020 maintains 15 samples, each representing a one-minute averaging interval.

Once every minute, the oldest of the 15 samples is replaced with a new one minute average. This moving average provides a 15-minute average of the last 15 minutes with a one-minute update rate. Since the average is calculated using 15 one-minute averages, the meter display will only update once every minute.

STEL is set to zero each time the instrument is turned on. Since STEL is a 15-minute moving average, there is no need to clear or reset the STEL.

STEL calculations are always being performed by 2020. You can display the results of the calculations by selecting STEL as the Display mode.

5.4.2 Time-weighted Average (TWA) Mode

The TWA accumulator sums concentrations every second until 8 hours of data have been combined. If this value exceeds the TWA alarm setting, a TWA alarm is generated. The TWA is not calculated using a moving average. Once 8 hours of data have been summed, the accumulation stops. In order to reset the TWA accumulator, press the "Clr" key.

This sum will only be complete after 8 hours, so the meter displays the current sum divided by 8 hours. While you are in TWA mode, the time on the status display will show the number of minutes and hours of data that TWA has accumulated. When this reaches 8 hours 2020 stops accumulating data and the TWA is complete.

TWA calculations are always being performed by 2020. You can display the results of the calculations by selecting TWA as the Display mode.

5.4.3 MAX Mode

The MAX mode displays the maximum signal, with the date and time that it was recorded. 2020 continues to log data according to the selected averaging interval, but only the maximum detected concentration is displayed on the meter display.

The right soft key is used to clear the meter when displaying MAX. The "Clr" key only affects the reading that the meter is displaying. For example, if you display the MAX reading, and you press "Clr," only the MAX value is cleared. The TWA is still accumulating in the background.

5.4.4 PEAK Mode

The PEAK mode displays the current detected concentration. The reading is updated once a second. In the background, the 2020 data logger is sampling the concentration and measuring minimum, maximum, and average concentrations for the selected averaging interval. At the end of every interval, one entry is placed in the data logger until the data logger is full. Typical application concerning the use of this instrument is operated in this mode. Operation within the other specialized modes are the responsibility of the SSO.

5.5 Set Functions

Set functions are used to setup 2020. There are three functions which can be set on the 2020: Calibration, Pump and Clock.

5.5.1 Pump

The Pump function is used to control the pump. After selecting Set Pump, 2020 responds by displaying the new pump status.

The detector is also turned off when you turn the pump off. This prevents the detector from being damaged when there is no sample flowing through the detector.

When the pump and the detector are off, the meter display will be blank. Turn the pump and detector off when concentration measurements are not necessary, and 2020 will only be used for reviewing data or generating reports. By operating the instrument with the pump and detector off when you do not need them, you will conserve the lives of the battery and ultraviolet (UV) lamp.

1. Press the ENTER key. The top line of the status display changes to "Select?". The bottom line displays 3 soft key names: "Set," "Log," and "Disp."

2. Press the soft key below "Set."

3. The names of the soft keys change to reflect the Set options. The display now shows 3 devices which can be set: "Clock," "Pump," and "Cal." Press the "Pump" key.

4. The 2020 turns the pump off. If the pump was off, pressing "Pump" will turn the pump on.

5. A message will be displayed to show you the status of the pump. 2020 reverts back to the previous menu after a few seconds

6. To return to the default display, press the ENTER key.

5.5.2 Clock

The Clock function is used to set both the current date and time.

1. Press the ENTER key.

2. Press the "Set" key.

3. When the names of the soft keys change, press the "Clock" key.

The up and down arrows are used to change the character underlined by the cursor. The right arrow is used to advance the cursor to the next character on the right. When the cursor is advanced past the right-most character, it wraps around to the first character again.

Formatting characters, such as the colon (:) in the time and the slash (/) in the date are skipped when advancing the cursor.

4. Use the "arrow keys" to enter the correct time. The time is formatted as Hour:Minute:Second.

5. Press the ENTER key to confirm the time and move to the date option.

6. When setting the date, the 2020 prompts you for the current date formatted as Year/Month/Day. Use the "arrow keys" to enter the correct date.

7. Press the ENTER key to confirm the date and return to the Set options. You can wait for the display to timeout or press ENTER to return to the default display.

5.5.3 Calibration (Cal)

Cal allows you to setup and calibrate 2020. You have three options under the Cal function: "Zero," Span," and "Mem."

A calibration memory consists of a name, a response factor, and PEAK, TWA, and STEL alarm levels.

The "Zero" and "Span" keys are covered in detail in the manufacturer's operations manual for the instrument.

To edit the calibration memory, select "Mem" and then "Chng." The 2020 prompts you with two new soft keys: "User" and "Lib."

5.5.4 Library (Lib)

Library selections simplify Cal Memory programming, and provide standard response factors for approximately 70 applications. "Lib" allows you to select an entry from a pre-programmed library. The name, response factor, and three alarm levels are all set from the library. To select a library entry to program the selected Cal Memory:

1. Select "Set," "Cal," "Mem," "Chng," and "Lib."

2. Use the "Next" and "Prev" keys to scroll through the list. See the manufacturer's manual Appendix 8.7 for a list of the library entries.

5.6 Preparing for Field Operation of the Photovac 2020

Turning 2020 On

1. Turn 2020 on by pressing the ON/OFF key.

2. 2020 will display the software version number. Wait for the 2020 to proceed to the default display.

3. Allow 10 minutes for the instrument to warm up and stabilize.

4. Press the Enter Key. The default display will provide 3 soft key selection "Set," "Log," and "Display."

5. Press "Set." From this option 3 other soft key selections will be offered: "Pump," "Clock," and "Cal."

6. Press "Cal." This will begin the calibration sequence. The first selection is to Zero the instrument.

7. Press Enter, zeroing will begin. (Note: When employing zero gas attach and activate zero gas supply at this time.)

8. The next selection offered will be Span. Press Enter at which time the concentration will be requested. The isobutylene calibration gas employed under general service will be marked on the side of the container. Use the soft keys to toggle into position and to log the concentration. Once the concentration is logged press "Enter." The direction or status display will indicate spanning. At this time hook up the span gas with a regulator to the Photovac 2020, and open it to supply enough flow to elevate the flow rate indicator to the green indicator line (1/8" from the rest position).

9. Once spanning is complete, the alarms which have been disabled during calibration will activate indicating that calibration is complete.

10. Document this calibration procedure using a Document of Calibration form as illustrated in Figure 5-1.

This instrument is ready for general purpose application.

Calibration is to be performed daily or prior to each use in accordance with Section 5.6 of this SOP.

5.7 Maintenance and Calibration Schedule

Function	Frequency
Routine Calibration	Prior to each use
Factory Inspection and Calibration	Once a year, or when malfunctioning
Wipe Down the Outer Casing of the Unit	After each use
Clean UV Light Source	Every 24 hours of operation
Sample Inlet Filter	Change on a weekly basis or as required by level of use
Battery charging	After each use
Clean ionization chamber	Monthly

FIGURE 5-1

DOCUMENTATION OF FIELD CALIBRATION

SITE NAME: _____ PROJECT NO.: _____

Date of Calibration	Instrument Name and Model	B & R Environmental Instrument I.D. Number	Person Performing Calibration	Instrument Settings/Readings		Calibration Standard (Lot Number)	Remarks/ Comments
				Pre-Calibration Setting	Post-Calibration Reading		

5.7.1 Cleaning the UV Light Source Window

1. Turn the FUNCTION switch to the OFF position. Use 2020 multi-tool and remove lamp housing cover.

2. Tilt the lamp housing with one hand over the opening, slide the lamp out of the housing.

3. The lamp window may now be cleaned with any of the following compounds using lens paper:

   a. 11.7 eV Lamp - Dry Aluminum Oxide Powder (3.0 micron powder)
   b. HPLC Grade Methanol - All other lamps

4. Following cleaning, reassemble by first sliding the lamp back into the lamp housing. Replace o-ring as necessary, reinstall lamp housing cover, tighten using 2020 multi-tool. (Do not over tighten).

5. Recalibrate as per Section 5.6.

5.7.2 Cleaning the Ionization Chamber

1. Turn the FUNCTION switch to the OFF position and remove the lamp housing cover and lamp as per Section 5.7.1.

2. Using a gentle jet of compressed air, gently blow out any dust or dirt.

3. Following cleaning, reassemble by first sliding the lamp back into the lamp housing. Replace o-ring as necessary, reinstall lamp housing cover, tighten using 2020 multi-tool. (Do not over tighten).

4. Recalibrate as per Section 5.6.

5.8 Instrument Advantages

The Photovac 2020 is easy to use in comparison to many other types of monitoring instrumentation. Its detection limit range is in the low parts-per-million range. Response time rapidly reaches 90 percent scale of the indicated concentration (less than 3 seconds for benzene). This instrument's automated performance covers multiple monitoring functions simultaneously, incorporating data logging capabilities.

5.9 Limitations of the Photovac 2020 Photoionization Monitor

- Since the 2020 is a nonspecific total gas/vapor detector, it cannot be used to identify unknown chemicals; it can only quantitate them in relationship to a calibration standard (relative response ratio).

- For appropriate application of the 2020, ionization potentials of suspected contaminants must be known.

- Because the types of compounds that the 2020 can potentially detect are only a fraction of the chemicals possibly present at a hazardous waste site or incident, a background or zero reading on this instrument does not necessarily signify the absence of air contaminants.

- The 2020 instrument can monitor only certain vapors and gases in air. Many nonvolatile liquids, toxic solids, particulates, and other toxic gases and vapors cannot be detected.

- PID's are generally not specific. Their response to different compounds is relative to the calibration gas used. This is referred to as relative response ratio. Instrument readings may be higher or lower than the true concentration. This can be an especially serious problem when monitoring for total contaminant concentrations if several different compounds are being detected at once.

- The 2020 is a small, portable instrument which cannot be expected to yield results as accurately as laboratory instruments.

5.9.1 Variables Affecting Monitoring Data

Monitoring hazardous waste site environment can pose a significant challenge in assessing airborne concentrations and the potential threats to site personnel. Several variables may influence both dispersion and the instrument's ability to detect actual concentrations. Some of the variables which may impact these conditions are as follows:

- Temperature - changes in temperature or pressure will influence volatization, and effect airborne concentrations. Additionally, an increase or decrease in temperature ranges may have an adverse effect on the instrument's ability to detect airborne concentrations.

- Humidity - excessive levels of humidity may interfere with the accuracy of monitoring results.

- Rainfall - through increased barometric pressure and water may influence dispersion pathways effecting airborne emissions.

- Electromagnetic interference - high voltage sources, generators, other electrical equipment may interfere with the operation and accuracy of direct-reading monitoring instruments.

6.0 TROUBLESHOOTING

6.1 Fault Messages

When the "Fault" status is displayed, 2020's operation is comprised.

Fault 1: Signal from zero gas is too high.

Cause: If another fault occurred while 2020 was setting its zero point, then this fault is displayed.

Action: Ensure no faults are occurring and calibrate 2020 again.

Cause: Contamination of sample line, sample line, sample probe or fittings before the detector.

Action: Clean or replace the sample line, sample probe or the inlet filter.

Cause: Span gas and zero air are mixed up.

Action: Ensure clean air is used to zero 2020. If you are using gas bags, mark the calibration and zero gas bags clearly.

Cause: Ambient air is contaminated.

Action: If you are unsure about the quality of ambient air, use a supply of commercial zero grade air to zero 2020.

Fault 2: Signal from span gas is too small.

Cause: Operator may have confused the span gas and zero air.

Action: Ensure clean air is used to zero 2020. If you are using gas bags, mark the calibration and zero gas bags clearly.

Action: Ensure the span gas is of a reliable concentration.

Cause: UV lamp window is dirty.

Note: Do not remove the detector lamp in a hazardous location.

Action: Clean the UV lamp window.

Cause: UV lamp is failing.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: Install a new UV lamp.

Cause: Incompatible application

Action: The concentration and sample gas are incompatible for use with 2020.

Fault 3: UV lamp fault. UV lamp has not started.

Cause: UV lamp has not started immediately

Action: This fault may be seen momentarily when 2020 is first turned on. Allow 30 to 60 seconds for the UV lamp to start and the fault to clear.

Cause: UV lamp serial number label is blocking the photocell.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the label is blocking the photocell. Rotate the lamp approximately 90 degree and then try to start 2020 again. If the fault persists, replace the lamp.

Cause: UV lamp not installed.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: Install a UV lamp.

Cause: UV lamp has failed.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: Install a new UV lamp.

Cause: Electronic problem.

Action: If a new UV lamp still generates this fault, then contact the Photovac Service Department.

Fault 4: Pump current too low or too high.

Cause: If the pump sounds labored, then the pump is operating beyond normal operating parameters.

Action: Check for an obstruction in the sample line. Make sure sample line, sample probe or inlet filter are not plugged.

Note: Do not replace the inlet filter in a hazardous location.

Action: Replace the inlet filter.

Action: Ensure the sample outlet, located on the underside of 2020, is not obstructed.

Cause: UV lamp is too wide, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the Equipment Manager.

Cause: 2020 has been exposed to a solvent that can pass through the inlet filter and liquid has been aspirated.

Action: Contact the Equipment Manager.

Cause: The pump has failed.

Action: Contact the Equipment Manager.

6.2 Specific Problems

Problem: Very low or no instrument response detected, yet compounds are known to be present.

Cause: 2020 has not been calibrated properly.

Action: Ensure the calibration gas is of a reliable concentration and then calibrate the instrument as outlined in Section 3.2 or 3.3 of the User's Manual.

After the instrument has been calibrated, sample the bag of calibration gas. A reading equivalent to the calibration gas should be displayed. If not, contact the Equipment Manager.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Disconnect the battery charger before calibrating 2020.

Cause: Calibration Memories have not been programmed correctly.

Action: Program all the calibration memories you require for your application. You must use the correct calibration gas and concentration for each Cal Memory.

Cause: Response factor has been set to zero.

Action: Enter the correct response factor. Refer to Appendix 8.6 for a list of response factors. If the compound is not listed in Appendix 8.6 or you are measuring gas mixtures, then enter a value of 1.0. See User's Manual.

Cause: You are not using the correct Cal Memory.

Action: Select the correct Cal Memory for your application.

Note: It does not matter which Cal Memory is selected or which response factor is entered. 2020's response is not specific to any one compound. The reading displayed represents the total concentration of all ionizable compounds in the sample.

Cause: Detector is leaking. A decrease in sensitivity may be due to a leak in the detector.

Note: Do not remove or replace the detection lamp in a hazardous location.

Action: Ensure the UV lamp has been installed correctly.

Action: Ensure the lamp cover has been tightened down. Do not overtighten the cover.

Action: Ensure the o-ring seal on the lamp cover is positioned correctly..

Cause: UV lamp is too long, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too long for the lampholder. Replace the lamp and contact the Equipment Manager

Cause: UV lamp is too wide, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the Equipment Manager.

Cause: Sampling environment is extremely humid.

Action: Water vapor is not ionized by the PID, but it does scatter and absorb the light and results in a lower reading.

The 2020 detector has been designed to operate under high humidity conditions. Under extreme conditions you may notice decreased response due to humidity.

Cause: UV lamp is failing.

Note: Do not remove or replace the detector lamp in a hazardous location.

Cause: High concentration of non-ionizable compounds.

Action: Chemical compounds, such as methane, with IPs greater than the 10.6 eV scatter and absorb the UV light. Sensitivity may be decreased significantly.

Application with high backgrounds of such materials, may be incompatible with 2020. Contact the Photovac Applications Group for more information.

Problem: Erroneously high readings.

Cause: Sampling environment is extremely humid.

Action: Water vapor may contain mineral salts which carry a charge. The water vapor becomes an electrolytic solution which becomes ionized when it enters the detector.

Atmospheric water in areas around the sea or stagnant water may produce a response in the absence of contaminants. The same effect may be seen when conducting ground water investigations in areas where the water is hard because it contains a significant concentration of minerals.

Cause: 2020 has not been calibrated properly

Action: Ensure the calibration gas is of a reliable concentration and then calibrate the instrument as outlined in Section 5.6.

After the instrument has been calibrated, sample the bag of calibration gas. A reading equivalent to the calibration gas should be displayed. If not contact the Equipment Manager.

Cause: Cal Memories have not been programmed correctly.

Action: Program all the Cal Memories you require for your application. You must use the correct calibration gas and concentration for each Cal Memory. See Section 3.4, of the User's Manual.

Cause: You are not using the correct Cal Memory.

Action: Select the correct Cal Memory for your application. See Section 3.2.2 or 3.3.2, of the User's Manual.

Note: It does not matter which Cal Memory is selected or which response factor is entered. 2020's response is not specific to any one compound. The reading displayed represents the total concentration of all ionizable compounds in the sample.

Cause: Detector has been short circuited by foreign matter in the detector cell.

Note: Do not service 2020 in a hazardous location.

Action: Do not touch the wire grid inside the detector cell. Use a gentle jet of compressed air to remove any dust in the detector cell.

Warning: Do not insert any object, other than the UV lamp, into the lampholder.

Cause: There is an undetermined problem.

Action: Contact the Equipment Manager.

Problem: Date and time settings are not retained.

Cause: The battery pack has been removed before 2020 was turned off.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Replace the battery pack and reset the time and date. Ensure 2020 has been turned off before removing the battery pack.

Cause: 2020 has not been used for 3 months or more and the internal battery (not the external battery pack) has discharged.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Connect 2020 to the AC adapter and turn 2020 on. Turn the pump off. While 2020 is running the internal battery is charging. Leave the instrument running for approximately 24 hours.

Problem: Instrument status shows "Over."

Cause: High concentrations of gases and vapors will cause a rapid change in signal level. The detector and associated electronics may become temporarily saturated.

Action: Wait a few seconds for the status to return to normal. PIDs are designed to detect relatively low concentrations of gases and vapors. Exposure to very high concentrations may result in a very high or maximum response.

Cause: The detector has become saturated.

Action: Move 2020 to a location where it can sample clean air. Sample clean air until the reading stabilizes around 0.

Cause: Detector has been short circuited by foreign matter in the detector cell.

Note: Do not service 2020 in a hazardous location.

Action: Do not touch the wire grid inside the detector cell. Use a gentle jet of compressed air to remove any dust or dirt in the detector cell.

Warning: Do not insert any object, other than the UV lamp, into the lampholder.

Cause: There is an undetermined problem.

Action: Contact the Equipment Manager.

Problem: Display is blank.

Cause: Battery pack is critically low.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Replace the battery pack or connect 2020 to the AC adapter.

Cause: The battery pack is not connected to the instrument correctly.

Action: Ensure the battery pack connector is securely attached to the connector on 2020.

Cause: There is an undetermined problem

Action: Reset 2020. You must leave the instrument on while you disconnect the battery pack. This will reset the instrument. Reconnect the battery pack and close the battery hatch. Turn on 2020, set the time and date and program all the calibration memories that you are using.

Action: Contact the Equipment Manager.

Problem: Sample flow rate is less than 300 ml/min.

Cause: Inlet filter is plugged.

Note: Do not replace the inlet filter in a hazardous location.

Action: Replace inlet filter.

Cause: Inlet filter has not been installed properly.

Action: Ensure that the inlet filter has been installed correctly.

Cause: UV lamp is too long, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too long for the lampholder. Replace the lamp and contact the Equipment Manager.

Cause: UV lamp is too wide, causing flow to be restricted.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the Equipment Manager.

Cause: 2020 has been exposed to a solvent that can pass through the inlet filter and liquid has been aspirated.

Action: Contact the Equipment Manager.

Cause: Sample outlet is obstructed.

Action: Ensure the sample outlet is? not obstructed in any way.

Cause: Pump has been damaged.

Action: Contact the Equipment Manager.

Problem: Liquid has been aspirated.

Cause: 2020 has been exposed to a solvent that can pass through the inlet filter.

Action: Contact the Equipment Manager.

Problem: Corrosive gases and vapors have been sampled.

Cause: 2020 has been exposed to corrosive gases and vapors.

Action: Corrosive gases and vapors can affect the electrodes within the detector as well as the lamp window Prolonged exposure to corrosive materials may result in permanent fogging or etching of the window. If 2020 is exposed to corrosive material. contact the Equipment Manager.

7.0 SHIPPING

The Photovac may be shipped as cargo or carried on as luggage providing there is no calibration gas cylinder accompanying the kit. When shipping or transporting the calibration gas, a Hazardous Airbill including the information as stipulated in Figure 7-1 will be entered.

8.0 REFERENCES

Photovac 2020 Photoionization Monitor User's Manual, 1995.

FIGURE 7-1

EXAMPLE OF A HAZARDOUS AIRBILL FOR ISOBUTYLENE

SHIPPER'S DECLARATION FOR DANGEROUS GOODS (Provide at least two copies to the airline)

Shipper BROWN & ROOT ENVIRONMENTAL
SPRING RUN ROAD EXTENSION
CORAOPOLIS, PA 15108

Air Waybill No.
Page of Pages
Shipper's Declaration Number (optional)

Consignee

FedEx. Federal Express

Two completed and signed copies of this Declaration must be handed to the operator.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable)

PASSENGER AND CARGO AIRCRAFT	~~CARGO AIRCRAFT ONLY~~

Airport of Departure

Airport of Destination:

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder, or an IATA cargo agent.

Shipment type: (delete non-applicable)

NON-RADIOACTIVE	~~RADIOACTIVE~~

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification					Quantity and type of packaging	Packing Inst.	Authorization
Proper Shipping Name	Class or Division	UN or ID No.	Packing Group	Subsidiary Risk			
COMPRESSED GAS N.O.S. (AIR, ISOBUTYLENE)	2.2	UN 1956			1 FIBER BOARD box x KG	200	

Additional Handling Information

Emergency Telephone Number (412) 262-4583

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable International and National Governmental Regulations.

Name/Title of Signatory
TOM PATTON _ EQUIPMENT MANAGER
Place and Date
PITTSBURGH, PA
Signature
(see warning above)

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

FedEx M-1421 10/88 LOGOS 2011730848

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1.0 PURPOSE

To establish procedures for the use, calibration, maintenance, troubleshooting, and shipment of the Photovac MicroFID handheld flame ionization detector.

2.0 SCOPE

Applies to all Brown & Root Environmental personnel who operate the MicroFID instrument during the performance of their work.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Health and Safety Manager (HSM) - The HSM shall ensure that the user has been appropriately trained and certified in the usage of the Photovac 2020 instrument.

Equipment Manager - The Equipment Manager shall ensure that all air monitoring instrumentation slated for field activities has been operationally checked out, fully charged, and calibrated prior to issuance for field service. Maintenance deficiencies identified by the Equipment Manager will require those instruments to be pulled from service until repairs can be facilitated.

Field Operations Leader (FOL)/Field Team Leader (FTL) - The FOL/FTL shall ensure all field team members using monitoring instruments as part of their assigned duties are adequately trained in their proper operation and limitations. The FOL/FTL shall ensure that the air monitoring instruments are employed as directed by site guidance documents (i.e., Work Plan, Health and Safety Plan, etc.). Additionally, the FOL/FTL shall ensure that the appropriate documentation and recordkeeping requirements are fulfilled including Documentation of Calibration and Direct Reading Instrument Response Data Sheets for air monitoring activities.

Health and Safety Officer (HSO) - The HSO is responsible for determining air monitoring requirements for the site activities, and providing direction for air monitoring during specific site activities. This identification of types of air monitoring and direction for use are indicated within the Site-Specific Health and Safety Plan (HASP).

Site Safety Officer (SSO) - The SSO shall ensure the instruments identified are employed in the manner directed by the HSO and action levels employed as contingencies marks for the application of engineering controls, personal protective equipment (PPE) use, and administrative controls are employed as directed. Additionally, he/she shall ensure the instruments are properly maintained and calibrated prior to use in the field. The SSO during specific air monitoring applications including STEL and TWA mode measurements will be responsible for operation and application of this specialty air monitoring employment duty.

5.0 PROCEDURES

5.1 Principles of Operation

The MicroFID is a flame ionization detector used for the measurement of combustible organic compounds in air at parts per million levels. Permanent air gases (argon, carbon dioxide, nitrogen, oxygen, water vapor, etc.) are not ionized by the flame.

When the MicroFID is turned on, the display prompts you to turn on the hydrogen. The internal pump draws air in through MicroFID's inlet. This sample air provides the oxygen necessary for combustion in the hydrogen-fueled flame. When the proper ratio of hydrogen to air is present in the combustion chamber, the flame is automatically started with a glow plug. A thermocouple is used to monitor the status of the flame. When the sample passes through the flame the combustible organic compounds in the sample will be ionized. After the compounds have been ionized, they are subjected to a continuous electric field between the repeller electrode at the jet and the collector electrode. The ions in the electric field generate a current which is proportional to the concentration of the ionized molecules in the ionization chamber. An electrometer circuit converts the current to a voltage that is then fed to the microprocessor which interprets the current in units of ppm. After the sample passes through the flame and has become ionized, it is vented from the detector through a flame arrestor. The flame arrestor prevents the flame from igniting any flammable gases present in the working atmosphere.

MicroFID is strictly an organic compound detector. It does not respond to inorganic compounds. MicroFID's sensitivity is highly dependent on chemical structure and bonding characteristics. The combustion efficiency of a compound determines its sensitivity. Simple saturated hydrocarbons (methane, ethane, etc.) posses high combustion efficiencies and are among the compounds that produce the highest MicroFID response. Organic fuels (acetylene, refined petroleum products), burn easily and are also extremely well detected.

The presence of substituted functional groups (amino, hydroxyl, halogens) on a simple hydrocarbon reduces its combustion efficiency and the MicroFID's sensitivity to the compound. For example, methanol and chloromethane are detectable with MicroFID, but not at the same sensitivity as methane. The number of carbon atoms can also affect the instrument's sensitivity due to substitution. For example, MicroFID is more sensitive to n-butanol than it is to methanol. For additional information regarding response factors of the MicroFID, consult Appendix 8.5 of the User's Manual.

Beginning Operation

You can operate MicroFID without the flame to print or review logged data. In this way you can conserve the hydrogen fuel.

If you choose to start the flame, MicroFID will attempt to ignite the flame once you have turned on the flow of hydrogen gas. If the MicroFID has not been used for a while, it is possible that the gas supply lines are filled with air. If the flame cannot be started, MicroFID will begin a 30 second purge cycle. During the purge cycle it will flush the gas supply lines with hydrogen. After the purge cycle, it will attempt to light the flame again. If it fails again, another purge cycle will be performed and MicroFID will try a third time to ignite the flame. The following steps summarize proper start-up procedures.

1. Turn the instrument on by pressing the front of the On/Off switch. When the instrument is powered up, the version number and creation date of the instrument software are displayed. Press ENTER.

2. You will be prompted to start the flame. If you do not want to start the flame, use the ARROW keys to select "No Flame Needed" and press ENTER. To start the flame, use the ARROW keys to select Start Flame and press ENTER.

3. If you selected "Start Flame," MicroFID will prompt you to turn on the hydrogen. Turn the shut-off valve counterclockwise to start the flow of hydrogen and press ENTER.

4. The pump will start and MicroFID will then ignite the flame. You will hear a small pop when the flame has been ignited. Once the flame has been started the message "Detector flame has been started OK" will be displayed followed by the default display.

The default display provides the following information: instrument status, current detected concentration, event name (if the datalogger is on), time, and date. If an event name is longer than three characters, the bottom line of the display will scroll through the information.

The instrument status appears at the left of the upper line of the display and on the Print and Graph outputs. Each status has a priority assigned to it. If more than one status is in effect, then the status with the highest priority is displayed until the condition is corrected or until the option is turned off.

5.2 Calibration

The calibration (CAL) key is used to calibrate MicroFID. Before beginning calibration, ensure that you have a reliable source of both zero air and calibration gas. To document calibration efforts, field personnel will record information on Figure 1-1. A brief description of the functions under the CAL key are as follows:

1. When you press the CAL key you will first be prompted to select a Cal Memory. Each Cal Memory stores a unique zero point, sensitivity setting, response factor and alarm level.

2. You will then be prompted to enter a response factor. Refer to Appendix 8.5 of the User's Manual for a list of response factors. If the compound is not in that reference, or if you are measuring gas mixtures, enter a value of 1.00. The concentration detected by MicroFID will be multiplied by the response factor before it is displayed and logged.

3. Next select Low Range or High Range operation. Use Low Range if you are sampling concentrations between 0.5 and 2000 ppm (methane equivalents). Use High Range if you are sampling concentrations between 10 and 50,000 ppm (methane equivalents).

4. You will now be prompted to connect a supply of zero air. You can use ambient air or, for best results, use a clean sampling bag filled with zero grade air. In most cases, ambient air will be used provided calibration is performed in an area in which airborne concentrations of contaminants are not present. If using ambient air, press <ENTER> to being zeroing.

5. If you are using a charcoal filter to clean ambient air, connect the filter by loading the Teflon ferrules into the nut (the ferrules and the nut are supplied with the filter). Connect the nut to MicroFID's inlet. Do not tighten the nut. Remove the charcoal filter from its plastic bag and insert it into the nut. Finger tighten the nut onto the inlet. If the filter is not secure, ensure you have inserted the tube far enough into the nut. Do not over-tighten the fitting. Press <ENTER> and the MicroFID will set its zero point. NOTE: The charcoal filter does not filter methane or ethane. If these compounds are present, use a gas bag with a supply of commercial zero air.

6. If you are using a gas bag with zero air, connect the gas bag to the inlet. Open the bag and press <ENTER>. MicroFID will set its zero point.

7. After MicroFID has set its zero point, you can then enter the concentration of the calibration gas (span gas), and then connect the gas bag adapter to the inlet. Open the bag and press <ENTER>. MicroFID sets its sensitivity. Note: You must have a supply of calibration gas ready before calibrating MicroFID. When calibrating MicroFID, ensure the instrument is level. If MicroFID is tilted from side to side, gravity will affect the flame height and cause erroneous readings.

FIGURE 1-1

DOCUMENTATION OF FIELD CALIBRATION

SITE NAME: _____ PROJECT NO.: _____

Date of Calibration	Instrument Name and Model	B & R Environmental Instrument I.D. Number	Person Performing Calibration	Instrument Settings/Readings		Calibration Standard (Lot Number)	Remarks/ Comments
				Pre-Calibration	Post-Calibration		

8. When MicroFID's display reverts to normal, it is calibrated and ready to use. Remove the span gas bag from the inlet.

9. Press the ALARM key and enter the alarm level for the selected CAL memory.

5.3 Routine Maintenance

5.3.1 Battery Charging

A fully charged battery will power the MicroFID for approximately 15 hours. If the instrument is to be used for more than 15 hours, carry a spare battery pack. Battery life is reduced if the instrument is turned off and then on again repeatedly.

When the instrument status displays "LoBat," the battery pack requires changing. When the "LoBat" status is displayed, you have a few minutes of operation left. MicroFID will turn itself off before the battery pack becomes critically low.

To remove the battery pack:

1. Stop the flow of hydrogen gas by turning the hydrogen shut-off valve fully clockwise. Turn the instrument off by pressing the On/Off switch twice.

2. Use the MicroFID multi-tool to loosen the two captive screws in the bottom of the battery pack.

3. A retainer at the rear of the instrument helps secure the battery pack to the instrument. Free the battery pack from the instrument

4. Connect the charged battery pack to the retainer at the rear of the instrument.

5. Retighten the two captive screws and the bottom of the battery pack.

To charge the battery pack:

1. Ensure the correct plug is installed on the line cord of the battery charger.

2. Plug the charger into the jack located on the front of the battery pack.

3. Plug the charger into an AC outlet. The LED. on the battery pack indicates the charge state. Red indicates the battery is being charged. Green indicates the battery is fully charged and ready for use. It is normal for a fully charged battery to indicate it is charging (red light) when first plugged in. The LED will turn green as the battery charges

4. When the battery pack is charged remove the charger, first from the wall outlet then from the battery pack.

Charging a fully discharged battery pack will take approximately 8 hours. Leaving the charger connected to a charged battery pack will not harm the battery or the charger in any way. If a battery pack is to be left indefinitely, leave it connected to the charger so that it will be fully charged and ready for operation.

5.3.2 Emptying the Hydrogen Cylinder

When you transport the MicroFID, you should empty the internal hydrogen cylinder and then refill it when you arrive at your destination.

To empty the cylinder:

1. Turn the MicroFID off and open the hydrogen shut-off valve.
2. Remove the battery pack as described above.
3. Locate the purge outlet. It is located on the underside of the instrument.
4. Use the MicroFID multi-tool to turn the screws counterclockwise. Loosen the screw but do not remove it.
5. Leave the instrument so that the purge outlet is facing up. If the purge outlet is facing down, hydrogen will vent into MicroFID's case.
6. If the cylinder is full, it will take approximately 15 minutes to empty.
7. Watch the Contents gauge. When the cylinder is empty, close the purge outlet. Use the MicroFID multi-tool to turn the screw clockwise
8. Replace the battery pack as discussed above

5.3.3 Replacing the Sample Inlet Filter

MicroFID is equipped with a combined dust and water filter to reduce detector contamination. As the filter collects dust, MicroFID's inlet flow rate and sensitivity decrease. The filter will not allow water to pass through, but the filter will not stop all solvents.

Replace the filter on a weekly basis, or more frequently if MicroFID is used in a dusty or wet environment. You must replace the filter if MicroFID has been exposed to liquid water. The pump will sound labored when the filter requires replacement.

1. Turn off the instrument and unscrew the filter housing from the detector housing. Be careful not to lose the o-ring seal.
2. Remove the Teflon/Polypropylene filter and install the new filter. Place the filter in the filter housing with the Teflon side facing down into the filter housing and the mesh side facing the MicroFID. Handle the filter disk only by the edges The mesh may be damaged or contaminated by excessive handling. Use forceps if possible.
3. Replace the filter housing.
4. Calibrate the CAL Memories that you are using before continuing operation.

5.4 Troubleshooting

This section provides guidance for troubleshooting the MicroFID. If problems are not corrected through these troubleshooting methods, contact the Photovac Service Department.

5.4.1 MicroFID Fault Messages

When the "Check" status is displayed, MicroFID's operation is compromised. Press the <TUTOR> key for a two-line description of the fault. One exception is the flame out fault. When a flame out fault occurs, the instrument status changes to "NoFlm."

Fault: **Detector flame has gone out.**

Cause: The hydrogen gas has run out.

Action: Ensure the shut-off valve is open. Check the hydrogen contents gauge on the side of the instrument and refill the hydrogen cylinder if necessary. Ensure the cylinder purge outlet has been closed.

Cause: Oxygen supply is deficient.

Action: Ensure there is an adequate supply of oxygen. If you are sampling very high concentrations it is possible you are sampling above the flame out concentration. The flame out concentration for methane is approximately 52,000 ppm (5.2 percent methane in air).

A minimum of 17 percent oxygen is required to start the hydrogen flame. The oxygen is supplied from the sample as it is drawn in by the pump. A minimum of 10 percent oxygen is required to maintain the hydrogen flame.

Flame out also may occur when sampling enclosed or confined spaces where vapors and gases cannot escape. Watch for indications of increased flame height such as erratic readings or sudden high concentrations followed by a flame out fault.

If you will be using the MicroFID in a highly contaminated area where it is possible that the oxygen content is below 10 percent, watch for indication of reduced flame height such as lowered detection limits or a flame out fault.

Cause: High concentrations of flammable gases (gases within their flammable range) are present. High concentrations of flammable gases can act as an additional fuel source. When this happens, the flame height may increase beyond the confines of the combustion chamber. The hydrogen supply will then be cut-off and the flame will go out.

Action: Move to a location where there is an adequate supply of air and restart the flame. See the information above. Watch for indications of increased flame height such as erratic readings or sudden height concentrations followed by a flame out fault.

Cause: Exhaust port is blocked.

Action: At low temperatures, water vapor, a by-product of the hydrogen flame, may condense at the exhaust port. At sub-zero temperatures the water will freeze and obstruct the exhaust port. If the exhaust port becomes obstructed, pump operation will be inhibited. Flame out may also result. Operate the MicroFID within the operating temperature range 41 to 105 degrees Fahrenheit. In the event that the flame arrestor becomes clogged, contact the Photovac Service Department.

Cause: Sample line is blocked.

Action: Ensure the sample line is not obstructed in any way. If you are using the long sample probe, ensure flow is maintained through the entire length of tubing.

Cause: Inlet filter is plugged.

Action: Replace the inlet filter.

Fault: **Signal form zero gas is too high.**

Cause: Contamination of sample line or fittings before the detector.

Action: Clean or replace the sample line of the inlet filter.

Cause: Span gas is used instead of zero gas.

Action: Ensure clean gas is used to zero the MicroFID. Mark the calibration and zero gas bags clearly.

Cause: Ambient air is contaminated.

Action: If you are unsure about the quality of the ambient air, use a charcoal filter or a supply of commercial zero grade air.

Cause: Hydrogen supply is contaminated.

Action: Hydrogen may react with the carbon element of the steel tank to produce methane. This will only occur if the cylinder is in poor condition and if the hydrogen has a high moisture content. Replace the hydrogen tank. Empty and refill the MicroFID internal cylinder with fresh hydrogen.

Fault: **Signal form the span gas is too small**

Cause: Span gas and zero air are switched.

Action: Ensure calibration is used to calibrate MicroFID. Mark the calibration and zero gas bags clearly. Ensure the span gas is of a reliable concentration.

Fault: **Detector field voltage is low.**

Cause: Internal fault in electronics.

Action: Contact the Photovac Service Department.

Problem: **No instrument response detected, yet compounds are known to be present.**

Cause: MicroFID has not been calibrated properly.

Action: Ensure calibration gas is of a reliable concentration and then calibrate the instrument. After the instrument has been calibrated, sample the bag of calibration gas. A reading equivalent to the calibration gas should be displayed. If not, contact the Photovac Service Department.

Action: When calibrating the MicroFID, ensure the instrument is level. If the MicroFID is tilted side to side, gravity will affect the flame height and cause erroneous readings. If the sampling location is difficult to reach without tilting the instrument, use the long sample probe.

Cause: Background contamination from the hydrogen.

Action: It is possible that the hydrogen has become contaminated and is contributing a high background signal. If the hydrogen supply tank is more than 6 months old it should be replaced with a new cylinder. When ordering hydrogen, specify ultra-high purity (99.999 percent pure). Empty the MicroFID hydrogen cylinder and then refill with hydrogen from the new cylinder.

Problem: **Date and time settings are not retained.**

Cause: MicroFID has not been used for 3 months or more and the internal battery (not the external battery pack) has been discharged.

Action: Turn MicroFID on and allow it to run until a "LoBat" status appears. This will take approximately 15 hours. Remove the battery pack and recharge it overnight. Repeat this procedure for 3 or 4 days. While MicroFID is running the internal battery is charging.

Problem: **Cannot bill the internal hydrogen cylinder to 1800 psig.**

Cause: Supply tank has less than 1800 psig of pressure. You can only fill the internal cylinder to a pressure of less than or equal to the tank pressure.

Action: Fill the internal cylinder to the pressure of the tank or replace the tank with a full one.

Cause: The hydrogen purge outlet is open

Action: Close the outlet and fill the cylinder.

Cause: There is a problem with the refill adapter.

Action: Contact the Photovac Service Department

Problem: Instrument status shows "Over."

Cause: Rapid change in signal level. The detector electronics have been momentarily saturated.

Action: Wait a few seconds for the status to return to "Ready."

Cause: The detector has become saturated.

Action: Move the MicroFID to a location where it can sample clean air. Sample zero air until the reading stabilizes around "0." If you were using Low Range, switch to High Range. Calibrate the CAL Memory you were using when the "Over" status appeared.

Problem: Display contrast bars are on or display is blank.

Cause: Battery pack is critically low.

Action: Recharge the battery pack or connect the MicroFID to the battery charger.

Cause: The battery pack is not connected to the instrument properly.

Action: Ensure the battery pack has been aligned correctly. Ensure the battery pack is secured by the retainer at the rear of the instrument.

Problem: Sample flow rate varies from 600 ml/min. +/-10 percent.

Cause: Inlet filter has not been installed.

Action: Install an inlet filter.

Cause: Inlet filter has not been tightened onto the detector cap.

Action: Finger-tighten the filter cap

Cause: Inlet filter is plugged.

Action: Replace the inlet filter

Cause: Pump has been damaged.

Action: Contact the Photovac Service Department

Cause: Exhaust port is blocked.

Action: At low temperatures, water vapor (a by-product of the hydrogen flame) may condense at the exhaust port. At sub-zero temperatures the water will freeze and obstruct the exhaust port. If the exhaust port becomes obstructed, pump operation will be inhibited. Flame out may also result. Operate the MicroFID within the operating temperature range 41 to 105 degrees Fahrenheit. In the event that the flame arrestor becomes clogged, contact the Photovac Service Department.

Problem: Flame will not ignite.

Cause: The hydrogen gas has run out.

Action: Ensure the shut-off valve is open. Check the hydrogen contents gauge on the side of the instrument and refill the hydrogen cylinder if necessary. Ensure the hydrogen purge outlet is closed.

Cause: Oxygen supply is deficient.

Action: Ensure there is an adequate supply of oxygen. Do not attempt to ignite the flame in a location where there is greater than 10,000 ppm methane or the equivalent concentration of a flammable gas. Move to a location where there are lower concentrations, start the flame and then begin sampling higher concentrations. If the flame goes out while you are sampling very high concentrations, it is possible you are sampling above the flame out concentration. The flame out concentration of methane is approximately 52,000 ppm (5.2 percent methane in air). A minimum of 17 percent oxygen is required to start the hydrogen flame. Oxygen is supplied from the sample as it is drawn in by the pump. A minimum or 10 percent oxygen is required to maintain the hydrogen flame.

Cause: Exhaust port is blocked.

Action: At low temperatures, water vapor (a by-product of the hydrogen flame) may condense at the exhaust port. At sub-zero temperatures the water will freeze and obstruct the exhaust port. If the exhaust port becomes obstructed, pump operation will be inhibited. Flame out may also result. Operate the MicroFID within the operating temperature range 41 to 105 degrees Fahrenheit. In the event that the flame arrestor becomes clogged, contact the Photovac Service Department.

Cause: Hydrogen supply lines are full of air.

Action: If MicroFID has not been operated for some time, it is possible that the hydrogen supply lines contain air. Fill the hydrogen cylinder and then open the hydrogen shut-off valve. Allow the hydrogen to purge the system for about 5 minutes and then turn MicroFID on and start the flame.

Cause: Hydrogen lines are blocked.

Action: Contact the Photovac Service Department.

Problem: Liquid has been aspirated.

Cause: MicroFID has been exposed to a solvent that can pass through the Teflon/Polypropylene filter.

Action: Contact the Photovac Service Department.

5.5 Transporting MicroFID

When you transport MicroFID, you should empty the internal hydrogen cylinder and then refill it when you arrive at your destination. If you are traveling by passenger aircraft, you must empty the hydrogen cylinder. You cannot transport MicroFID by passenger aircraft with hydrogen in the cylinder.

The MicroFID can be shipped to sites. However, if shipment is to be performed while the cylinder still contains hydrogen, a hazardous materials airbill must be filled out. Examples of various completed forms are provided as Figures 6-1 and 6-2.

6.0 SHIPPING

The Photovac may be shipped as cargo or carried on as luggage providing there is no hydrogen fuel source or calibration gas cylinder accompanying the kit. If shipping or transporting the hydrogen fuel source, a Hazardous Airbill (such as the example in Figure 6-1) must be completed. When shipping or transporting the calibration gas, a separate Hazardous Airbill such as the one illustrated in Figure 6-2 must be prepared.

7.0 REFERENCES

MicroFID Handheld Flame Ionization Detector User's Manual, 1995.

FIGURE 6-1

EXAMPLE OF A HAZARDOUS AIRBILL FOR HYDROGEN

SHIPPER'S DECLARATION FOR DANGEROUS GOODS (Provide at least two copies to the airline)

Shipper
BROWN & ROOT ENVIRONMENTAL
SPRING RUN ROAD EXTENTION
CORAOPOLIS, PA 15108

Air Waybill No.
Page of Pages
Shipper's Reference Number (optional)

Consignee

FedEx. Federal Express

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder, or an IATA cargo agent.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable)

[redacted]	CARGO AIRCRAFT ONLY

Airport of Departure

Airport of Destination:

Shipment type: (delete non-applicable)

NON-RADIOACTIVE	[redacted]

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification							
Proper Shipping Name	Class or Division	UN or ID No.	Packing Group	Subsidiary Risk	Quantity and type of packaging	Packing Inst.	Authorization
HYDROGEN, COMPRESSED	2.1	UN 1049			1 PLASTIC BOX X KG	200	

Additional Handling Information

(412) 262-4583

Emergency Telephone Number

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable International and National Governmental Regulations.

Name/Title of Signatory
TON PATTON, EQUIPMENT MGR.

Place and Date
PITTSBURGH, PA

Signature
(see warning above)

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

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FIGURE 6-2

EXAMPLE OF A HAZARDOUS AIRBILL FOR METHANE IN AIR

SHIPPER'S DECLARATION FOR DANGEROUS GOODS (Provide at least two copies to the airline)

Shipper: Brown & Root Environmental, Spring Run Rd. Ext., Coraopolis, PA 15108

Page 1 of 1 Pages

Consignee

FedEx. Federal Express

Two completed and signed copies of this Declaration must be handed to the operator.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable) PASSENGER AND CARGO AIRCRAFT / ~~CARGO AIRCRAFT ONLY~~

Airport of Departure

Airport of Destination:

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder, or an IATA cargo agent.

Shipment type: (delete non-applicable) NON-RADIOACTIVE / ~~RADIOACTIVE~~

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification					Quantity and type of packaging	Packing Inst.	Authorization
Proper Shipping Name	Class or Division	UN or ID No.	Packing Group	Subsidiary Risk			
Compressed Gas N.O.S. (Methane in Air)	2.2	UN 1956			1 Fiberboard Box x ____ KG	200	

Additional Handling Information

Emergency Telephone Number (412) 262-4583

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable International and National Governmental Regulations.

Name/Title of Signatory: Tom Patton, Equip Mgr.

Place and Date: Pittsburgh, PA

Signature (see warning above)

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

The analytical data shall be delivered electronically in a Dbase III file format (filename.dbf). The exact structure of the database is described in the table below. It shall be the responsibility of the laboratory to ensure that all electronic entries are in strict accordance with the information provided on the Form I.

An example database shall be sent for review prior to the first electronic deliverable in Dbase III format. The example file will be examined for completeness and comments will be sent to the laboratory. Any questions regarding the electronic deliverable shall be directed to Patrick Hooper at Brown and Root Environmental (412)921-8250.

DATA FIELD	DATA TYPE	FIELD WIDTH	DATA FIELD DESCRIPTION
SAMPLE_NO	C	15	Field sample ID as listed on the chain-of-custody. The sample number indicated in this field should never be truncated. The only exception for this field not mathcing the chain-of-custody is for reanalyses and matrix spike results in which a RE or MS suffix will be added to the sample number respectively.
TRUNCATE	C	15	If the field sample ID listed on the Chain of Custody is truncated by the laboratory for use with the laboratory software, the truncated sample ID should appear in this field.
LAB_ID	C	15	Laboratory number for the given sample.
LABORATORY	C	25	Laboratory name.
BATCH_NO	I	10	Laboratory code for batch of samples included in a given run.
ASSOC_BLNK	C	15	Laboratory name of the method blank associated with that particular batch of samples.
QC_TYPE	C	15	Normal, Duplicate, Matrix Spike, etc.
COLL_DATE	D	8	Date of sample collection as indicated on the Chain of Custody. Example: 11/07/93.
REC_DATE	D	8	Date sample was received by the laboratory.
EXTR_DATE	D	8	Date sample was extracted or prepared by the laboratory.
ANAL_DATE	D	8	Date sample was analyzed by the laboratory.
SDG	C	15	Sample delivery group identifier assigned by the laboratory.
PROJECT_NO	C	10	Identification of Project Number or CTO number
PARAMETER	C	45	Chemical or analyte name as reported on Form I.
CAS_NO	C	10	Chemical Abstract Service number for the parameter listed. This field should be left blank for those parameters not having CAS numbers (e.g. Total Organic Carbon).

DATA FIELD	DATA TYPE	FIELD WIDTH	DATA FIELD DESCRIPTION
FRACTION	C	5	Metals = 'M', Volatiles = 'OV', Semivolatiles/BNAs = 'OS', Pesticides = 'PEST', Polychlorinated Biphenyls = 'PCB', Radionuclide = 'RAD', Miscellaneous = 'MISC'
METHOD	C	20	Analytical method used to quantitate parameter concentrations. SW846 method names should be used if applicable.
LAB_RESULT	N	15 (4)	Reported value in units specified in the UNITS field containing the proper number of siginificant digits. The % Recovery shall be placed in this field for matrix spike results.
UNITS	C	5	The units of measure as reported on the Form I.
LAB_QUAL	C	2	The laboratory qualifier as reported on the Form I. For example, a U qualifier should be used for all nondetected results.
IDL	N	10 (4)	Instrument detection limit in units specified in the UNITS field.
MDL	N	10 (4)	Method detection limit in units specified in the UNITS field and method specified in the METHOD field.
CRDL_CRQL	N	10 (4)	Contract Required Detection/Quantitation Limit in the units specified in the UNITS field. RDL for non-CLP parameters.
DIL_FACTOR	I	5	Dilution factor.
PCT_MOIST	N	5 (1)	Percent moisture for soil samples; blank for water samples.
COMMENTS	C	20	Analytical result qualifier or comment other than that listed in the LAB_QUAL field. Example: 'Reanalysis'.

C = Character string (everything shall be reported in capital letters)
I = Integer string (i.e. 0 decimal places)
N = Numeric string (decimal places are in parentheses in field width column)
D = Date (Ex: 05/25/95)

APPENDIX C

QUALITY ASSURANCE PROJECT PLAN

Quality Assurance Project Plan
for
Lower Subase Remedial Investigation Naval Submarine Base

New London
Groton, Connecticut

Northern Division
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0260

September 1997

019707/P

QUALITY ASSURANCE PROJECT PLAN
FOR
NAVAL SUBMARINE BASE - LOWER SUBASE REMEDIAL INVESTIGATION
NEW LONDON
GROTON, CONNECTICUT

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Northern Division
Environmental Branch Code 18
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
Lester, Pennsylvania 19113-2090

Submitted by:
Brown & Root Environmental
600 Clark Avenue, Suite 3
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CONTRACT NUMBER N62472-90-D-1298
CONTRACT TASK ORDER 0260

SEPTEMBER 1997

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ACRONYMS/ABBREVIATIONS

ASTM	American Society for Testing and Materials
AVS	Acid Volatile Sulfide
B&R Environmental	Brown & Root Environmental
BFB	Bromofluorobenzene
CLEAN	Comprehensive Long-Term Environmental Action, Navy
CLP	Contract Laboratory Program
COC	Chain of Custody
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
CTDEP	Connecticut Department of Environmental Protection
CTO	Contract Task Order
CVAA	Cold Vapor Atomic Absorption
DFTPP	Decaflourotriphenyl phosphine
DQO	Data Quality Objective
FID	Flame Ionization Detector
FOL	Field Operations Leader
FTMR	Field Task Modification Request
GC	Gas Chromatograph
GFAA	Graphite Furnace Atomic Absorption
HASP	Health & Safety Plan
ICP	Inductively Coupled Plasma
LCS	Laboratory Control Sample
MS	Mass Spectrometer
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NFESC	Naval Facilities Engineering Service Center
NIST	National Institute of Science and Technology
NSB-NLON	Naval Submarine Base New London
PARCC	Precision, Accuracy, Representativeness, Comparability, Completeness
PCB	Polychlorinated Biphenyl
PEM	Performance Evaluation Mixture
PID	Photoionization Detector
PQL	Practical Quantitation Limit
QA	Quality Assurance
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	Quality Control
REDOX	Oxidation-Reduction Potential
RI	Remedial Investigation
RPD	Relative Percent Difference
SEM	Simultaneously Extracted Metals
SOP	Standard Operating Procedure
SOW	Statement of Work
SPLP	Synthetic Precipitation Leaching Procedure
TAL	Target Analyte List
TCL	Target Compound List
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

WP/SAP	Work Plan and Sampling Analysis Plan
%R	Percent Recovery

1.0 PROJECT DESCRIPTION

1.1 INTRODUCTION

This Quality Assurance Project Plan (QAPP) has been prepared by Brown & Root Environmental (B&R Environmental) on behalf of the United States Navy Northern Division Naval Facilities Engineering Command and the Naval Submarine Base New London (NSB-NLON), Groton, Connecticut, under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract Number N62472-90-D-1298, Contract Task Order (CTO) 260. The QAPP and other associated documents, including the Work Plan and Sampling and Analysis Plan (WP/SAP) and the Health and Safety Plan (HASP), constitute the project planning documents for the Remedial Investigation (RI) to be performed at the Lower Subase, NSB-NLON.

This QAPP presents the organization, objectives, planned activities, and specific Quality Assurance/Quality Control (QA/QC) procedures associated with the Work Plan and Sampling and Analysis Plan for the site investigation. Specific protocols for sampling, sample handling and storage, chain-of-custody, and laboratory and field analyses are described within this document. All QA/QC procedures are structured in accordance with applicable technical standards, the Naval Facilities Engineering Service Center (NFESC) guidance document "Navy Installation Restoration Laboratory Quality Assurance Guide (February 1996), and United States Environmental Protection Agency (USEPA) Region I and Connecticut Department of Environmental Protection (CTDEP) requirements, regulations, guidance, and technical standards.

1.2 FACILITY DESCRIPTION

A description of the Lower Subase at NSB-NLON, including its location, size and borders, site conditions, natural and manmade features, and zones of investigation, is provided in Sections 1.2 and 1.3 of the WP/SAP.

1.3 PROJECT OBJECTIVES

This section discusses the overall project objectives, the anticipated target parameters and intended data uses for both field and laboratory analytical data.

1.3.1 Overall Project Objectives

The overall objectives of the work will be to perform further investigation and characterization of the soil and groundwater in the seven zones of the Lower Subase and the sediment and surface water in the adjacent areas of the Thames River. Project objectives are discussed in more detail in Section 1.1 of the WP/SAP.

1.3.2 Project Target Parameters and Intended Data Uses

This section discusses the field and laboratory analytical information to be generated during the course of the investigation. Field parameters and intended data uses are discussed in Section 1.3.2.1. Laboratory parameters and intended data uses are discussed in Section 1.3.2.2.

1.3.2.1 Field Parameters

Field parameters will include those parameters associated with the completion of soil borings, installation and development of monitoring wells, groundwater sampling and analysis, and surface water sampling. All field measurements will be completed using simple field instrumentation or field test kits.

Field measurements of total volatile organic compounds will be completed using a Photoionization Detector (PID) or Flame Ionization Detector (FID). These measurements will be used to determine appropriate subsurface sample horizons to be submitted for laboratory analysis and for safety monitoring to determine breathing zone conditions for site workers.

Field parameters including pH, specific conductance, turbidity, and temperature will be completed for all groundwater samples. These measurements will be used to support monitoring well development and purging of stagnant water from well casings. Specific conductance and pH will also be used as general indicators of water quality. In addition, all groundwater samples will be analyzed for dissolved oxygen, oxidation-reduction (REDOX) potential, salinity, and divalent iron. Divalent iron will be measured using a field test kit. Turbidity will be measured using a LaMonte Turbidity meter. The remaining field parameters will be measured using a meter with a flow-through cell. These additional parameters, along with pH and several laboratory parameters, will be used to assess the potential for natural attenuation of petroleum hydrocarbons in the groundwater system at the Lower Subase. Surface water samples will also be analyzed for temperature, pH, dissolved oxygen, specific conductance, turbidity, and salinity. These measurements will be taken to evaluate general water quality characteristics and to evaluate the impact of tidal recharge on groundwater. Further details regarding field sampling methods are provided in Section 2.6 of the WP/SAP.

1.3.2.2 Laboratory Parameters

The analytical methods to be used for analysis of the NSB-NLON samples have been selected based on existing analytical data from previous investigations. The suite of analyses for the NSB-NLON Lower Subase RI includes Target Compound List (TCL) volatiles (soil samples) and low-concentration TCL volatiles (groundwater samples), TCL semivolatiles, TCL pesticides (one sediment sample only), Target Analyte List (TAL) metals, and Total Petroleum Hydrocarbons (TPH). These parameters will be used to evaluate the nature and extent of contamination, to evaluate contaminant migration pathways and link source areas to potential receptors, and to support decision making via ecological and human health risk assessment. The Synthetic Precipitation Leaching Procedure (SPLP) followed by either lead or TAL metals analysis will be performed for soil samples to determine the mobility of metals in soil at the site. Additional laboratory parameters, which will be used in conjunction with the field parameters previously discussed to evaluate natural attenuation of petroleum hydrocarbons in the groundwater system, include total organic carbon (TOC), alkalinity, hardness, chloride, nitrate, sulfate, phosphate, ammonia, and methane. In addition, Acid Volatile Sulfide (AVS) and Simultaneously Extracted Metals (SEM) as well as pH, TOC, and grain-size distribution analyses will be performed to evaluate the bioavailability of metals in the sediment. Ammonia will also be measured in sediment samples to determine the levels of this naturally-occurring compound that may be toxic to macroinvertebrates. Tables 1-1 through 1-6 provide a summary of all target analytes and associated Contract Required Quantitation Limits (CRQL) for TCL organics, Contract Required Detection Limits (CRDL) for TAL metals, and typical Practical Quantitation Limits (PQLs) for all remaining parameters. Analytical methods are further discussed in Section 7.0 of this QAPP.

1.4 SAMPLE NETWORK DESIGN AND RATIONALE

The sample network design and rationale is discussed in detail in Section 1.4 of the WP/SAP. Figures displaying all proposed sampling locations are provided in Section 2.3 of the WP/SAP.

1.5 PROJECT SCHEDULE

The project schedule is discussed in Section 1.8 of the project WP/SAP.

TABLE 1-1

ANALYTICAL DETECTION LIMITS - TCL LOW-CONCENTRATION VOLATILES NSB-NLON, GROTON, CONNECTICUT

Parameter	CRQL(1)
	Groundwater Samples
Volatile Organic Compounds	µg/L
Acetone	5
Benzene	1
Bromochloromethane	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	1
2-Butanone	5
Carbon disulfide	1
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	1
Chloroform	1
Chloromethane	1
Dibromochloromethane	1
1,2-Dibromo-3-chloropropane	1
1,2-Dibromoethane	1
1,2-Dichlorobenzene	1
1,3-Dichlorobenzene	1
1,4-Dichlorobenzene	1
1,1-Dichloroethane	1
1,2-Dichloroethane	1
1,1-Dichloroethene	1
cis-1,2-Dichloroethene	1
trans-1,2-Dichloroethene	1
1,2-Dichloropropane	1
cis-1,3-Dichloropropene	1
trans-1,3-Dichloropropene	1
Ethylbenzene	1
2-Hexanone	5
4-Methyl-2-pentanone	5
Methylene chloride	2
Styrene	1
1,1,2,2-Tetrachloroethane	1
1,1,1-Trichloroethane	1
1,1,2-Trichloroethane	1
Trichloroethene	1
Tetrachloroethene	1
Toluene	1
Vinyl chloride	1
Xylenes (total)	1

1 CRQL Contract Required Quantitation Limit; as specified in OLC02.0.

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TCL ORGANICS
NSB-NLON, GROTON, CONNECTICUT
PAGE 1 OF 4

Parameter	CRQL[1]
	Solid Samples[2]
Volatile Organic Compounds	**µg/kg**
Acetone	10
Benzene	10
Bromodichloromethane	10
Bromoform	10
Bromomethane	10
2-Butanone	10
Carbon disulfide	10
Carbon tetrachloride	10
Chlorobenzene	10
Chloroethane	10
Chloroform	10
Chloromethane	10
Dibromochloromethane	10
1,1-Dichloroethane	10
1,2-Dichloroethane	10
1,1-Dichloroethene	10
1,2-Dichloroethene (total)	10
1,2-Dichloropropane	10
cis-1,3-Dichloropropene	10
trans-1,3-Dichloropropene	10
Ethylbenzene	10
2-Hexanone	10
4-Methyl-2-pentanone	10
Methylene chloride	10
Styrene	10
1,1,2,2-Tetrachloroethane	10
1,1,1-Trichloroethane	10
1,1,2-Trichloroethane	10
Trichloroethene	10
Tetrachloroethene	10
Toluene	10
Vinyl chloride	10
Xylenes (total)	10

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TCL ORGANICS
NSB-NLON, GROTON, CONNECTICUT
PAGE 2 OF 4

Parameter	CRQL[1]	
	Groundwater Samples	Solid Samples[2]
Semivolatile Organic Compounds	**µg/L**	**µg/kg**
Acenaphthene	10	330
Acenaphthylene	10	330
Anthracene	10	330
Benzo(a)anthracene	10	330
Benzo(a)pyrene	10	330
Benzo(b)fluoranthene	10	330
Benzo(g,h,i)perylene	10	330
Benzo(k)fluoranthene	10	330
Bis(2-chloroethoxy)methane	10	330
Bis(2-chloroethyl)ether	10	330
Bis(2-ethylhexyl)phthalate	10	330
4-Bromophenyl-phenylether	10	330
Butylbenzylphthalate	10	330
Carbazole	10	330
4-Chloro-3-methylphenol	10	330
4-Chloroaniline	10	330
2-Chloronaphthalene	10	330
2-Chlorophenol	10	330
4-Chlorophenyl-phenylether	10	330
Chrysene	10	330
Dibenz(a,h)anthracene	10	330
Dibenzofuran	10	330
3,3'-Dichlorobenzidine	10	330
Diethylphthalate	10	330
Di-n-butylphthalate	10	330
Di-n-octylphthalate	10	330
4,6-Dinitro-2-methylphenol	25	830
2,4-Dinitrophenol	25	830
2,4-Dinitrotoluene	10	330
1,2-Dichlorobenzene	10	330
1,3-Dichlorobenzene	10	330
1,4-Dichlorobenzene	10	330
2,4-Dichlorophenol	10	330

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TCL ORGANICS
NSB-NLON, GROTON, CONNECTICUT
PAGE 3 OF 4

Parameter	CRQL[1]	
	Groundwater Samples	Solid Samples[2]
Semivolatile Organic Compounds	**µg/L**	**µg/kg**
Dimethylphthalate	10	330
2,4-Dimethylphenol	10	330
2,6-Dinitrotoluene	10	330
Fluoranthene	10	330
Fluorene	10	330
Hexachlorobenzene	10	330
Hexachlorobutadiene	10	330
Hexachlorocyclopentadiene	10	330
Hexachloroethane	10	330
Indeno(1,2,3-cd)pyrene	10	330
Isophorone	10	330
2-Methylnaphthalene	10	330
2-Methylphenol	10	330
4-Methylphenol	10	330
Naphthalene	10	330
2-Nitroaniline	25	830
3-Nitroaniline	25	830
4-Nitroaniline	25	830
Nitrobenzene	10	330
2-Nitrophenol	10	330
4-Nitrophenol	25	830
N-nitroso-di-n-propylamine	10	330
N-nitrosodiphenylamine	10	330
2,2'-Oxybis(1-chloropropane)	10	330
Pentachlorophenol	25	830
Phenanthrene	10	330
Phenol	10	330
Pyrene	10	330
1,2,4-Trichlorobenzene	10	330
2,4,5-Trichlorophenol	25	830
2,4,6-Trichlorophenol	10	330

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TCL ORGANICS
NSB-NLON, GROTON, CONNECTICUT
PAGE 4 OF 4

Parameter	CRQL[1]
	Sediment Samples
Pesticides	**µg/kg**
Aldrin	1.7
alpha-BHC	1.7
alpha-Chlordane	1.7
beta-BHC	1.7
4,4'-DDE	3.3
4,4'-DDD	3.3
4,4'-DDT	3.3
delta-BHC	1.7
Dieldrin	3.3
Endosulfan I	1.7
Endosulfan II	3.3
Endosulfan sulfate	3.3
Endrin	3.3
Endrin aldehyde	3.3
Endrin ketone	3.3
gamma-BHC (Lindane)	1.7
gamma-Chlordane	1.7
Heptachlor	1.7
Heptachlor epoxide	1.7
Methoxychlor	17
Toxaphene	170

1 CRQL Contract Required Quantitation Limit; as specified in OLM01.8.

2 Solid (soil, sediment) samples.

TABLE 1-3

ANALYTICAL DETECTION LIMITS - TAL METALS
NSB-NLON, GROTON, CONNECTICUT

Parameter	CRDL[1]	
	Groundwater Samples	Solid Samples[2]
Target Analyte List Metals	µg/L	mg/kg
Aluminum	200	40
Antimony	60	12
Arsenic	10	2
Barium	200	40
Beryllium	5	1
Cadmium	5	1
Calcium	5000	1000
Chromium (total)	10	2
Cobalt	50	10
Copper	25	5
Iron	100	20
Lead	3	0.6
Magnesium	5000	1000
Manganese	15	3
Mercury	0.2	0.1
Nickel	40	8
Potassium	5000	1000
Selenium	5	1
Silver	10	2
Sodium	5000	1000
Thallium	10	2
Vanadium	50	10
Zinc	20	4

1 CRDL Contract Required Detection Limit; as specified in ILM03.0.
2 Solid (soil, sediment) samples.

TABLE 1-4

ANALYTICAL DETECTION LIMITS - NATURAL ATTENUATION PARAMETERS NSB-NLON, GROTON, CONNECTICUT

Parameter	PQL[1]
	Groundwater Samples
	mg/L
Total Organic Carbon (TOC)	1.0
Alkalinity (as $CaCO_3$)	20
Hardness (as $CaCO_3$)	5.0
Chloride	2.0
Nitrate	0.050
Sulfate	1.0
Phosphate (Total)	0.10
Ammonia	0.10
Methane	5

1 PQLTypical Practical Quantitation Limit; actual PQL may vary based on the laboratory.

TABLE 1-5

ANALYTICAL DETECTION LIMITS - AVS/SEM PARAMETERS
NSB-NLON, GROTON, CONNECTICUT

Parameter	PQL[1]
	Sediment Samples
	mg/kg
Acid Volatile Sulfide (AVS)	10
Cadmium (SEM)	0.40
Copper (SEM)	1.0
Lead (SEM)	0.20
Mercury (SEM)	0.008
Nickel (SEM)	1.6
Zinc (SEM)	1.0

1 PQLTypical Practical Quantitation Limit; actual PQL may vary based on the laboratory.

TABLE 1-6

ANALYTICAL DETECTION LIMITS - MISCELLANEOUS PARAMETERS
NSB-NLON, GROTON, CONNECTICUT

Parameter	PQL[1]	
	Groundwater Samples	Solid Samples[2]
	mg/L	mg/kg
Total Petroleum Hydrocarbons (TPH)	1.0	25
Total Organic Carbon (TOC)	NA[3]	100
Ammonia	NA	8.0
pH (pH units)	NA	0.1
Grain Size (% finer)	NA	#200 sieve

1 PQL Typical Practical Quantitation Limit; actual PQL may vary based on the laboratory.
2 Solid (soil, sediment) samples.
3 Not Applicable.

2.0 PROJECT ORGANIZATION

The project organization for the NSB-NLON Lower Subase RI is discussed in Section 1.5 of the WP/SAP.

3.0 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

The overall QA objective for this project is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide results which are legally defensible in a court of law. Intended data uses are described in Section 1.3.2 of this QAPP. Specific procedures for sampling, chain-of-custody, laboratory instrument calibration, laboratory analysis, reporting of data, internal quality control, audits, preventive maintenance of field and laboratory equipment, and corrective action are described in other sections of this QAPP.

The PARCC parameters (precision, accuracy, representativeness, comparability, and completeness) are qualitative and/or quantitative statements regarding the quality characteristics of the data used to support project objectives and ultimately, environmental decisions. These parameters are discussed in the remainder of this section. Specific routine procedures used to assess the quantitative parameters (precision, accuracy, and completeness) are provided in Section 12.0.

3.1 PRECISION

3.1.1 Definition

Precision is a measure of the amount of variability and bias inherent in a data set. Precision describes the reproducibility of measurements of the same parameter for samples under similar conditions. The equation for determining precision is provided in Section 12.2.

3.1.2 Field Precision Objectives

Field duplicate precision monitors the consistency with which environmental samples were obtained and analyzed. Field duplicate results for solid matrix samples are considered to be precise if the relative percent difference (RPD) is less than or equal to 50 percent. Field duplicate results for aqueous matrix samples are considered to be precise if the RPD is less than or equal to 30 percent. Field precision is assessed through the collection and measurement of field duplicates at a rate of 1 duplicate per 10 environmental samples of like matrix.

3.1.3 Laboratory Precision Objectives

Laboratory precision QC samples are analyzed at a frequency of 5 percent (i.e., one quality control sample per 20 environmental samples). Laboratory precision is measured via comparison of calculated

RPD values and Precision Control Limits specified in the analytical method or by the laboratory's QA/QC Program.

With the exception of low-concentration volatiles analysis, precision for TCL volatile and semivolatile organic and pesticide analyses will be measured via the RPDs for matrix spike/matrix spike duplicate (MS/MSD) samples. Although the Statement of Work for low-concentration TCL volatile analysis does not require a specific QC sample to monitor precision, the calibration requirements of the method (i.e., specific limits of precision for the calibration standards) do ensure that a sufficient level of precision is achieved. (Calibration is further discussed in Section 6.0.) Precision for TAL metals analysis will be measured via RPDs for laboratory duplicates. Table 3-1 presents precision control limits for MS/MSD RPDs for TCL organics. Table 3-2 presents precision control limits for laboratory duplicate RPDs for TAL metals. Precision for the remaining parameters (i.e., natural attenuation, AVS/SEM, and miscellaneous parameters) will typically be measured via the RPD results for laboratory duplicate samples. Internal laboratory control limits for precision, which are typically set at three times the standard deviation of a series of RPDs, will be used for evaluation of precision for these parameters.

3.2 ACCURACY

3.2.1 Definition

Accuracy is the degree of agreement between are observed value and an accepted reference value. The equation for determining accuracy is provided in Section 12.1.

3.2.2 Field Accuracy Objectives

Accuracy in the field is assessed through the use of rinsate and trip blanks and is ensured through the adherence to all sample handling, preservation and holding times. Accuracy and precision requirements for field measurements are ensured through calibration as discussed in Section 6.0.

3.2.3 Laboratory Accuracy Objectives

Accuracy in the laboratory is measured through the comparison of a spiked sample result against a known or calculated value expressed as a percent recovery (%R). Percent recoveries are derived from the analysis of known amounts of compounds spiked into deionized water [i.e., laboratory control sample (LCS) analysis], or into actual samples (i.e., surrogate or MS analysis). LCS analyses measure the accuracy of laboratory operations. Surrogate and MS analyses measure the accuracy of laboratory operations as affected by matrix. LCS and/or MS analyses are performed with a frequency of one per

TABLE 3-1

PRECISION CONTROL LIMITS (RPDs)[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES
VOLATILE AND SEMIVOLATILE ORGANIC ANALYSIS VIA OLM01.8[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples	Solid Samples
VOLATILE ORGANICS		
1,1-Dichloroethene	NA[3]	22
Trichloroethene	NA	24
Benzene	NA	21
Toluene	NA	21
Chlorobenzene	NA	21
SEMIVOLATILE ORGANICS		
Phenol	42	35
2-Chlorophenol	40	50
1,4-Dichlorobenzene	28	27
N-Nitroso-di-n-propylamine	38	38
1,2,4-Trichlorobenzene	28	23
4-Chloro-3-methylphenol	42	33
Acenaphthene	31	19
4-Nitrophenol	50	50
2,4-Dinitrotoluene	38	47
Pentachlorophenol	50	47
Pyrene	31	36
PESTICIDES		
gamma-BHC (Lindane)	NA	50
Heptachlor	NA	31
Aldrin	NA	43
Dieldrin	NA	38
Endrin	NA	45
4,4'-DDT	NA	50

1 RPD - Relative Percent Difference as described in Section 12.0.
2 USEPA Contract Laboratory Program (CLP), 1991. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM01.8.
3 NA - Not Applicable since TCL Volatile or Pesticide analysis using OLM01.8 will not be performed for aqueous samples.

TABLE 3-2

PRECISION CONTROL LIMITS (RPDs)[1]
LABORATORY DUPLICATE SAMPLES
METALS ANALYSIS VIA ILM03.0[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples[3]	Solid Samples[4]
METALS		
Aluminum	20	35
Antimony	20	35
Arsenic	20	35
Barium	20	35
Beryllium	20	35
Cadmium	20	35
Calcium	20	35
Chromium (total)	20	35
Cobalt	20	35
Copper	20	35
Iron	20	35
Lead	20	35
Magnesium	20	35
Manganese	20	35
Mercury	20	35
Nickel	20	35
Potassium	20	35
Selenium	20	35
Silver	20	35
Sodium	20	35
Thallium	20	35
Tin	20	35
Vanadium	20	35
Zinc	20	35

1 RPD - Relative Percent Difference as described in Section 12.0.
2 USEPA CLP. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM03.0.
3 For aqueous sample results less than 5X CRDL, a control limit of ±CRDL is used.
4 For solid sample results less than 5X CRDL, a control limit of ±2X CRDL is used.

twenty associated samples of like matrix. Surrogate spike analysis is performed for all chromatographic organic analyses. Laboratory accuracy is assessed via comparison of calculated %Rs with Accuracy Control Limits specified in the analytical method or by the laboratory's QA/QC Program.

Accuracy for TCL volatile and semivolatile organic and pesticide analysis will be measured via the %Rs for surrogate spikes and MS/MSDs. Accuracy for TAL metals analysis will be measured via %Rs for MSs and LCSs. Table 3-3 presents control limits for LCS and surrogate spike recoveries for low-concentration TCL volatiles. Tables 3-4 and 3-5 present control limits for matrix and surrogate spike recoveries, respectively, for TCL organics. Tables 3-6 and 3-7 present control limits for MS and LCSs, respectively, for TAL metals. Accuracy for the remaining parameters will typically be measured via %Rs for MSs and/or LCSs. Internal laboratory control limits for accuracy, which are typically set at three times the standard deviation of a series of %R values, will be used for evaluation of accuracy for these parameters.

3.3 COMPLETENESS

Completeness is a measure of the amount of usable, valid analytical data obtained, compared to the amount expected to be obtained. Completeness is typically expressed as a percentage. The equation for completeness is presented in Section 12.3.

The ideal objective for completeness is 100 percent (i.e., every sample planned to be collected is collected; every sample submitted for analysis yields valid data). However, samples can be rendered unusable during shipping or preparation (e.g., bottles broken or extracts accidentally destroyed), errors can be introduced during analysis (e.g., loss of instrument sensitivity, introduction of ambient laboratory contamination), or strong matrix effects can become apparent (e.g., extremely low matrix spike recovery).

These instances result in data that do not meet QC criteria. Based on these considerations, 95 percent is considered an acceptable target for the data completeness objective. If critical data points are lost, resampling and/or reanalysis may be required.

As further discussed in Section 9.2, one hundred percent of the laboratory data for the NSB-NLON Lower Subase RI will be validated in accordance with the USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (February 1994) and Inorganic Data Review (February 1994). Data rejected as a result of the validation process will be treated as unusable data.

TABLE 3-3

ACCURACY CONTROL LIMITS (%R)[1]
LABORATORY CONTROL SAMPLE AND SURROGATE SPIKE
LOW-CONCENTRATION VOLATILE ORGANIC ANALYSIS VIA OLC02.0[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples
LABORATORY CONTROL SAMPLE	
Vinyl chloride	60-140
1,2-Dichloroethane	60-140
Carbon tetrachloride	60-140
1,2-Dichloropropane	60-140
Trichloroethene	60-140
1,1,2-Trichloroethane	60-140
Benzene	60-140
cis-1,3-Dichloropropene	60-140
Bromoform	60-140
Tetrachloroethene	60-140
1,2-Dibromoethane	60-140
1,4-Dichlorobenzene	60-140
SURROGATE SPIKE	
Bromoflourobenzene	80-120

1 %R - Percent Recovery as described in Section 12.0.
2 USEPA CLP, 1992. Superfund Analytical Methods for Low Concentration Water for Organics Analysis, 10/92, OLC02.0.

TABLE 3-4

ACCURACY CONTROL LIMITS (%R)[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES
VOLATILE AND SEMIVOLATILE ORGANIC ANALYSIS VIA OLM01.8[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples	Solid Samples
VOLATILE ORGANICS		
1,1-Dichloroethene	NA[3]	59-172
Trichloroethene	NA	62-137
Benzene	NA	66-142
Toluene	NA	59-139
Chlorobenzene	NA	60-133
SEMIVOLATILE ORGANICS		
Phenol	12-110	26-90
2-Chlorophenol	27-123	25-102
1,4-Dichlorobenzene	36-97	28-104
N-Nitroso-di-n-propylamine	41-116	41-126
1,2,4-Trichlorobenzene	39-98	38-107
4-Chloro-3-methylphenol	23-97	26-103
Acenaphthene	46-118	31-137
4-Nitrophenol	10-80	11-114
2,4-Dinitrotoluene	24-96	28-89
Pentachlorophenol	9-103	17-109
Pyrene	26-127	35-142
PESTICIDES		
gamma-BHC (Lindane)	NA	46-127
Heptachlor	NA	35-130
Aldrin	NA	34-132
Dieldrin	NA	31-134
Endrin	NA	42-139
4,4'-DDT	NA	23-134

1 %R - Percent Recovery as described in Section 12.0
2 USEPA CLP, 1991. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM01.8.
3 NA - Not applicable since TCL volatile and pesticide analyses using OLM01.8 will not be used for aqueous samples.

TABLE 3-5

ACCURACY CONTROL LIMITS (%R)[1]
SURROGATE SPIKES
VOLATILE AND SEMIVOLATILE ORGANIC ANALYSIS VIA OLM01.8[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples	Solid Samples
VOLATILE ORGANICS		
Toluene-d8	NA[3]	84-138
Bromofluorobenzene	NA	59-113
1,2-Dichloroethane-d4	NA	70-121
SEMIVOLATILE ORGANICS		
Nitrobenzene-d5	35-114	23-120
2-Fluorobiphenyl	43-116	30-115
Terphenyl-d14	33-141	18-137
Phenol-d5	10-110	24-113
2-Fluorophenol	21-110	25-121
2,4,6-Tribromophenol	10-123	19-122
2-Chlorophenol-d4	33-110[4]	20-130[4]
1,2-Dichlorobenzene-d4	16-110[4]	20-130[4]
PESTICIDES		
Tetrachloro-m-xylene	NA	60-150
Decachlorobiphenyl	NA	60-150

1 %R - Percent Recovery as described in Section 12.0.
2 USEPA CLP, 1991. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM01.8.
3 NA - Not applicable since TCL volatile and pesticide analyses using OLM01.8 will not be performed for aqueous samples.
4 Advisory limits only.

TABLE 3-6

ACCURACY CONTROL LIMITS (%R)[1]
MATRIX SPIKE SAMPLES
METALS ANALYSIS VIA ILM03.0[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples	Solid Samples
METALS		
Aluminum	75-125	NS[3]
Antimony	75-125	75-125
Arsenic	75-125	75-125
Barium	75-125	75-125
Beryllium	75-125	75-125
Cadmium	75-125	75-125
Calcium	NS	NS
Chromium (total)	75-125	75-125
Cobalt	75-125	75-125
Copper	75-125	75-125
Iron	75-125	NS
Lead	75-125	75-125
Magnesium	NS	NS
Manganese	75-125	75-125
Mercury	75-125	75-125
Nickel	75-125	75-125
Potassium	NS	NS
Selenium	75-125	75-125
Silver	75-125	75-125
Sodium	NS	NS
Thallium	75-125	75-125
Tin	75-125	75-125
Vanadium	75-125	75-125
Zinc	75-125	75-125

1 %R - Percent Recovery as described in Section 12.0.
2 USEPA CLP. Statement of work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM03.0.
3 No spike required.

TABLE 3-7

ACCURACY CONTROL LIMITS (%R)[1]
LABORATORY CONTROL SAMPLES
METALS ANALYSIS VIA ILM03.0[2]
LOWER SUBASE, NSB-NLON, GROTON, CONNECTICUT

Chemical	Aqueous Samples	Solid Samples
METALS		
Aluminum	80-120	TBD[3]
Antimony	80-120[4]	TBD
Arsenic	80-120	TBD
Barium	80-120	TBD
Beryllium	80-120	TBD
Cadmium	80-120	TBD
Calcium	80-120	TBD
Chromium	80-120	TBD
Cobalt	80-120	TBD
Copper	80-120	TBD
Iron	80-120	TBD
Lead	80-120	TBD
Magnesium	80-120	TBD
Manganese	80-120	TBD
Mercury	NA[5]	TBD
Nickel	80-120	TBD
Potassium	80-120	TBD
Selenium	80-120	TBD
Silver	80-120[4]	TBD
Sodium	80-120	TBD
Thallium	80-120	TBD
Tin	80-120	TBD
Vanadium	80-120	TBD
Zinc	80-120	TBD

1 %R - Percent Recovery as described in Section 12.0.
2 USEPA CLP. Statement of Work for Inorganic Analysis, Multi-Media, Multi- Concentration, ILM03.0.
3 TBD - To Be Determined at time of analysis based on USEPA LCS lot number.
4 Advisory limits only.
5 NA - Not Applicable.

3.4 REPRESENTATIVENESS

3.4.1 Definition

Representativeness is an expression of the degree to which the data accurately and precisely depict the actual characteristics of a population or environmental condition existing at an individual sampling point. Use of standardized sampling, handling, analytical, and reporting procedures ensures that the final data accurately represent actual site conditions.

3.4.2 Measures to Ensure Representativeness of Field Data

Representativeness is dependent upon the proper design of the sampling program. It will be satisfied by ensuring that the SAP is followed and that proper sampling techniques are used. The sampling network for the NSB-NLON Lower Subase RI was designed to provide data representative of facility conditions. During development of this network, consideration was given to past waste disposal practices, existing analytical data, and physical setting and processes. The rationale of the sampling network is discussed in detail in Section 1.4 of the WP/SAP.

3.4.3 Measures to Ensure Representativeness of Laboratory Data

Representativeness in the laboratory data is ensured by using the proper analytical procedures, meeting sample holding times, and analyzing and assessing duplicate samples.

3.5 COMPARABILITY

3.5.1 Definition

Comparability is defined as the confidence with which one data set can be compared to another (e.g., between sampling points; between sampling events). Comparability is achieved by using standardized sampling and analysis methods, and data reporting formats (including use of consistent units of measure and reporting of solid matrix sample results on a dry-weight basis). Additionally, consideration is given to seasonal conditions and other environmental variations that could influence data results.

3.5.2 Measures to Ensure Comparability of Field Data

Comparability is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the SAP is followed and that proper sampling techniques are used. It is also dependent on

recording field measurements using the correct units. Field measurement units are further discussed in Section 9.1.1.

3.5.3 Measures to Ensure Comparability of Laboratory Data

Planned analytical data will be comparable when similar sampling and analytical methods are used and documented. Results will be reported in units that ensure comparability with previous data and with current state and Federal standards and guidelines. Laboratory measurement units are further discussed in Section 9.1.2.

3.6 LEVEL OF QUALITY CONTROL EFFORT

Trip blank, rinsate blank, ambient condition blank, source water blank, method blank, field and laboratory duplicate, laboratory control, and matrix spike samples will be analyzed to assess the quality of the data resulting from the field sampling and analytical programs. In addition, field duplicate measurements will be completed for all field parameters.

External QC measures (i.e., field quality control samples) consist of field duplicates, ambient condition blanks, trip blanks, source water blanks, and equipment rinsate blanks. Information gained from these analyses further characterizes the level of data quality obtained to support project goals. Each of these types of field quality control samples undergo the same preservation, analysis, and reporting procedures as the related environmental samples. Each type of field quality control sample is discussed below.

Field duplicates are either two samples collected independently at a sampling location (e.g., surface water), or a single sample homogenized and split into two portions. [When volatile organic compounds (VOCs) are to be analyzed, the VOC sample aliquots are containerized first to avoid loss of constituents, then the remaining sample matrix is homogenized.] Field duplicates are collected and analyzed for all chemical constituents to measure the precision of the sampling and analysis methods employed. The level of the QC effort will be one field duplicate for every 10 or fewer investigative samples.

Trip blanks and ambient condition blanks, consisting of distilled water, will be submitted to the laboratory to provide the means to assess the quality of the data resulting from the field sampling program. Ambient blanks are not collected using the same sampling equipment as the field samples, but are collected while at the field sampling site by placing distilled water directly into the same type of container, preserved and stored in the same manner, as the field samples. Ambient blank samples are analyzed to check for background contamination at the facility (e.g., vapors, dust, or exhaust fumes that are part of normal

operations at the site) which may cause sample contamination. The exposure of the ambient blank to ambient conditions should be similar to the ambient exposure of the field samples. Ambient blanks will be collected based on conditions at the time of sampling at the discretion of the Field Operations Leader (FOL), with a minimum of one ambient blank being collected during the investigation.

Trip blanks only pertain to samples collected for VOC analysis. Trip blanks are used to assess the potential for contamination of samples to be analyzed for VOCs by contaminant migration into sample containers during sample shipment and storage. Trip blanks are prepared by the laboratory prior to the sampling event, shipped to the site with the sample containers, and kept with the investigative samples throughout the sampling event. They are then packaged for shipment with other VOC samples and sent for analysis. There should be one trip blank included in each sample shipping container that contains samples for VOC analysis. At no time after trip blank preparation are their sample containers opened before they reach the laboratory.

Source water blanks consist of the potable water used for decontamination of sampling equipment. These blanks are used to determine if the potable water may be contributing to sample contamination. Source water blanks will be collected at a rate of one blank per each potable water source.

Equipment rinsate blanks are obtained under representative field conditions by collecting the rinse water generated by running analyte-free water through sample collection equipment after decontamination and prior to use. At least one equipment blank will be collected per day, per matrix. If pre-cleaned, dedicated, or disposable sampling equipment is used, one rinsate blank per type of equipment used must be collected as a "batch blank." Rinsate blanks are analyzed for the same chemical constituents as the associated environmental samples.

Method blank samples are generated within the laboratory and used to assess contamination resulting from laboratory procedures. Laboratory duplicate samples are analyzed for inorganic parameters to check for sampling and analytical reproducibility. MSs provide information about the effect of the sample matrix on the digestion and measurement methodology. All MSs for organic analyses are performed in duplicate and, as previously defined, are referred to as MS/MSD samples.

MS/MSD samples are investigative samples. Soil MS/MSD samples require no extra volume for VOCs or extractable organics. However, aqueous MS/MSD samples must be collected at triple the volume for VOCs and extractable organics. One MS/MSD sample will be collected/designated for every 20 or fewer investigative samples per sample matrix (i.e., groundwater, soil, surface water, sediment).

The level of QC effort provided by the laboratory for the TCL and TAL parameters to be tested will be equivalent to the level of QC effort specified under the USEPA Contract Laboratory Program (CLP). The level of QC effort for testing of TCL organics (volatiles, semivolatiles, and pesticides) will conform to the applicable Statement of Work for organics (OLM01.8) or low-concentration organics (OLC02.0). The level of QC effort for testing of metals will conform to the Statement of Work for inorganics (ILM03.0). The level of QC effort for testing of the remaining parameters will conform to the appropriate analytical methods, as specified in Tables 7.1 and 7.2 of this QAPP.

4.0 SAMPLING PROCEDURES

Field sampling procedures for the NSB-NLON Lower Subase RI are discussed in detail in Sections 2.4 and 2.5 of the WP/SAP. In addition, the WP/SAP addresses the following sampling procedures and field investigation tasks:

- Mobilization and demobilization - Section 2.2
- Groundwater-level and product thickness measurements - Section 2.5.1
- Monitoring well development and purging - Section 2.5.2
- Sample containers, preservatives, and volume requirements - Table 2-3
- Field measurements - Section 2.6
- Decontamination procedures - Section 2.7
- Investigation derived waste - Section 2.8
- Surveying - Section 2.9
- Sample identification system - Section 3.1
- Sample packaging and shipping procedures - Section 3.2
- Field quality control samples - Section 3.4
- Recordkeeping - Section 3.5

Standard Operating Procedures regarding sampling, recordkeeping, and field investigation tasks are included in Appendix B to the WP/SAP.

5.0 CUSTODY PROCEDURES

Custody is one of several factors which is necessary for the admissibility of environmental data as evidence in a court of law. Custody procedures help to satisfy the two major requirements for admissibility: relevance and authenticity. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files. Final evidence files, including all originals of laboratory reports and purge files, are maintained under document control in a secure area. A sample or evidence file is under custody if:

- the item is in the actual physical possession of an authorized person, or;
- the item is in view of the person after being in his or her possession, or;
- the item was placed in a secure area to prevent tampering; or
- the item is in a designated and identified secure area with access restricted to authorized personnel only.

The chain-of-custody (COC) report is a multi-part, standardized form used to summarize and document pertinent sample information, such as sample identification and type, matrix, date and time of collection, preservation, and requested analyses. Furthermore, through the sequential signatures of various sample custodians (e.g., sampler, airbill number, laboratory sample custodian), the COC report documents sample custody and tracking. A "Cradle-to-Grave" sample tracking system, as further described in Section 1.8.1 of the WP/SAP, will be employed. Custody procedures apply to all environmental and associated field quality control samples obtained as part of the data collection system.

5.1 FIELD CUSTODY PROCEDURES

The FOL (or designee) is responsible for the care and custody of the samples collected until they are relinquished to the analyzing laboratory or entrusted to a commercial overnight courier. COC reports are completed for each sample shipment. The reports are filled out in a legible manner, using waterproof ink, and are signed (and dated) by the sampler. Pertinent notes, such as whether the sample was field filtered, or whether the sample is suspected to be high in contaminant concentration, are also indicated on the COC report. Information similar to that contained in the COC report is also provided on the sample label, which is securely attached to the sample bottle. COC report forms and sample labels will be supplied by the laboratory subcontractor. In accordance with NFESC guidelines, samples for chemical constituent analysis must be sent (for next-day receipt) to the laboratory within 24-hours of collection.

Full details regarding sample COCs (including use of custody seals and sample shipment protocols) are contained in B&R Environmental Standard Operating Procedure (SOP) SA-6.1, which is provided in Appendix B of the attendant WP/SAP. B&R Environmental SOP SA-6.3, also provided in Appendix B of the WP/SAP, discusses maintenance of site logbooks, site notebooks, and other field records. Additionally, each of the various sampling SOPs incorporated into the WP/SAP contains a section that addresses relevant sample documentation (i.e., completion of sample logsheets, etc.). All sample records are eventually docketed into the B&R Environmental project central file.

5.2 LABORATORY CUSTODY PROCEDURES

When samples are received by the laboratory subcontractor, the laboratory's sample custodian examines each cooler's custody seals to verify that they are intact and that the integrity of the environmental samples has been maintained. The sample custodian then signs the COC report. The custodian then opens the cooler and measures its internal temperature. The temperature reading is noted on the accompanying COC report. The sample custodian then examines the contents of the cooler. Sample container breakages or discrepancies between the COC report and sample label documentation are recorded. With the exception of samples for volatile analysis, the pH of chemically preserved samples is checked using Hydrion paper and recorded. All problems or discrepancies noted during this process are to be promptly reported to the B&R Environmental Project Manager. Inter-laboratory COC procedures and specific procedures for sample handling, storage, dispersement for analysis, and remnant disposal will be followed as specified by the subcontract laboratory's SOPs and/or QA Plan.

5.3 FINAL EVIDENCE FILES

The B&R Environmental central file will be the repository for all documents which constitute evidence relevant to sampling and analysis activities as described in this QAPP. B&R Environmental is the custodian of the evidence file and maintains the contents of these files, including all relevant records, reports, logs, field notebooks, photographs, subcontractor reports and data reviews in a secure, limited access location and under custody of the B&R Environmental facility manager. The control file will include at a minimum:

- field logbooks
- field data and data deliverables
- photographs
- drawings
- soil boring logs

- laboratory data deliverables
- data validation reports
- data assessment reports
- progress reports, QA reports, interim project reports, etc.
- all custody documentation (chain-of-custody forms, airbills, etc.)

Upon completion of the contract, all pertinent files will be relinquished to the custody of the United States Navy.

6.0 CALIBRATION PROCEDURES AND FREQUENCY

All instrumentation used to perform chemical measurements must be properly calibrated prior to use in order to obtain valid and usable results. The requirement to properly calibrate instruments prior to use applies equally to field instruments as it does to fixed laboratory instruments. Field instrument calibration is discussed in Section 6.1. Laboratory instrument calibration is discussed in Section 6.2.

6.1 FIELD INSTRUMENT CALIBRATION

Field instrument calibration is discussed in Section 2.6 of the attendant WP/SAP.

6.2 LABORATORY INSTRUMENT CALIBRATION

Calibration procedures for a specific laboratory instrument will consist of initial calibration (generally 3 to 5 points), initial calibration verification (inorganic methods only), and continuing calibration verification. In all cases, the initial calibration will be verified using an independently prepared calibration verification solution. The frequency of calibration will be performed according to the requirements of the specific methods.

All standards used to calibrate analytical instruments must be obtained from the National Institute of Standards and Technology (NIST) or through a reliable commercial supplier with a proven record for quality standards. All commercially supplied standards must be traceable to NIST reference standards, where possible, and appropriate documentation will be obtained from the supplier. In cases where documentation is not available, the laboratory will analyze the standard and compare the results to an USEPA-supplied known or previous NIST-traceable standard.

The calibration procedures and frequencies used by the subcontract laboratory will comply with the applicable CLP Statement of Work (SOW) or analytical method. Brief descriptions of calibration procedures for major instrument types follow.

6.2.1 GC/MS Volatile Organic Compound Analyses

For volatile organic compounds, the gas chromatograph/mass spectrometer (GC/MS) system will be tuned and calibrated in accordance with the appropriate CLP SOW (low-concentration water - OLC02.0; multi-media/multi-concentration - OLM01.8). A bromofluorobenzene (BFB) instrument performance check (tuning check) must be run prior to the initial and each continuing calibration and must meet all method-specified criteria before analysis may continue. Initial calibration is required before any samples are

analyzed and must include a blank and a minimum of five different concentrations as specified in the method. A BFB tuning check and a continuing calibration check, including the mid-range standard and a blank, must be performed at the beginning of each 12-hour shift during which analyses are performed.

6.2.2 GC/MS Semivolatile Organic Compound Analyses

For semivolatile organic compounds, the GC/MS system will be tuned and calibrated in accordance with the appropriate CLP SOW (OLM01.8). A decafluorotriphenyl phosphine (DFTPP) instrument performance check (tuning check) must be run prior to the initial and each continuing calibration and must meet all method-specified criteria before analysis may continue. Initial calibration is required before any samples are analyzed and must include a blank plus five different concentrations as specified in the method. A DFTPP tuning check and a continuing calibration check, including the mid-range standard and a blank, must be performed at the beginning of each 12-hour shift during which analyses are performed.

6.2.3 Organochlorine Pesticide Analyses

For organochlorine pesticide analyses, the GC system will be calibrated in accordance with the appropriate CLP SOW (OLM01.8) with one exception; Polychlorinated biphenyl (PCB) standards may be omitted from the calibration sequence since they are not project-specific target compounds. Initial calibration is required before any samples are analyzed. A multi-point initial calibration sequence is analyzed using dual column injection. The calibration sequence consists of a resolution check to prove analyte separation, a performance evaluation mixture (PEM) to show endrin and 4,4'-DDT degradation, and a three-point calibration of the individual pesticides to prove linearity. An instrument blank, to show system cleanliness, and a second PEM sample are then analyzed.

If all initial calibration criteria are met, samples may be analyzed for a period of 12 hours after the injection of the instrument blank. At the end of the 12-hour period, a second instrument blank followed by continuing calibration standard mixtures must be analyzed. If continuing calibration criteria are met, sample analysis may continue for an additional 12 hours. At this point, an instrument blank followed by a PEM is analyzed. The 12-hour clock continues, alternating between the continuing calibration standard mixtures and the PEM, until failure to meet method-specified criteria requires a new initial calibration.

6.2.4 Metals Analyses

6.2.4.1 Inductively Coupled Argon Plasma (ICP) Analyses

Inductively coupled plasma (ICP) spectrometry systems will be calibrated for the analysis of TAL metals in accordance with the USEPA CLP protocols outlined in ILM03.0. Initial calibration is required each day before any samples are analyzed and consists of a calibration blank and at least one standard. The standard must be within the demonstrated linear range of the instrument. The linear range is verified quarterly. Following initial calibration, an initial calibration verification sample (obtained from a different source than the solutions used for calibration), an initial calibration blank, and an interference check sample are analyzed. A continuing calibration verification sample and a continuing calibration blank are run every 2 hours or every 10 samples, whichever occurs first. A continuing calibration verification sample, a continuing calibration blank, and an interference check sample are also run after analysis of the last sample. The initial calibration verification standard, continuing calibration verification standard, and interference check sample each contain analytes of interest at different concentrations. In addition, a standard prepared at a concentration of two times the quantitation limit is analyzed at the beginning and end of each sample analysis run or a minimum of twice per 8-hour period. Linearity spanning the range of analysis is verified using this combination of standards. All calibration standards contain acids at the same concentrations as the sample digestates.

6.2.4.2 Atomic Absorption Analyses

Graphite furnace and cold vapor atomic absorption (GFAA and CVAA) analyses will be calibrated in accordance with the USEPA CLP protocols outlined in ILM03.0. Initial calibration is required each day before any samples are analyzed and consists of a calibration blank and at least three calibration standards (at least four standards for mercury) covering the range of concentrations of interest. The correlation coefficient of the regression of concentration versus response should be 0.995 or greater. Immediately following initial calibration, an initial calibration verification sample (obtained from a different source than the solutions used for calibration) and an initial calibration blank are analyzed. A continuing calibration verification sample and a continuing calibration blank are run every two hours or every ten samples, whichever occurs first. A continuing calibration verification sample and a continuing calibration blank are also run after analysis of the last sample.

6.2.5 Miscellaneous Parameters

Calibration and standardization requirements for the analysis of the remaining parameters will be performed as specified in the applicable analytical methods. Analytical methods are further discussed in Section 7.0 of this QAPP.

7.0 ANALYTICAL AND MEASUREMENT PROCEDURES

Samples will be subjected to field and laboratory parameter measurement as necessary based on the sample location under investigation. The analytical program for environmental samples collected at each anticipated location is provided in Table 2-2 of the WP/SAP.

Chemical/physical parameters to be measured using field instrumentation include volatile organics as methane equivalents (breathing zone air and soil vapors); temperature, specific conductance, pH, turbidity dissolved oxygen, and salinity (groundwater and surface water samples); and REDOX potential (groundwater samples only). In addition, divalent iron will be measured for groundwater samples using a field test kit. Measurement of field parameters and calibration of field instruments are discussed in Section 2.6 of the WP/SAP.

It is anticipated that Katahdin Analytical Services, 340 County Road #5, Westbrooke, Maine 04098; telephone (207)874-2400; fax (207)775-4029, will be used as the primary laboratory for analytical services. It is anticipated that grain size and methane analyses will be subcontracted by Katahdin Analytical Services to Summit Contest of Portland, Maine, and Air Toxics Limited of Folsom, California, respectively.

All groundwater, soil, and sediment samples collected for fixed-laboratory analysis during the NSB-NLON Lower Subase RI will be analyzed by a NFESC-approved laboratory. All groundwater samples for low-concentration volatiles analysis will be analyzed in accordance with the Superfund Analytical Methods for Low Concentration Water for Organics Analysis (OLC02.0). All samples for TCL organics and TAL metals will be analyzed in accordance with the CLP analytical procedures set forth in the USEPA SOWs for Organics Analysis (OLM01.8) and Inorganics Analysis (ILM03.0), respectively. Non-CLP methods will be used for quantitation of the remaining parameters. Tables 7-1 and 7-2 provide a summary of the laboratory analytical methods for the NSB-NLON Lower Subase RI.

A complete list of the target compounds/analytes, CRQLs, CRDLs, and estimated PQLs is provided in Section 1.3.2.2 of this QAPP. Data generated through use of CLP protocols will be reported to the CRQL for organics analysis and the CRDL for inorganics analysis. Analytes which are positively identified and which can be quantitated at concentrations below the CRQL/CRDL will be reported as specified in the appropriate CLP SOW. All environmental data generated through use of non-CLP methods will be reported to the analyte's PQL. An analyte's PQL is an expression of the method detection limit with consideration given to required adjustments to ensure that the precision and accuracy requirements of the

TABLE 7-1

SUMMARY OF ORGANIC AND INORGANIC ANALYTICAL PROCEDURES
AQUEOUS MATRICES
NSB-NLON, GROTON, CONNECTICUT

Analytical Parameter	Analytical Method
TCL Volatile Organics - Low Concentration	OLC02.0[1]
TCL Semivolatile Organics	OLM01.8[2]
TAL Metals	ILM03.0[3]
Lead	ILM03.0
Total Petroleum Hydrocarbons (TPH)	USEPA[4] 418.1
Total Organic Carbon (TOC)	USEPA 415.1
Alkalinity (as $CaCO_3$)	USEPA 310.1
Hardness (as $CaCO_3$)	USEPA 130.2
Chloride	USEPA 325.2
Nitrate	USEPA 353.2
Sulfate	USEPA 375.4
Phosphate (Total)	USEPA 365.4
Ammonia	USEPA 350.1
Methane	USEPA RSKSOP-175[5]

1 USEPA CLP, 1992. Superfund Analytical Methods for Low Concentration Water for Organics Analysis, OLC02.0.
2 USEPA (U. S. Environmental Protection Agency) CLP, 1991. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM01.8.
3 USEPA CLP. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM03.0.
4 USEPA, 1983. Methods for Chemical Analysis of Water and Wastes.
5 USEPA, R.S. Kerr Environmental Laboratory, B.S. Newell, Sample Preparation and Calculations for Dissolved Gas Analysis in Water Samples Using a GC Headspace Equilibration Technique, Revision No. 0, August 1994.

TABLE 7-2

SUMMARY OF ORGANIC AND INORGANIC ANALYTICAL PROCEDURES
SOLID MATRICES
NSB-NLON, GROTON, CONNECTICUT

Analytical Parameter/Procedure	Method
TCL Volatile Organics	OLM01.8[1]
TCL Semivolatile Organics	OLM01.8
TCL Pesticides	OLM01.8
TAL Metals	ILM03.0[2]
Total Petroleum Hydrocarbons (TPH)	USEPA[3] 418.1
Total Organic Carbon (TOC)	Lloyd Kahn[4]
Ammonia	Modified USEPA 350.1[5]
pH	SW-846[6] 9045
AVS/SEM	USEPA, 1991[7]
Grain Size	ASTM[8] D422
Synthetic Precipitation Leaching Procedure (SPLP)	SW-846 1312

1 USEPA (U. S. Environmental Protection Agency) CLP, 1991. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM01.8.
2 USEPA CLP. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM03.0.
3 USEPA, 1983. Methods for Chemical Analysis of Water and Wastes.
4 USEPA, Region II, Environmental Services Division, Monitoring Management Branch. Lloyd Kahn, Determination of Total Organic Carbon in Sediment.
5 Solid Sample preparation involves distillation by SM 4500-NH_3 B (Standard Methods for the Examination of Water and Wastewater, 1992. American Public Health Association, American Water Works Association, Water Environment Association, 18th ed.), using 5g (dry-weight) of sample and 250 ml of deionized water. Distillate is then analyzed using EPA Method 350.1.
6 USEPA, 1986. Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods. SW-846, 3rd ed.
7 USEPA, 1991. Draft Analytical Method for Determination of Acid Volatile Sulfide in Sediment.
8 American Society for Testing and Materials (ASTM), 1995. Annual Book of ASTM Standards. Volume 04.08, Soil and Rock; Building Stones.

method are attainable. The PQLs provided in the tables in Section 1.3.2.2 are estimated since these values may vary based on the laboratory.

All solid sample results will be reported on a dry-weight basis. Percent solids determination will be based on CLP protocol. Quantitation and detection limits will also be adjusted, as necessary, based on dilutions and sample volume.

8.0 INTERNAL QUALITY CONTROL CHECKS

Field-related QC checks were discussed in Section 3.0 of this QAPP and in Section 3.4 of the attendant WP/SAP. This section provides additional information regarding internal quality control checks for the field and the laboratory.

8.1 FIELD QUALITY CONTROL CHECKS

QC procedures for field measurements will include calibrating the instruments as discussed in Section 2.6 of the WP/SAP. Assessment of field sampling precision and bias will be made by collection of field duplicates and rinsate blanks for laboratory analysis as discussed in Section 3.6 of this QAPP.

8.2 LABORATORY QUALITY CONTROL CHECKS

The subcontract laboratory will have a QC program that ensures the reliability and validity of the analyses performed at the laboratory. Internal quality control procedures for CLP analyses (volatile and semivolatile organics and metals) will comply with the SOWs for low-concentration water organics (OLC02.0), multi-media/multi-concentration organics (OLM03.1), and inorganics (ILM04.0). Internal quality control procedures for non-CLP analyses will comply with the applicable analytical method requirements.

Several internal laboratory QC checks are briefly discussed in the remainder of this section.

Laboratory method blanks are prepared and analyzed in accordance with the analytical method employed to determine whether contaminants originating from laboratory sources have been introduced and have affected environmental sample analyses. A method blank generally consists of an aliquot of analyte-free water (or purified sodium sulfate for soil/sediment samples) that is subjected to the same preparation and analysis procedures as the environmental samples undergoing analysis. With the exception of recognized volatile and semivolatile common laboratory contaminants (i.e., methylene chloride, acetone, 2-butanone, and phthalate esters) detected through use of the organic SOW, method blanks must not contain levels of target analytes above the reported detection limits (above 2.5X the CRQL for methylene chloride and above 5X the CRQL for acetone, 2-butanone, and phthalate esters). If method blank contamination is found to exist above allowable limits, corrective actions indicated in the CLP SOWs or laboratory SOPs must be followed. Under no circumstances are laboratory method blank contaminant values subtracted from environmental sample analysis results.

Matrix spike analysis for organic fraction analyses is performed in duplicate as a measure of laboratory precision. For inorganic analyses, one matrix spike analysis and one **laboratory duplicate** analysis are performed for every 20 environmental sample analyses of like matrix. With the exception of VOC MSD analyses, laboratory duplicates are prepared by thoroughly mixing and splitting a sample aliquot into two portions and analyzing each portion following the same analytical procedures that are used for the environmental sample analyses. For VOC MSD analyses, a second sample aliquot is used for analysis in order to avoid VOC constituent loss through the homogenization process. The field crew provides extra volumes of sample matrices designated for laboratory quality control analyses, as required. As discussed in Section 3.0 of this QAPP, control limits for MS and laboratory duplicate analyses are specified in the SOWs for CLP analyses and are established by the laboratory for non-CLP analyses.

Surrogates are organic compounds (typically brominated, fluorinated, or isotopically labeled) which are similar in nature to the compounds of concern, and which are not likely to be present in environmental media. Surrogates are spiked into each sample, standard, and method blank prior to analysis, and are used only in organic chromatographic analysis procedures as a check of method effectiveness. As discussed in Section 3.0, surrogate recoveries are evaluated against control limits specified in the CLP SOW, where applicable, or laboratory-derived control limits.

Laboratory control samples serve to monitor the overall performance of each step during the analysis, including the sample preparation. Laboratory control sample analysis will be performed for low-concentration TCL volatiles, TAL metals, and as required by the applicable analytical methods for non-CLP methods. Aqueous LCS results must fall within the control limits specified in the CLP SOW, where applicable, or established by the laboratory. Solid LCS results must fall within the control limits established by the supplier of the LCS standard. Aqueous and solid LCSs shall be analyzed utilizing the same sample preparations, analytical methods, and QA/QC procedures as employed for the samples.

Internal standard performance criteria ensure that volatile and semivolatile GC/MS analysis sensitivity and response are stable during every analytical run. Internal standard area counts for samples and blanks must not vary by more than a factor of two (- 50% to + 100%) from the associated 12-hour calibration standard (±40% for low-concentration volatile analysis). The retention time of the internal standards in samples and blanks must not vary by more than ±30 seconds from the retention time of the associated 12-hour calibration standard (±20 seconds for low-concentration volatile analysis).

9.0 DATA REDUCTION, VALIDATION, AND REPORTING

This section describes the procedures to be used for data reduction, validation, and reporting for the NSB-NLON Lower Subase RI. All data generated during the course of the investigation will be maintained in hardcopy format by B&R Environmental in the Naval Facilities Engineering Command Northern Division designated central files located in B&R Environmental's Pittsburgh, Pennsylvania office.

In addition to the central files, photocopies of all hardcopy data (as well as electronic data) will be maintained in the Chemistry/Toxicology/Risk Assessment Department database records files located in B&R Environmental's Pittsburgh, Pennsylvania office. Upon completion of the contract, all files will be relinquished to the Navy.

9.1 DATA REDUCTION

Data reduction will be completed for both field measurements and laboratory-generated analytical data. Field data reduction will be relatively limited versus the degree of laboratory data reduction required for the project. Reduction of both field data and laboratory data are discussed in the remainder of this section.

9.1.1 Field Data Reduction

Field data will be generated as a result of real time measurement of organic vapor concentrations via a PID or FID (for health and safety monitoring and to support selection of soil samples for shipment to the analytical laboratory), through on-site water quality testing for general indicator parameters including pH, specific conductance, turbidity, and temperature, and through the use of field instruments or field test kits for measurement of additional parameters including REDOX potential, dissolved oxygen, salinity, and divalent iron.

Field measurements of organic vapor concentrations (parts per million on a volume/volume basis relative to methane or benzene) will be recorded in the site logbook and incorporated into the RI Report. The remaining field parameters will be recorded in the site logbook and on sample logsheets immediately after the measurements are taken and later encoded in the NSB-NLON data base for presentation in the RI Report. If an error is made in the logbook, the error will be legibly crossed out (single-line strikeout), initialed and dated by the field member, and corrected in a space adjacent to the original (erroneous) entry. No calculations will be necessary to reduce these data for inclusion in RI Report. Field data will be entered in the electronic data base manually, and the entries will be verified by an independent reviewer to make sure that no "transcription" errors occurred.

Field measurements will be recorded and reported in the following units:

- Hydronium ion concentration (standard pH units)
- Temperature (degrees Celsius)
- Specific Conductance (millimhos)
- Turbidity (Nephelometric turbidity units)
- Dissolved oxygen (mg/L)
- Divalent iron (mg/L)
- REDOX Potential (mV)
- Salinity (%)

Standard pH units as specified above is the negative logarithm (base 10) of the hydronium ion concentration in moles/liter.

9.1.2 Laboratory Data Reduction

Data reduction for laboratory analytical data generated via the USEPA CLP analytical protocol, quality assurance requirements, and reporting procedures (TCL volatile and semivolatile organics and TAL metals) will be completed in accordance with the most current SOWs for Organic and Inorganic Analysis as identified in previous sections of this QAPP. Laboratory data reduction of analytical results generated via non-CLP methods will be completed in accordance with the applicable analytical methods.

Laboratory analytical data will be reported using standard concentration units to ensure comparability with regulatory standards/guidelines and previous analytical results. Reporting units for solid and aqueous matrices for the classes of chemicals under consideration are as follows:

Groundwater samples:

- TCL volatile and semivolatile organics - µg/L
- TAL metals - µg/L
- TPH, TOC, alkalinity, hardness, chloride, nitrate, sulfate, phosphate, ammonia, and methane - mg/L

Soil/Sediment samples:

- TCL volatile and semivolatile organics - µg/kg
- TCL pesticides - µg/kg
- TAL metals - mg/kg
- TPH, TOC, ammonia, AVS, SEM metals - mg/kg
- pH - standard pH units
- Grain size - percent finer (#200 sieve)

SPLP Leachates:

- TAL metals and/or lead - µg/L

Field Quality Control sample results will be included in the database for the NSB-NLON Lower Subase RI. Specifically, the analytical results for field duplicates, source water blanks, trip blanks, rinsate blanks, and ambient condition blanks will be provided. The results for field QC samples will be considered during the course of data validation (in concert with laboratory method blanks) to eliminate false positive results according to the 5- and 10-times rules specified in the National Functional Guidelines for Organic and Inorganic Data Review. The results for laboratory QC samples such as method blanks will not be presented in the RI Report database. In addition, only the original (unspiked) sample results for MS/MSD samples will be provided in the database.

9.2 DATA VALIDATION

Validation of field measurements and laboratory analytical data are discussed in this section. Validation of field data will be limited to real time "reality" checks whereas laboratory analytical data will be validated in accordance with current USEPA guidance. Validation of field measurements is discussed in Section 9.2.1. Validation of laboratory analytical data is discussed in Section 9.2.2.

9.2.1 Field Measurement Data Validation

Field measurements will not be subjected to a formal data validation process. However, field technicians will ensure that the equipment used for field measurement is performing accurately via calibration as discussed in Section 2.6 of the WP/SAP. As described in Section 9.1.1, all field data entered into the electronic database will be independently reviewed for transcription errors.

9.2.2 Laboratory Data Validation

One hundred percent of the laboratory data will be validated. Validation of analytical data will be completed by the B&R Environmental Chemistry Department located in B&R Environmental's Pittsburgh, Pennsylvania office. Final review and approval of validation deliverables will be completed by the Department's Data Validation Coordinator.

All CLP laboratory analytical data will be subjected to validation in accordance with the National Functional Guidelines for Organic and Inorganic Data Review. Data validation will be completed to ensure that the data are of evidentiary quality. Particular emphasis will be placed on holding time compliance, equipment calibration, spike recoveries, and blank results, although all required elements of the validation process will be considered. The analytical results for non-CLP parameters will be validated versus the applicable analytical methods. Validation of these data will conform to the National Functional Guidelines to the greatest extent practicable.

9.3 DATA REPORTING

9.3.1 Field Measurement Data Reporting

Field data will be reported in the units discussed in Section 9.1.1. The RI Report will include a comprehensive database including all field measurements (specifically organic vapor concentrations, pH, specific conductance, temperature, turbidity, dissolved oxygen, REDOX potential, and divalent iron). Field measurements will be transferred from the site logbook or sample logsheets to the electronic database manually and will be reviewed for accuracy by an independent reviewer. Transcription of field measurements to the electronic database will be completed shortly after completion of the field investigation and prior to receipt of laboratory analytical data.

All records regarding field measurements (i.e., field logbooks, sampling logbooks, and sample logsheets) will be placed in B&R Environmental's Northern Division central files upon completion of the field effort. Entry of these results in the data base will require removal of these results from the files. Outcards will be used to document the removal of any such documentation from the files (date, person, subject matter). Field measurement data will be reported in an appendix of the RI Report at a minimum and may also be reported in summary fashion if they are indicative of the presence of contamination (e.g., high specific conductance readings).

9.3.2 Laboratory Data Reporting

Data reported by the laboratory will be in accordance with CLP reporting format, including all non-CLP data (to the extent practicable). All pertinent quality control data including raw data and summary forms for blanks, standards analysis, calibration information, etc., will be provided for the non-CLP analyses. Case narratives will be provided for each Sample Delivery Group.

All environmental and field QC sample results (trip blanks, field duplicates, rinsate blanks, source water blanks, ambient condition blanks) will be included in the RI Report as an appendix. The database will include pertinent sampling information such as sample number, sampling date, general location, depth, and survey coordinates (if applicable). Sample-specific detection limits will be reported for nondetected analytes. Units will be clearly summarized in the data base and will conform to those identified in Section 9.1.2. The analytical data may also be reported in summary fashion within the body of the RI Report text in tabular and graphic fashion.

Data will be handled electronically pursuant to the electronic deliverable requirements specified in B&R Environmental's Basic Ordering Agreement with analytical laboratories. This agreement requires the analytical laboratories to provide data in both hardcopy and electronic form. The original electronic diskettes and the original hardcopy analytical data are maintained in B&R Environmental's Northern Division central files as received.

Validation will be completed using the hard copy data. Upon completion of validation of a Sample Delivery Group and review by the Data Validation Coordinator, the validation qualifiers will be entered in the electronic data base and will be subjected to independent review for accuracy. During this review process, the electronic data base printout will also be contrasted with the hard copy data (Form Is) to ensure that the hard copy data and electronic data are consistent.

In addition, a summary of the data validation qualifiers for all project samples will be prepared. This summary will include a list of chemicals identified as laboratory and/or field QC blank contaminants, holding time exceedences, samples exhibiting field duplicate/replicate imprecision as well as affected chemicals, rejected results and associated specific causes, and general causes of estimated results. This summary will facilitate the preparation of a summary of the data validation results and completeness assessment for inclusion in the RI Report.

10.0 PERFORMANCE AND SYSTEM AUDITS

Performance and system audits will be performed periodically to ensure that work is being implemented in accordance with the approved Project Plans and in an overall satisfactory manner. Such audits will be performed by various personnel and will include evaluation of field, laboratory, data validation, and data reporting processes. Examples of pertinent audits are as follows:

- The FOL will supervise and check daily that the field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and fieldwork is documented accurately and neatly.

- Performance and system audits of the laboratory will be performed regularly, in accordance with the requirements of the CLP (external), by a Navy Contractor (internal), and in accordance with the Laboratory Quality Assurance Plan (internal).

- Data validators will review (on a timely basis) the chemical analytical data packages submitted by the laboratory. The data validators will check that the data were obtained through use of an approved methodology, that the appropriate level of QC effort and reporting was conducted, and whether or not the results are in conformance with QC criteria. On the basis of these factors, the data validator will generate a report describing data limitations, which will be reviewed internally by the Data Validation Coordinator prior to submittal to the Project Manager.

- A formal audit of the field sampling procedures may be conducted by the B&R Environmental Quality Assurance Manager (QAM) or designee in addition to the auditing that is an inherent part of the daily project activities. The purpose of this audit is to ensure that sample collection, handling, and shipping protocols, as well as equipment decontamination and field documentation procedures, are being performed in accordance with the approved Project Plans and SOPs.

- A sample tracking system, as further described in Section 1.8.1 of the WP/SAP, will be employed for all environmental samples. This system will allow for early detection of errors made in the field or by the laboratory so that necessary adjustments can be made while the field crew is mobilized.

- The Project Manager will maintain contact with the FOL and Data Validation Coordinator to ensure that management of the acquired data proceeds in an organized and expeditious manner. Similarly,

the Project Manager will interface with the Risk Assessment and Modeling Coordinators, as applicable.

11.0 PREVENTIVE MAINTENANCE PROCEDURES

Measuring equipment used in environmental monitoring or analysis for the NSB-NLON Lower Subase RI shall be maintained in accordance with the manufacturer's operation and maintenance manuals. Equipment and instruments shall be calibrated in accordance with the procedures, and at the frequency, discussed in Section 6.0 (Calibration Procedures and Frequency). Preventive maintenance for field and laboratory equipment is discussed in the remainder of this section.

11.1 FIELD EQUIPMENT PREVENTIVE MAINTENANCE

B&R Environmental 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 B&R Environmental 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 also maintains the equipment manual library.

- 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 B&R Environmental SOPs before being taken to the job site and during field activities.

- During calibration, an appropriate maintenance check is performed on each piece of equipment. Any problems encountered while operating the instrument will be recorded in the field log book including a description of the symptoms and corrective actions taken.

- If problem equipment is detected or should require service, the equipment should be logged, tagged, and segregated from equipment in proper working order. Use of the instrument will not be resumed until the problem is resolved.

11.2 LABORATORY INSTRUMENT PREVENTIVE MAINTENANCE

Proper maintenance of laboratory instruments and equipment is essential to ensuring their readiness when needed. Dependent on manufacturer's recommendations, maintenance intervals are established for each instrument. All instruments must be labeled with a model number and serial number, and a maintenance logbook must be maintained for each instrument. Personnel must be alert to the maintenance status of the equipment they are using at all times.

11.2.1 Major Instruments

Table 11-1 provides a summary of preventive maintenance procedures typically performed for key analytical instruments. Maintenance of key instruments is sometimes covered under service contracts with external firms. These contracts provide for periodic routine maintenance to help guard against unexpected instrument downtime. The contracts also provide for quick response for unscheduled service calls when malfunctions are observed by the operator.

The use of manufacturer recommended grades or better of supporting supplies and reagents is also a form of preventive maintenance. For example, gases used in the various gas chromatographs and metals instruments should be of sufficient grade to minimize fouling of the instrument. The routine use of septa, chromatographic columns, ferrules, AA furnace tubes, and other supporting supplies from reputable manufacturers will assist in averting unnecessary periods of instrument downtime.

11.2.2 Refrigerators/Ovens

The temperatures of refrigerators used for sample storage and drying ovens will be monitored a minimum of once daily. The acceptable range for refrigerator temperatures is 4°C ±2°C. Required temperatures of ovens will vary based on the analytical methods for which the ovens are used. The temperatures will be recorded on temperature logs. The logs will contain the following information at a minimum:

- Date
- Temperature
- Initials of person performing the check

Maintenance of the logs is typically the responsibility of the sample custodian. However, assignment of responsibilities for temperature monitoring to specific personnel does not preclude the participation of other laboratory personnel. If unusual temperature fluctuations are noted, it is the responsibility of the

TABLE 11-1

TYPICAL PREVENTIVE MAINTENANCE FOR KEY ANALYTICAL INSTRUMENTS NSB-NLON, GROTON, CONNECTICUT

Instrument	Preventive Maintenance	Maintenance Frequency
GC/MS	Volatiles: Bake oven, replace septum, check carrier gas. Semivolatiles: Replace the septum, clean injection port, replace liner, bake oven, check carrier gas, clean the source. Replace solvent washes and clean syringe.	As required. As required. Daily.
GC	Replace solvent washes and clean syringe. Clip column, clean injection port, replace liner, and bake oven.	Daily. As required.
ICP	Change sample introduction tubing, clean nebulizer, clean spray chamber, clean torch, manual profile, and automatic profile optics.	As required.
GFAA	Clean contact cylinders, replace/clean tube, check lamp alignment.	As required.
CVAA	Change sample introduction tubing, change drying cell, re-zero detector.	As required.
Spectrophotometer	Check that cuvette has no scratch on its surface. Turn power off at the end of the day and warm up for at least one hour before use.	Daily. Daily
TOC Analyzer	Refresh phosphoric acid. Clean catalyst. Replace water in IC chamber.	Biweekly. As required. Biweekly.

observer to immediately notify the person in charge of the discrepancy before the condition of the samples is compromised.

Unstable or fluctuating temperatures may be indicative of malfunctions in the cooling or heating system. On the other hand, the instability may be due to frequent opening of the door. Regardless of the cause, such an observation must be investigated, and modifications must be made to access procedures or repairs to equipment must be made to prevent jeopardizing the integrity of the samples.

12.0 SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY, AND COMPLETENESS

Compliance with the QC objectives outlined in Section 3.0 will be monitored via two separate mechanisms. Precision and accuracy will be assessed through data validation in accordance with the National Functional Guidelines (to the extent practicable for non-CLP analyses). Compliance with the completeness objectives for field and laboratory data/measurement will be calculated by hand (field measurements) and electronically via a database subroutine (laboratory data). Information necessary to complete the precision and accuracy calculations will be provided in electronic and hardcopy form by the subcontract laboratory. Equations to be used for the precision, accuracy, and completeness assessment are outlined in the remainder of this section.

12.1 ACCURACY ASSESSMENT

To assure the accuracy of the analytical procedures, a minimum of 1 of every 20 samples is spiked with a known amount of the analyte or analytes to be evaluated. The spiked sample is then analyzed. The increase in concentration of the analyte observed in the spiked sample, because of the addition of a known quantity of the analyte, compared to the reported value of the same analyte in the unspiked sample determines the percent recovery. Control charts are plotted for each commonly analyzed compound and kept on matrix-specific and analyte-specific bases. The %R for a spiked sample is calculated according to the following formula:

$$\%R = \frac{\text{Amount in Spiked Sample} - \text{Amount in Sample}}{\text{Known Amount Added}} \times 100\,\%$$

12.2 PRECISION ASSESSMENT

Duplicate samples (for inorganic analyses) and MSD samples (for organic analyses) are prepared and analyzed at a minimum frequency of 1 per every 20 environmental samples. Duplicate samples are prepared by dividing an environmental sample into equal aliquots.

MSD samples are prepared by dividing an environmental sample into equal aliquots and then spiking each of the aliquots with a known amount of analyte. The duplicate samples are then included in the analytical sample set. The splitting of the sample allows the analyst to determine the precision of the preparation and analytical techniques associated with the duplicate samples. The RPD between the sample (or spike)

and duplicate (or duplicate spike) is calculated and plotted. The RPD is calculated according to the following formula:

$$RPD = \frac{\text{Amount in Sample} - \text{Amount in Duplicate}}{0.5\ (\text{Amount in Sample} + \text{Amount in Duplicate})} \times 100\ \%$$

12.3 COMPLETENESS ASSESSMENT

Completeness is the ratio of the number of valid sample results to the total number of sample results expected to be obtained for the project as a whole. Following the completion of the analytical testing and data validation, the percent completeness will be calculated by the following equation:

$$\text{Completeness} = \frac{(\text{number of valid measurements})}{(\text{number of measurements planned})} \times 100\ \%$$

The results of the data validation process and the completeness assessment will be summarized in the RI Report using the summary format discussed in Section 9.3.2 and an electronic database subroutine.

13.0 CORRECTIVE ACTION

Under the B&R Environmental QA/QC program, it is required that any and all personnel noting conditions adverse to quality report these conditions immediately to the Project Manager and QAM. These parties, in turn, are charged with performing root-cause analyses and implementing appropriate corrective action in a timely manner. It is ultimately the responsibility of the QAM to document all findings and corrective actions taken and to monitor the effectiveness of the corrective measures performed.

13.1 FIELD CORRECTIVE ACTION

Field nonconformances or conditions adverse to quality must be identified and corrected as quickly as possible so that work integrity or quality of product is not compromised. The need for corrective action may arise based on deviations from Project Plans and procedures, adverse field conditions, or other unforeseen circumstances. Corrective action needs may become apparent during the performance of daily work tasks or as a consequence of internal or external field audits.

Corrective action may include resampling and may involve amending previously approved field procedures. If warranted by the severity of the problem (e.g., if a change in the approved Project Plan documents or SOPs is required), the Navy will be notified in writing via a Field Task Modification Request (FTMR), and Navy (in conjunction with USEPA Region I and CTDEP) approvals will be obtained. The FOL is responsible for initiating FTMRs; an FTMR will be initiated for all deviations from the Project Plan documents, as applicable. An example of an FTMR is provided as Figure 13-1. Copies of all FTMRs will be maintained with the onsite project planning documents and will be placed in the final evidence file.

Minor modifications to field activities such as a slight offset of a boring location will be initiated at the discretion of the FOL, subject to onsite approval by NSB-NLON personnel. Approval for major modifications (e.g., elimination of a sampling point) must be obtained via an FTMR.

FIGURE 13-1

BROWN & ROOT ENVIRONMENTAL
FIELD TASK MODIFICATION REQUEST FORM

Client Identification | Project Number | FTMR Number

To_____ Location_____ Date_____

Description:

_____
_____
_____
_____

Reason for Change:

_____
_____
_____
_____

Recommended Disposition:

_____
_____
_____
_____

_____
Field Operations Leader (Signature, if applicable) | Date

Disposition:

_____
_____
_____
_____

_____
Project Manager (Signature, if required) | Date

_____
Distribution:
Program Manager
Quality Assurance Officer
Project Manager
Field Operations Leader

Others as required_____
_____
_____
_____

13.2 LABORATORY CORRECTIVE ACTION

In general, laboratory corrective actions are warranted whenever an out-of-control event or potential out-of-control event is noted. The specific corrective action taken depends on the specific analysis and the nature of the event. Generally, the following occurrences alert laboratory personnel that corrective action may be necessary:

- QC data are outside established warning or control limits;
- Method blank analyses yield concentrations of target analytes above acceptable levels;
- Undesirable trends are detected in spike recoveries or in duplicate RPDs;
- There is an unexplained change in compound detection capability;
- Inquiries concerning data quality are received; and
- Deficiencies are detected by laboratory QA staff audits or from performance evaluation sample test results.

Corrective actions are typically documented for out-of-control situations on a corrective action form. Using a corrective action form, any employee may notify the QA/QC Officer of a problem. The QA/QC Officer generally initiates the corrective action by relating the problem to the appropriate Laboratory Manager and/or Internal Coordinator, who then investigates or assigns responsibility for investigating the problem and its cause. Once determined, an appropriate corrective action is approved by the QA/QC Officer. Its implementation is verified and documented on the corrective action form and is further documented through audits.

13.3 CORRECTIVE ACTION DURING DATA VALIDATION AND DATA ASSESSMENT

The need for corrective action may become apparent during data validation, interpretation, or presentation activities, or problems may be identified as a result of oversight findings. The performance of rework, instituting a change in work procedures, or providing additional/refresher training are possible corrective actions relevant to data evaluation activities. The Project Manager will be responsible for approving the implementation of corrective action.

14.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

QA reports to management will be provided in three primary formats during the course of the NSB-NLON Lower Subase RI. Data validation letter reports will be prepared on a Sample Delivery Group-specific basis and will summarize QA issues for the subcontract laboratory data. In addition, written weekly reports summarizing accomplishments and QA/QC issues during the field investigation will be provided by the FOL. Finally, monthly progress reports are provided by the Project Manager. In addition, a summary of data validation qualifiers and a completeness assessment for all project samples will be included in the RI Report.

14.1 CONTENTS OF PROJECT QUALITY ASSURANCE REPORTS

The contents of the specific QA reports are as follows. The data validation reports address all major and minor laboratory noncompliances as well as noted sample matrix effects. In the event that major problems occur with the analytical laboratory (e.g., holding time exceedances or calibration noncompliances, etc.) the Data Validation Coordinator will notify the Project Manager, the Technical Program Manager, and the Laboratory Services Coordinator. Such notifications (if necessary) are typically provided via internal memoranda and are placed in the project file. Such reports contain a summary of the noncompliance, a synopsis of the impact on individual projects, and recommendations regarding corrective action and compensational adjustments. Corrective actions are initiated at the program level.

The FOL will provide the Project Manager with weekly reports regarding accomplishments, deviations from the WP/SAP, upcoming activities, and a QA summary during the course of the field investigation. In addition, monthly project review meetings are held for all active Navy CLEAN projects. Issues discussed at the project review meeting include all aspects of budget and schedule compliance, and QA/QC problems. The Project Manager provides a monthly progress report to the Navy which addresses the project budget, schedule, accomplishments, planned activities, required revisions of the QAPP, and QA/QC issues and intended corrective actions.

14.2 INDIVIDUALS RECEIVING/REVIEWING QUALITY ASSURANCE REPORTS

Data validation QA Reports are provided to the Project Manager for inclusion in the project files. In the event that major problems are observed for a given laboratory, the Program Manager, Deputy Program Manager, QA Manager, Project Manager, and Laboratory Services Coordinator are provided with copies of the QA report. Weekly field progress reports are provided to the Project Manager. Monthly progress

reports are provided to the Navy CLEAN Program Manager and the Navy CLEAN Contracting Officers Technical Representative.

APPENDIX D

HEALTH & SAFETY PLAN

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1.0 INTRODUCTION

This Health and Safety Plan (HASP) has been developed to provide practices and procedures for Brown & Root Environmental and subcontractor personnel engaged in investigatory activities at the Lower Subase of the Naval Submarine Base - New London (NSB-NLON), located in Groton, Connecticut. This HASP must be used in conjunction with the Brown & Root Environmental (B&R Environmental) Health and Safety Guidance Manual. Both of these documents must be present at the site during the performance of all site activities. The Guidance Manual provides detailed information pertaining to the HASP as well as applicable B&R Environmental Standard Operating Procedures (SOPs). This HASP and the contents of the Guidance Manual were developed to comply with the requirements stipulated in 29 CFR 1910.120 (OSHA's Hazardous Waste Operations and Emergency Response Standard).

This HASP has been developed using the latest available information regarding known or suspected chemical contaminants and potential physical hazards associated with the proposed work at the Lower Subase. The HASP will be modified if new information becomes available. All changes to the HASP will be made with the approval of the B&R Environmental Site Safety Officer (SSO) and the B&R Environmental Health and Safety Manager (HSM). Requests for modifications to the HASP will be directed to the SSO who will determine whether to make the changes. The SSO will notify the Project Manager (PM), who will notify all affected personnel of changes.

1.1 KEY PROJECT PERSONNEL AND ORGANIZATION

This section defines responsibility for site safety and health for B&R Environmental and subcontractor employees engaged in onsite activities. Personnel assigned to the positions discussed below will exercise the primary responsibility for all onsite health and safety. These persons will be the primary point of contact for any questions regarding the safety and health procedures and the selected control measures that are to be implemented for onsite activities.

- The B&R Environmental PM is responsible for the overall direction of health and safety for this project.

- The Project Health and Safety Officer (PHSO) is responsible for developing this HASP in accordance with applicable OSHA regulations. Specific responsibilities include:

    i. Providing information regarding site contaminants and physical hazards associated with the site

ii. Establishing air monitoring and decontamination procedures
iii. Assigning personal protective equipment
iv. Determining emergency response procedures and emergency contacts
v. Stipulating training requirements and reviewing appropriate training and medical surveillance certificates
vi. Providing standard work practices to minimize potential injuries and exposures associated with hazardous waste work.

- The B&R Environmental Field Operations Leader (FOL) is responsible for implementation of the HASP with the assistance of an appointed SSO. The FOL manages field activities, executes the work plan, and enforces safety procedures as applicable to the work plan.

- The SSO supports site activities by advising the FOL on all aspects of health and safety on-site. These duties may include:

  i. Coordinates all health and safety activities with the FOL
  ii. Selects, applies, inspects, and maintains personal protective equipment
  iii. Establishes work zones and control points
  iv. Implements air monitoring program for onsite activities
  v. Verifies training and medical clearance of onsite personnel status in relation to site activities
  vi. Implements Hazard Communication and Respiratory Protection Programs
  vii. Coordinates emergency services.
  viii. Provides site specific training for all on-site personnel

- Compliance with the requirements stipulated in this HASP is monitored by the SSO and coordinated through the B&R Environmental CLEAN Health and Safety Manager.

1.2 SITE INFORMATION AND PERSONNEL ASSIGNMENTS

Site Name: NAVAL SUBMARINE BASE - NEW LONDON LOWER SUBASE

Client Contact: Mark Evans
Phone No.: (610) 595-0567 (Ext. 162)

Base Contact: Andy Stackpole
Phone No.: (860) 449-5191

Project Team:

B&R Environmental Personnel:	Discipline/Tasks Assigned:
Corey A. Rich, P.E.	Project Manager (PM)
TBD	Field Operations Leader (FOL)
TBD	Site Safety Officer (SSO)
Matthew M. Soltis, CIH, CSP	CLEAN Health and Safety Manager
Donald J. Westerhoff, CSP	Project Health and Safety Officer (PHSO)

Other Potential B&R Environmental Project Personnel:

TBD	Field Geologist

Non-B&R Environmental Personnel	Affiliation/Discipline/Tasks Assigned

Prepared by: Donald J. Westerhoff, CSP

Reviewed and Approved by:

Corey A. Rich, P.E.
Project Manager

Matthew M. Soltis CIH, CSP
CLEAN Health and Safety Manager

2.0 EMERGENCY ACTION PLAN

2.1 INTRODUCTION

This section has been developed as part of a preplanning effort to direct and guide field personnel in the event of an emergency. In the event of an emergency, which cannot be handled using onsite resources, personnel will evacuate to a safe place of refuge and the appropriate emergency response agencies will be notified. It has been determined that a majority of potential emergency situations would be better supported by outside emergency responders. Based on this determination, B&R Environmental and subcontractor personnel will not provide emergency response support beyond the capabilities of onsite response. Workers who are ill or who have suffered a non-serious injury may be transported by site personnel to nearby medical facilities, provided that such transport does not aggravate or further endanger the welfare of the injured/ill person. The emergency response agencies listed in this plan are capable of providing the most effective response, and as such, will be designated as the primary responders. These agencies are located within a reasonable distance from the area of site operations, which ensures adequate emergency response time. This Emergency Action Plan conforms to the requirements of 29 CFR 1910.38(a), as allowed in 29 CFR 1910.120(l)(1)(ii).

B&R Environmental will, through necessary services, provide the following response measures:

- Incipient stage fire fighting support and prevention
- Incipient spill control and containment measures and prevention
- Removal of personnel from emergency situations
- Initial medical support for injuries or illnesses requiring only first-aid level support
- Site control and security measures as necessary

2.2 PRE-EMERGENCY PLANNING

Through the initial hazard / risk assessment effort, injuries or illnesses resulting from exposure to chemical or physical hazards or fire are the most probable emergencies that could be encountered during site activities.

To minimize and eliminate these potential emergency situations, pre-emergency planning activities associated with this project include the following (which are the responsibility of the SSO and/or the FOL):

- Coordinating with local Emergency Response personnel to ensure that B&R Environmental emergency action activities are compatible with existing emergency response procedures.

- 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:

  - Chemical Inventory (used on-site), with Material Safety Data Sheets.
  - On-site personnel medical records (Medical Data Sheets).
  - A log book identifying personnel on site each day.

It will be the responsibility of the B&R Environmental FOL to ensure the information is available and present at the site, including:

- Identifying a chain of command for emergency action.

- Educating site workers to the hazards and control measures associated with planned activities at the site, and to provide early recognition and prevention where possible.

- Periodically practice and drill site workers in incidental response measures.

2.3 EMERGENCY RECOGNITION AND PREVENTION

2.3.1 Recognition

Foreseeable emergency situations that may be encountered during site activities will generally be recognizable by visual observation. Visual observation is primarily relevant for physical hazards that may be associated with the proposed scope of work. Visual observation will also play a role in detecting some chemical exposures. To adequately recognize exposures to site contaminants, site personnel must have a clear knowledge of signs and symptoms of exposure associated with the site contaminants. This information is provided in Table 6-1 of this HASP. Potential site hazards, the activities that they have been associated with, and the recommended control methods are discussed in detail in Section 5.0 and 6.0 of this HASP. Additionally, early recognition of emergency situations will be supported by daily site surveys to eliminate any situation predisposed to an emergency. The FOL and the SSO will be responsible for performing surveys. Site surveys will be conducted at least once a week during the initiation of this effort and will be documented in the Health and Safety Logbook. The above actions will provide early recognition for potential emergency situations. Should an incident occur, B&R Environmental will take measures to control these situations. However, if the FOL and the SSO determine that an incident has progressed to a serious emergency situation, B&R Environmental will withdraw, and notify the appropriate response agencies listed in Table 2-1 (page 2-7).

2.3.2 Prevention

B&R Environmental and subcontractor personnel will minimize the potential for emergencies by following the Health and Safety Guidance Manual and ensuring compliance with the HASP and applicable OSHA regulations.

2.4 SAFE DISTANCES AND PLACES OF REFUGE

In the event that the site must be evacuated, all personnel will immediately stop activities and report to the designated safe place of refuge. Safe places of refuge will be identified prior to the commencement of site activities and will be conveyed to personnel as part of the daily safety meeting conducted each morning. Whenever possible, the safe place of refuge will also serve as the telephone communications point for that area. During an evacuation, personnel will remain at the refuge location until directed otherwise by the B&R Environmental FOL or the on-site Incident Commander of the Emergency Response Team. The FOL or the SSO will take a head count at this location to account for and to confirm the location of all site personnel. Emergency response personnel will be immediately notified of any unaccounted personnel.

2.5 EVACUATION ROUTES AND PROCEDURES

An evacuation will be initiated whenever the health, safety or welfare of site workers is compromised. Specific examples of conditions that may initiate an evacuation include, but are not limited to the following: severe weather conditions; a fire or explosion occurs; readings on monitoring instrumentation indicate levels of contamination that are greater than instituted action levels; if personnel show signs or symptoms of overexposure to potential site contaminants. In the event of an evacuation, personnel will proceed immediately to the designated place of refuge unless doing so would further jeopardize the welfare of workers. In such an event, personnel will proceed to a designated alternate location and remain until further notification from the B&R Environmental FOL.

Evacuation procedures will be discussed prior to the initiation of any work at the site. Evacuation routes from the site and safe places of refuge are dependent upon the location at which work is being performed and the circumstances under which an evacuation is required. Additionally, site location and meteorological conditions (i.e., wind speed and direction) may dictate evacuation routes. As a result, assembly points will be selected and communicated to the workers relative to the site location where work is being performed.

2.6 DECONTAMINATION PROCEDURES / EMERGENCY MEDICAL TREATMENT

During an evacuation, decontamination procedures will be performed only if doing so does not further jeopardize the welfare of site workers. Decontamination will not be performed if the action which initiates an evacuation would further endanger the lives of workers if they were to perform decontamination procedures. However, it is unlikely that an evacuation would occur at this site which would require workers to evacuate the site without first performing decontamination procedures.

2.7 EMERGENCY ALERTING AND ACTION/RESPONSE PROCEDURES

At each site, B&R Environmental personnel will be working in close proximity to each other. As a result, hand signals, voice commands, and air horns will be sufficient to alert site personnel of an emergency. Since two distinct teams will be working simultaneously as part of this project, two-way radios will be used to communicate between teams of workers.

If an emergency occurs, the following procedures are to be initiated:

- Initiate an evacuation by hand signals, voice commands, air horn, or two-way radios. Report to the designated refuge point.

- Describe to the FOL (who will serve as the Incident Coordinator) what has occurred and as many details as possible. Once all personnel are evacuated, appropriate response procedures will be enacted to control the situation.

In the event that site personnel cannot control the incident through offensive and defensive measures, the FOL and SSO will enact the emergency notification procedures to secure additional assistance in the following manner:

- Call 911 or other emergency contacts (Table 2-1) and report the emergency. Give the emergency operator the location of the emergency, the type of emergency, the number of injured, and a brief description of what occurred. Stay on the phone and follow the instructions given by the operator. The operator will then notify and dispatch the proper emergency response agencies.

2.8 PPE AND EMERGENCY EQUIPMENT

A first-aid kit, eye wash units, stretcher, fire extinguishers (strategically placed), and fire blanket will be maintained on-site and shall be immediately available for use in the event of an emergency.

2.9 EMERGENCY CONTACTS

Prior to performing work at any of the sites, all personnel will be thoroughly briefed on the emergency procedures to be followed in the event of an accident. Table 2-1 provides a list of emergency contacts and their associated telephone numbers. This table must be posted on site where it is readily available to all site personnel.

2.10 EMERGENCY ROUTE TO HOSPITAL

DIRECTIONS TO NSB-NLON HOSPITAL:

From Zones 1, 2, 3, and 4: Depending on the zone, head east (away from the Thames River) on Cornvina Rd., Cisco Rd., Chapelin Rd., or Bullhead Rd. Turn left onto Argonaut Road and cross the railroad tracks. Turn left onto Shark Blvd. And travel North passed Building 338. Turn right onto Wahoo Avenue. Wahoo Avenue becomes Tautog Avenue and Hospital is on the right (Building 449).

From Zone 7: Take Amberjack Rd. (South) to Dorado Rd., turn left. At Shark Blvd. turn left. Pass Building 338 and turn right onto Wahoo Avenue. Wahoo Avenue becomes Tautog Avenue and Hospital is on the right (Building 449).

From Zones 5 and 6: Follow Amberjack Rd. north and turn right onto Barb Rd.. At the intersection of Barb Rd. And Shark Blvd. Make a right onto Shark Blvd. Follow Shark Blvd. south to Wahoo Ave. Make a left onto Wahoo Ave. Wahoo Avenue becomes Tautog Avenue and Hospital is on the right (Building 449).

DIRECTIONS TO LAWRENCE AND MEMORIAL HOSPITAL IN NEW LONDON:

Exit the base and proceed South on Route 12. Exit onto I-95 South and take exit 82A. Proceed on the service road and continue until turning on Coleman Street. Travel on Coleman to the intersection of Coleman and Bank Street. Turn right onto Bank Street follow to the intersection of Ocean Avenue. Turn left onto Ocean Avenue and follow signs to the Emergency entrance.

TABLE 2-1
EMERGENCY REFERENCE
NAVAL SUBMARINE BASE - NEW LONDON
Groton, Connecticut

CONTACT	PHONE NUMBER
Local emergency medical team located at NSB-NLON (ambulance/fire dispatcher):	Ext. 3333 from base phone or (860) 449-3333 (860) 449-3666
Nearest emergency room (NSB-NLON Hospital): Emergency Room at Lawrence and Memorial Hospital (New London)	(860) 449-3333 (860) 449-3666 (860) 442-0711
Groton Police: Groton Fire Department:	911 or 445-2451 911 or 445-2456
Utility Emergencies (electric, gas, water and sewer) NSB-NLON Public Works:	(860) 449-4711
Site Contact: Andy Stackpole:	(860) 449-5191
NSB-NLON Security:	(860) 449-3444
CHEMTREC: National Response Center:	(800) 424-9300 (800) 424-8802
B&R Environmental Project Manager Corey A. Rich, PE	(412) 921-8244
B&R Environmental Project Health and Safety Officer Donald J. Westerhoff, CSP	(412) 921-7281
B&R Environmental CLEAN Health and Safety Manager Matthew M. Soltis, CIH, CSP	(412) 921-8912

3.0 SITE BACKGROUND

3.1 SITE INFORMATION

The Naval Submarine Base - New London (NSB-NLON) is located in southern Connecticut, in the towns of Groton and Ledyard. This facility was placed on the National Priorities List by the U.S. EPA on August 28, 1991. NSB-NLON consists of approximately 547 acres of land and associated buildings, situated on the east bank of the Thames River, and is approximately six miles north of Long Island Sound. Location maps of NSB-NLON are included in the Work Plan (WP) and the Sampling and Analysis Plan (SAP) documents prepared for this effort. Copies of these documents will be maintained on site throughout all activities, in a location that is accessible to all site personnel. NSB-NLON 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, NSB-NLON greatly expanded in size and in the number of buildings to support the submarine fleet.

NSB-NLON currently provides a base command for naval submarine fleet activities in the Atlantic Ocean. In addition, NSB-NLON contains naval housing, submarine training facilities, military offices, medical facilities, and facilities for the maintenance, repair, and overhaul of submarines. A map of the Lower Subase of NSB-NLON is provided in Figure 3-1.

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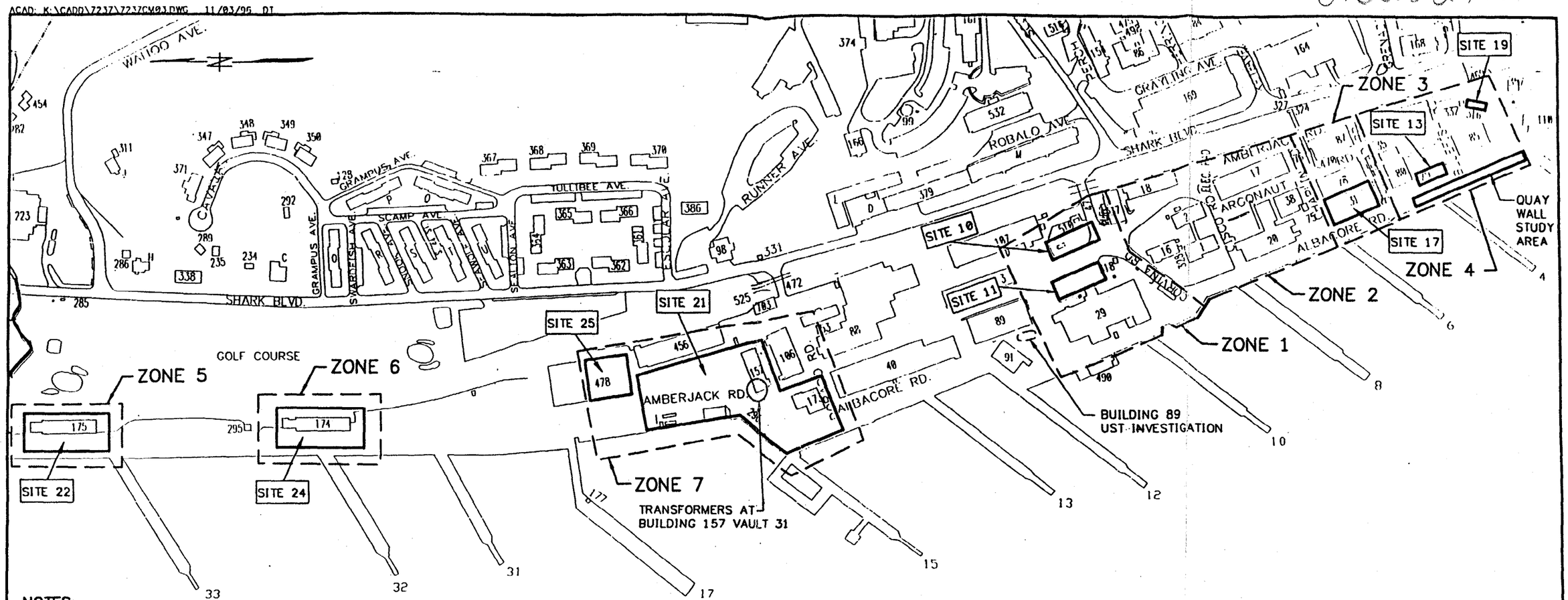

NOTES:

1. SITE AND STUDY AREA LOCATIONS WERE TAKEN FROM DRAWING 1, DRAFT FINAL PHASE II REMEDIAL INVESTIGATION REPORT, BROWN AND ROOT ENVIRONMENTAL, MARCH 1996.
2. SITE AND STUDY AREA BOUNDRIES ARE APPROXIMATE.
   - SITE 10 – FUEL STORAGE TANKS AND TANK 54-H
   - SITE 11 – POWER PLANT OIL TANKS
   - SITE 13 – BUILDING 79 WASTE OIL PIT
   - SITE 17 – HAZARDOUS MATERIALS/SOLVENT STORAGE AREA (BUILDING 31)
   - SITE 19 – SOLVENT STORAGE AREA (BUILDING 316)
   - SITE 21 – BERTH 16
   - SITE 22 – PIER 33
   - SITE 24 – CENTRAL PAINT ACCUMULATION AREA (BUILDING 174)
   - SITE 25 – CLASSIFIED MATERIALS INCINERATOR

LEGEND:

- — — — LOWER SUBASE REMEDIAL INVESTIGATION ZONE BOUNDARY
- ——— LOWER SUBASE REMEDIAL INVESTIGATION SITE OR STUDY AREA BOUNDARY

FIGURE 3-1

LOWER SUBASE
ZONE AND SITE LOCATION MAP
NSB–NLON, GROTON, CONNECTICUT

0 300 600
SCALE IN FEET

Brown & Root Environmental

4.0 SCOPE OF WORK

This section discusses the activities that are to be performed at the site. Table 5-1 of this HASP provides information related to each of the tasks that are to be performed as part of the scope of work. The planned activities involved in this effort are presented in detail in the Sampling and Analysis Plan developed for this project. If new tasks are to be performed at the site, Table 5-1 will be modified accordingly. If tasks other than those described below are performed at the site, this section will be modified accordingly.

The specific tasks planned to be performed and covered by this HASP include the following:

- Installation of monitoring wells
- Monitoring well development and groundwater sampling
- Test borings and subsurface soil sampling (geoprobe and hollow stem augering methods)
- Sediment sampling
- Surface water sampling
- Water level measurements and free product sampling

Work areas have been separated into seven distinct zones associated with the Lower Subase. Each zone is comprised of building(s) and surrounding areas which are identified as sites. Each site associated with each zone is identified as part of Figure 3-1 of this HASP. The Background Review Report for Lower Subase Remedial Investigation (January 1997) discusses each of the zones and the boundaries and sites associated with each. Soil, groundwater, surface water and sediments will be sampled at all zones. Additionally, five perminent monitoring wells will be installed at zone 6.

Surface water samples and sediment samples will be collected from the Thames River using a boat. Gasoline powered boats are not likely to be used due to the potential for contamination of samples. Sediment samples will be collected using a stainless steel dredge or similar device (Van Veen or ponar sampler). Potential hazards associated with this operation are discusses in Section 6.0 of this HASP.

5.0 TASKS/HAZARDS/ASSOCIATED CONTROL MEASURES SUMMARIZATION

Table 5-1 of this section serves as the primary portion of the site specific HASP which identifies the tasks that are to be performed as part of the scope of work. A new Table 5-1 must be developed and incorporated into this document as new or additional tasks are performed at the site. The anticipated hazards, recommended control measures, air monitoring recommendations, required Personal Protective Equipment (PPE), and decontamination measures for each site task are discussed in detail. This table and the associated control measures shall be changed if the scope of work, contaminants of concern, or other conditions change.

The site location, associated hazards, and control measures for each task are listed in the following table. By using the table, site personnel determine which hazards are associated with each task, what hazards are present at each site, and what associated control measures are necessary to minimize potential exposure or injuries related to those hazards. The table also assists field team members in determining which PPE and decontamination procedures to use based on proper air monitoring techniques and site-specific conditions.

As discussed earlier, this table and the associated site-specific HASP is accompanied by a Health and Safety Guidance Manual. This manual is designed to further explain supporting elements for any site specific operations as required by 29 CFR 1910.120. This Guidance Manual should be referenced for additional information regarding air monitoring instrumentation, decontamination activities, emergency response, hazard assessments, hazard communication and hearing conservation programs, medical surveillance, PPE, respiratory protection, site control measures, standard work practices, and training requirements. Many of Brown & Root Environmental's SOPs are also provided in this Guidance Manual.

TABLE 5-1
TASKS/HAZARDS/CONTROL MEASURES COMPENDIUM
FOR
NAVAL SUBMARINE BASE- NEW LONDON, GROTON, CONNECTICUT

Tasks/Operation/ Locations	Anticipated Hazards	Recommended Control Measures	Air Monitoring	Personal Protective Equipment	Decontamination Procedures
Geoprobe direct push soil boring and temporary monitoring well installations.	*Chemical Hazards* 1) Air/particulate/water borne contaminants - Total Petroleum Hydrocarbons (TPH) primarily consisting of No. 6 fuel oil and No. 2 diesel fuels, various metals (particularly lead) and to a lesser extent volatile and semivolatile organics. (See Table 6-1) Based on previous analytical results, the primary contaminants of concern from an occupational exposure standpoint are TPH and lead. Many of the contaminants present in the soils and sediments are in a particulate or bound to particulate form. Airborne particulates (dusts) are not anticipated to be generated during site activities and airborne concentrations of contaminants of concern are not anticipated to be at levels which would warrant respiratory protection. The greatest potential for exposure to particulate contaminants such as lead is through incidental ingestion as a result of hand to mouth activities (smoking, eating, chewing tobacco, etc.). Based on this observation, site personnel must ensure proper decontamination efforts and personnel hygiene measures are performed. 2) Transfer of contamination into clean areas or onto persons *Physical hazards* 3) Pinch/compression points 4) Noise 5) Energized systems 6) Ambient temperature extremes	1) Use real-time monitoring instrumentation, action levels, and identified PPE to control exposures to potentially contaminated medias (e.g. air, water, soils, etc.). 2) Decontaminate all equipment and supplies between boreholes and prior to leaving the site. 3) All equipment to be used will be - Inspected in accordance with Federal safety and transportation guidelines, OSHA (1926.600,.601,.602), and manufacturers design. - Operated by Certified operators, and knowledgeable ground crew. - Used within establish safe zones and routes of approach - Only manufacturer approved equipment may be used in conjunction with equipment repair procedures (i.e. pins, etc.). Additionally, the following safe operating procedures will be incorporated: - All personnel not directly supporting the subsurface investigation will remain at least 15 feet from the point of operation. - Hydraulic masts or other projecting devices shall be at least 20 feet from overhead power lines and a minimum of 3 feet from underground utilities. - Work areas will be kept clear of clutter. - Secure all loose articles to avoid possible entanglement. - All equipment shall be equipped with movement warning systems. - All personnel working in high equipment traffic areas are required to wear reflective vests for high visibility. - All personnel will be instructed in the location and operations of the emergency shut off device(s). This device will be tested initially (and then periodically) to insure its operational status. - Areas will be inspected prior to the movement of the Geoprobe and support vehicles to eliminate any physical hazards. This will be the responsibility of the FOL and/or SSO. - The Geoprobe and support vehicles will be moved no closer than 3 feet to banks, ditches, and other excavations and unstable terrain unless the sidewalls are supported. 4) Hearing protection will be used during all subsurface activities as directed by the SSO. 5) All utility clearances shall be obtained prior to subsurface activities. Prior to any subsurface investigations, the locations of all underground utilities will be identified and marked. Obtain written permit clearance prior to all subsurface investigations. 6) Wear appropriate clothing and provide necessary liquids and shelter. Implement work/rest regimens in accordance with ACGIH recommendations. 7) Use Safe Work Permits as discussed in Section 10.10.	Photoionization Detector w/ 10.6 eV UV lamp source, or a Flameionization Detector, will be used as follows: 1) Source (borehole and macrocore sampler) monitoring will be conducted at regular intervals determined by the SSO. Positive sustained (above background) results which may impact operations crew will require the following actions. a) Monitor the breathing zone of high risk employees. Any sustained readings above background in the breathing zone requires evacuation to a safe area until the following measurements can be taken. If PID/FID readings are greater than 10 ppm in the worker breathing zone or if airborne dusts are generated and cannot be controlled, Level C protection will be required. Level C protection shall consist of full-face air purifying respirators equipped with combination GMC-H filters. PID/FID readings greater than 25 ppm in worker breathing zones requires site activities to be suspended until the contaminant of concern can be identified. The PHSO must be immediately notified of such readings. 2) Where the utility clearance cannot be obtained in a reasonable period, or not located, drilling shall proceed with extreme caution using a magnetometer for periodic downhole surveys every 2 feet to a depth of at least 6 feet.	All subsurface operations are to be initiated in level D protection. Level D protection constitutes the following minimum protection - Standard field dress (long pants long sleeve shirts - Steel toe/shank safety shoes These following items will be incorporated during subsurface operations: - Surgical style inner gloves with outer nitrile gloves, - Hardhat, safety glasses, impermeable boot covers, and earplugs or muffs. *- Tyvek coveralls will be worn if there is a possibility of soiling work attire* *- PVC or PE coated Tyvek will be incorporated if there is a potential for saturation of work attire.* *(Items in italics are optional as conditions dictate)* Level C protection upgrade will consist of air-purifying respirators (APR) with combination GMC-H filter cartridges, and will be required based on monitoring instrument results of the following: - PID/FID readings greater then 10 ppm in worker breathing zones, or: - Airborne dusts that cannot be controlled with area wetting methods. Chemical protective clothing will consist of impermeable boot covers, nitrile gloves with a cotton liner, surgical style inner gloves, Tyvek coveralls (unless free phase product is encountered). Free phase product or splash potential PVC or PE splash suit. Level B protection Self-Contained Breathing Apparatus (SCBA), or airline respiratory protection will be used for: - PID/FID readings greater then 25 ppm. - IDLH concentrations are exceeded for compounds listed in Table 6-1 according to monitoring instrumentation results. Chemical protective clothing will consist of impermeable boot covers, nitrile gloves with a cotton liner, surgical style inner gloves, Tyvek coveralls (unless free phase product is encountered). Free phase product or splash potential PVC or PE splash suit. Use of Level B protection requires immediate notification of the PM, the Health and Safety Manager, and the Project Health and Safety Officer (Pgh Office) In addition to the above PPE requirement the following equipment will be maintained onsite during all onsite activities • Fire Extinguishers (Strategically placed) • Basket stretcher, blankets, and first-aid kit	**Personnel Decontamination** - Will consist of a soap/water wash and rinse for outer protective equipment (e.g. boots, gloves, PVC splash suits, etc.). This decontamination procedure for **Level D** protection will consist of - Equipment drop - Soap/water wash and rinse of outer boots and outer gloves - Soap/water wash and rinse of the splash suit, as applicable - Removal of disposable PPE beginning with coveralls, then outer boots, and then gloves. - Wash hands and face, leave contamination reduction zone For **Levels C & B** in addition to that described above: **Note:** SCBA air tank or APR cartridge change out would take place at this point. - Outer suit, boot covers, outer glove removal - Respiratory (face mask) protection removal - Inner surgical style glove removal - Wash hands and face, leave contamination reduction zone **Equipment Decontamination** - All heavy equipment decontamination will take place at a centralized decontamination pad utilizing steam or pressure washers. Heavy equipment such as geoprobe, will have the wheels and tires cleaned along with any loose debris removed, prior to transporting to the central decontamination area. All site vehicles will be restricted access to exclusion zones, or also have their wheels/tires sprayed off as not to track mud onto the roadways servicing this installation. Roadways shall be cleared of any debris resulting from the onsite activity. All equipment used in the exclusion zone will require a complete decontamination between locations and prior to removal from the site. The FOL or the SSO will be responsible for evaluating equipment arriving onsite and that which is to leave the site. No equipment will be authorized access or exit without this authorization. Evaluation will consist of - Visual inspection - Scanning equipment with monitoring instruments

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TABLE 5-1
TASKS/HAZARDS/CONTROL MEASURES COMPENDIUM
NAVAL SUBMARINE BASE - NEW LONDON, GROTON, CONNECTICUT

Tasks/Operation/ Locations	Anticipated Hazards	Recommended Control Measures	Air Monitoring Type Action Levels	Personal Protective Equipment	Decontamination Procedures
Installation of monitoring wells and drilling activities using hollow stem augering (HSA) methods at zone 6.	*Chemical Hazards* 1) Air/particulate/water borne contaminants - Total Petroleum Hydrocarbons (TPH) primarily consisting of No. 6 fuel oil and No. 2 diesel fuels, various metals (particularly lead) and to a lesser extent volatile and semivolatile organics. (See Table 6-1) Based on previous analytical results, the primary contaminants of concern from an occupational exposure standpoint are TPH and lead. Many of the contaminants present in the soils and sediments are in a particulate or bound to particulate form. Airborne particulates (dusts) are not anticipated to be generated during site activities and airborne concentrations of contaminants of concern are not anticipated to be at levels which would warrant respiratory protection. The greatest potential for exposure to particulate contaminants such as lead is through incidental ingestion as a result of hand to mouth activities (smoking, eating, chewing tobacco, etc.). Based on this observation, site personnel must ensure proper decontamination efforts and personnel hygiene measures are performed. 2) Transfer of contamination into clean areas or onto persons *Physical hazards* 3) Rotating machinery and hazards associated with heavy equipment (pinch/compression points) 4) Noise 5) Energized systems 6) Ambient temperature extremes	1) Use real-time monitoring instrumentation, action levels, and identified PPE to control exposures to potentially contaminated medias (e.g. air, water, soils, etc.). 2) Decontaminate all equipment and supplies between boreholes and prior to leaving the site. 3) All equipment to be used will be - Inspected in accordance with Federal safety and transportation guidelines, OSHA (1926.600,.601,.602), and manufacturers design. - Operated by Certified operators, and knowledgeable ground crew. - Used within establish safe zones and routes of approach - Only manufacturer approved equipment may be used in conjunction with equipment repair procedures (i.e. pins, etc.). Additionally, the following safe operating procedures will be incorporated: - All personnel not directly supporting the subsurface investigation will remain at least 15 feet from the point of operation. - Drill masts or other projecting devices shall be at least 20 feet from overhead power lines and a minimum of 3 feet from underground utilities unless the exact location of the underground utility is known. - Work areas will be kept clear of clutter. - Secure all loose articles to avoid possible entanglement. - All equipment shall be equipped with movement warning systems. - All personnel working in high equipment traffic areas are required to wear reflective vests for high visibility. - All personnel will be instructed in the location and operations of the emergency shut off device(s). This device will be tested initially (and then periodically) to insure its operational status. - Areas will be inspected prior to the movement of the Geoprobe and support vehicles to eliminate any physical hazards. This will be the responsibility of the FOL and/or SSO. - The drill rig and support vehicles will be moved no closer than 3 feet to banks, ditches, and other excavations and unstable terrain unless the sidewalls are supported. 4) Hearing protection will be used during all subsurface activities until the SSO can quantify associated noise levels. 5) All utility clearances shall be obtained prior to subsurface activities. Prior to any subsurface investigations, the locations of all underground utilities will be identified and marked. Obtain written permit clearance prior to all subsurface investigations. 6) Wear appropriate clothing and provide necessary liquids and shelter. Implement work/rest regimens in accordance with ACGIH recommendations. 7) Use Safe Work Permits as discussed in Section 10.10.	Photoionization Detector w/ 10.6 eV UV lamp source, or a Flameionization Detector, will be used as follows: 1) Source (boreholes) monitoring will be conducted at regular intervals determined by the SSO. Positive sustained (above background) results which may impact operations crew will require the following actions. a) Monitor the breathing zone of high risk employees. Any sustained readings above background in the breathing zone requires evacuation to a safe area until the following measurements can be taken. If PID/FID readings are greater than 10 ppm in the worker breathing zone or if airborne dusts are generated and cannot be controlled, Level C protection will be required. Level C protection shall consist of full-face air purifying respirators equipped with combination GMC-H filters. PID/FID readings greater than 25 ppm in worker breathing zones requires site activities to be suspended until the contaminant of concern can be identified. The PHSO must be immediately notified of such readings. 2) Where the utility clearance cannot be obtained in a reasonable period, or not located, drilling shall proceed with extreme caution using a magnetometer for periodic downhole surveys every 2 feet to a depth of at least 6 feet.	All subsurface operations are to be initiated in level D protection. Level D protection constitutes the following minimum protection - Standard field dress (long pants long sleeve shirts - Steel toe/shank safety shoes These following items will be incorporated during subsurface operations: - Surgical style inner gloves with nitrile outer gloves, - Hardhat, safety glasses, impermeable boot covers, and earplugs or muffs. *- Tyvek coveralls will be worn if there is a possibility of soiling work attire* *- PVC or PE coated tyvek will be incorporated if there is a potential for saturation of work attire.* *(Items in italics are optional as conditions dictate)* Level C protection upgrade will consist of air-purifying respirators (APR) with combination GMC-H filter cartridges, and will be required based on monitoring instrument results of the following: - PID/FID readings greater then 10 ppm in worker breathing zones, or: - Airborne dusts that cannot be controlled with are wetting methods. Chemical protective clothing will consist of impermeable boot covers, nitrile gloves with a cotton liner, surgical style inner gloves, Tyvek coveralls (unless free phase product is encountered). Free phase product or splash potential PVC or PE splash suit. Level B protection Self-Contained Breathing Apparatus (SCBA), or airline respiratory protection will be used for: - PID/FID readings greater than 25 ppm. - IDLH concentrations are exceeded for compounds listed in Table 6-1 according to monitoring instrumentation results. Chemical protective clothing will consist of impermeable boot covers, nitrile gloves with a cotton liner, surgical style inner gloves, Tyvek coveralls (unless free phase product is encountered). Free phase product or splash potential PVC or PE splash suit. Use of Level B protection requires immediate notification of the PM, the Health and Safety Manager, and the Project Health and Safety Officer (Pgh Office)	**Personnel Decontamination** - Will consist of a soap/water wash and rinse for outer protective equipment (e.g. boots, gloves, PVC splash suits, etc.). This decontamination procedure for **Level D** protection will consist of - Equipment drop - Soap/water wash and rinse of outer boots and outer gloves - Soap/water wash and rinse of the splash suit, as applicable - Removal of disposable PPE beginning with coveralls, then outer boots, and then gloves. - Wash hands and face, leave contamination reduction zone For **Levels C & B** in addition to that described above: **Note:** SCBA air tank or APR cartridge change out would take place at this point. - Outer suit, boot covers, outer glove removal - Respiratory (face mask) protection removal - Inner surgical style glove removal - Wash hands and face, leave contamination reduction zone **Equipment Decontamination** - All heavy equipment decontamination will take place at a centralized decontamination pad utilizing steam or pressure washers. Heavy equipment such as the drill rig, will have the wheels and tires cleaned along with any loose debris removed, prior to transporting to the central decontamination area. All site vehicles will be restricted access to exclusion zones, or also have their wheels/tires sprayed off as not to track mud onto the roadways servicing this installation. Roadways shall be cleared of any debris resulting from the onsite activity. All equipment used in the exclusion zone will require a complete decontamination between locations and prior to removal from the site. The FOL or the SSO will be responsible for evaluating equipment arriving onsite and that which is to leave the site. No equipment will be authorized access or exit without this authorization. Evaluation will consist of - Visual inspection - Scanning equipment with monitoring instruments

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TABLE 5-1
TASKS/HAZARDS/CONTROL MEASURES COMPENDIUM
NAVAL SUBMARINE BASE - NEW LONDON, GROTON, CONNECTICUT

Tasks/Operation/ Locations	Anticipated Hazards	Recommended Control Measures	Air Monitoring Type Action Levels	Personal Protective Equipment	Decontamination Procedures
Multi-media sampling including subsurface soils, sediments, surface water and groundwater. This activity includes performing water level measurements and free product sampling.	*Chemical Hazards* 1) Air/particulate/water borne contaminants - Total Petroleum Hydrocarbons (TPH) primarily consisting of No. 6 fuel oil and No. 2 diesel fuels, various metals (particularly lead) and to a lesser extent volatile and semivolatile organics. (See Table 6-1) Based on previous analytical results, the primary contaminants of concern from an occupational exposure standpoint are TPH and lead. Many of the contaminants present in the soils and sediments are in a particulate or bound to particulate form. Airborne particulates (dusts) are not anticipated to be generated during site activities and airborne concentrations of contaminants of concern are not anticipated to be at levels which would warrant respiratory protection. The greatest potential for exposure to particulate contaminants such as lead is through incidental ingestion as a result of hand to mouth activities (smoking, eating, chewing tobacco, etc.). Based on this observation, site personnel must ensure proper decontamination efforts and personnel hygiene measures are performed. 2) Transfer of contamination into clean areas *Physical hazards* 3) Noise 4) Lifting (muscle strains and pulls) 5) Pinches and compressions 6) Slip, trips, and falls 7) Biological hazards (Insect/animal bites and stings) 8) Ambient temperature extremes 9) Water hazards	1) Employ real-time monitoring instrumentation, action levels, and identified PPE to control exposures to potentially contaminated medias (e.g. air, water, soils). 2) Decontaminate all equipment and supplies between sampling locations and prior to leaving the site. 3) When sampling at the geoprobe employ hearing protection as indicated for that task. The use of hearing protection to protect against excessive noise outside of 25 feet from the point of operations should be incorporated under the following condition: Hearing protection during sample acquisition outside of the boring sample will be determined on a case by case scenario. As a general rule of thumb, if you have to raise your voice to talk to someone who is within 2 feet of your location, noise levels may be excessive. 4) Use machinery or multiple personnel for heavy lifts. Use proper lifting techniques. 5) Keeps fingers, hands and other body parts away from potential pinch points. Use pinch bars or other equipment to keep hands from the point of operation. Exercise particular caution when working with spring loaded ponar samplers for sediment sampling. 6) Preview work locations for unstable/uneven terrain. Barricade all excavations and other associated drop off points at least 3 feet from the edge. 7) Avoid nesting areas, employ repellents (Do NOT use repellents during sampling activities). Report potential hazards to the SSO. 8) Wear appropriate clothing and provide necessary liquids and shelter. Implement work/rest regimens in accordance with ACGIH recommendations. 9) Employ the use of U.S. Coast Guard approved personal floatation devices (life vests/jackets). 10) Use Safe Work Permits as discussed in Section 10.10.	Monitoring instrumentation will be employed as specified in the Sampling and Analyses Plan to bias samples. Subsurface soils monitoring direction and action levels will proceed in the following manner. Photoionization Detector w/ 10.6 eV UV lamp source or flameionization detector (FID) - Source monitoring will be conducted at regular intervals to be determined by the SSO. Positive sustained results at a source location (boreholes, well heads, MacroCore Samplers) which may impact the operations crew will require the following actions: **Note: Excessive chemical contaminant concentrations impacting field crews during this task is not anticipated. The following information is based on a contingency action only.** 1) Monitor the breathing zone of high risk employees. Any sustained readings above background in the breathing zone of the at risk employee(s) requires the person (SSO/sampler, etc.) monitoring to perform the following measures: If PID/FID readings are greater than 10 ppm in the worker breathing zone or if airborne dusts are generated and cannot be controlled, Level C protection will be required. Level C protection shall consist of full-face air purifying respirators equipped with combination GMC-H filters. PID/FID readings greater than 25 ppm in worker breathing zones requires site activities to be suspended until the contaminant of concern can be identified. The PHSO must be immediately notified of such readings.	Level D protection will be utilized for the initiation of all sampling activities. Level D protection constitutes the following minimum protection - Standard field dress (long pants long sleeve shirts - Steel toe/shank safety shoes These following items will be incorporated during sampling operations: - Inner nitrile surgeon gloves, layered if necessary. Nitrile outer gloves will be used when sampling free product. - *Hardhat, safety glasses, impermeable boot covers, and earplugs or muffs.* - *Tyvek coveralls will be worn if there is a possibility of soiling work attire particularly during free product sampling.* - *PVC or PE coated Tyvek will be incorporated if there is a potential for saturation of work attire. (Items in italics are optional as conditions dictate or as directed by the FOL or SSO)* **Excessive chemical contaminant concentrations impacting field crews during this task is not anticipated. The following information is based on a contingency action only.** Level C protection upgrade will consist of air-purifying respirator (APR) with combination GMC-H cartridges, and will be based on monitoring instrument results of the following: - PID/FID readings >10 ppm. - Observations of airborne particulates that cannot be controlled with area wetting methods. Chemical protective clothing will consist of impermeable boot covers, surgical style inner gloves with nitrile outer gloves with a cotton liner, Tyvek coveralls (unless free phase product is encountered). Free phase product or splash potential PVC or PE splash suit.	**Personnel Decontamination** will consist of a soap/water wash and rinse for outer protective equipment (e.g. boots, gloves, PVC splash suits, etc.). This function will take place at a satellite location. Disposable PPE will be bagged between sampling events. This procedure will consist of - Sample acquisition - Clean (Deionized water spray) the outside of the sample containers/label/bag This decontamination procedure for **Level D** protection will consist of: - Equipment drop - Soap/water wash and rinse of outer boots and outer gloves - Soap/water wash and rinse of the splash suit, as applicable - Outer coveralls, boot covers, and glove removal and disposal - Wash hands and face, leave contamination reduction zone For **Levels C** in addition to that described above: **Note:** APR cartridge change out would take place at this point. - Outer suit, boot covers, outer glove removal and disposal - Respiratory (face mask) protection removal - Wash hands and face, leave contamination reduction zone

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TABLE 5-1
TASKS/HAZARDS/CONTROL MEASURES COMPENDIUM
NAVAL SUBMARINE BASE - NEW LONDON, GROTON, CONNECTICUT

Tasks/Operation/ Locations	Anticipated Hazards	Recommended Control Measures	Air Monitoring	Personal Protective Equipment	Decontamination Procedures
Mobilization/ Demobilization Site Reconnaissance	*Physical Hazards* 1) Lifting (muscle strains and pulls) 2) Pinches and compressions 3) Slip, trips, and falls 4) Moving machinery 5) Biological hazards (Insect/animal bites and stings) 6) Vehicular and foot traffic	1) Use machinery or multiple personnel for heavy lifts. Use proper lifting techniques. 2) Keep hands out of machine points of operation. 3) Preview work locations for unstable/uneven terrain. Barricade all excavations from access closer than two feet from the edge. 4) All equipment will be - Inspected in accordance with OSHA, and manufacturers design. - Operated by Certified operators, and knowledgeable ground crew. 5) Avoid nesting areas. Report potential hazards to the SSO. - Establish safe zones of approach (Boom + 3 feet). - Secure all loose articles to avoid possible entanglement. 6) Use Safe Work Permits as discussed in Section 10.10.	Not required	Level D - (Minimum Requirements) - Standard field attire (Long sleeve shirt; long pants) - Safety shoes (Steel toe/shank) - *Safety glasses* - *Hardhat (when overhead hazards exists, or identified as a operation requirement)* - *Reflective vest for high traffic areas* - *Hearing protection for high noise areas, or as directed on an operation by operation scenario.* *(Items in italics are deemed optional as conditions or the FOL or SSO dictate.)*	Not required
Decontamination of Sampling and Heavy Equipment	*Chemical Hazards* 1) Air/particulate/water borne contaminants - Total Petroleum Hydrocarbons (TPH) primarily consisting of No. 6 fuel oil and No. 2 diesel fuels, various metals (particularly lead) and to a lesser extent volatile and semivolatile organics. (See Table 6-1) Based on previous analytical results, the primary contaminants of concern from an occupational exposure standpoint are TPH and lead. Many of the contaminants present in the soils and sediments are in a particulate or bound to particulate form. Airborne particulates (dusts) are not anticipated to be generated during site activities and airborne concentrations of contaminants of concern are not anticipated to be at levels which would warrant respiratory protection. The greatest potential for exposure to particulate contaminants such as lead is through incidental ingestion as a result of hand to mouth activities (smoking, eating, chewing tobacco, etc.). Based on this observation, site personnel must ensure proper decontamination efforts and personnel hygiene measures are performed. 2) Decontamination fluids - Liquinox (detergent), acetone or methanol, and hexane *Physical Hazards* 2) Lifting (muscle strains and pulls) 3) Pinches and compressions 4) Flying projectiles from debris or pressure washers	1) Employ protective equipment to minimize contact with site contaminants and hazardous decontamination fluids. 2) Use multiple persons where necessary for lifting and handling sampling equipment for decontamination purposes. 3) Keep hands out of machine points of operation. 4) Utilize face shields to prevent flying debris from striking the face and eyes of personnel performing decon using pressure washers 5) Utilize hearing protection when working in areas of excessive noise (i.e., near pressure washers). 6) Use Safe Work Permits as discussed in Section 10.10.	1) Use visual observation, and real-time monitoring instrumentation to ensure all equipment which has been cleaned and dried is properly cleaned of potentially contaminated medias (e.g. air, water, soils).	*For Heavy Equipment (i.e. MacroCore Sampler, etc.):* This applies to high pressure soap/water, steam cleaning wash and rinse procedures. Level D Minimum requirements - - Standard field attire (Long sleeve shirt; long pants) - Safety shoes (Steel toe/shank) - Chemical resistant boot covers - Nitrile outer gloves, cotton liners - PVC Rain suits or PE or PVC coated Tyvek - Safety glasses underneath a splash shield Respiratory protection is not anticipated for this activity. *For sampling equipment including trowels, MacroCore Samplers, bailers, etc.* the following PPE is required Level D Minimum requirements - - Standard field attire (Long sleeve shirt; long pants) - Safety shoes (Steel toe/shank) - Surgical style gloves and nitrile outer gloves - Safety glasses or goggles In the event of overspray of chemical decontamination fluids employ PVC Rain suits or PE or PVC coated Tyvek as necessary.	This decontamination procedure for **Level D** protection will consist of - Soap/water wash and rinse of outer gloves - Soap/water wash and rinse of the splash suit, as applicable - Removal of disposable PPE (outer splash suit, then boot covers, then gloves) - Wash hands and face, leave contamination reduction zone

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6.0 HAZARD ASSESSMENT

The following section provides information regarding the chemical and physical hazards associated with the seven zones of the Lower Subase and the activities that are to be conducted as part of the Remedial Investigation. Table 6-1 provides information related to the chemical hazards that may be present at the site. Specifically, toxicological information, exposure limits, symptoms of exposure, physical properties, and air monitoring and sampling data are discussed in the table. Section 6.1 provides a general list of all contaminants that may be present at the site. Section 6.2 lists all of the physical hazards that may be present at the site or associated with site activities. Table 5-1 discusses what contaminants and physical hazards are associated with each of the proposed tasks that are to be performed at the site.

6.1 CHEMICAL HAZARDS

Analytical data from previous investigations have determined the presence of numerous contaminants in shallow and deep soils as well as sediments and groundwater. From an occupational exposure standpoint, the primary contaminants of concern are lead, Total Petroleum Hydrocarbons (TPH) and the constituents associated with No. 6 and No. 2 diesel fuels. Previous analytical results have detected various semivolatiles and other metals including aluminum, antimony, chromium, copper, magnesium, manganese, and nickel. Several of these contaminants are included in Table 6-1. The primary contaminants of concern are discussed in greater detail below.

Based on previous analytical results, chemical contaminant concentrations in worker breathing zones are not anticipated to be at levels which would exceed established exposure limits. Air monitoring activities will be conducted to evaluate airborne concentrations of potential site contaminants. Control measures such as area wetting procedures, decontamination and personal hygiene practices, PPE usage, and general safe work practices will be employed to further reduce the risk of exposure to potential site contaminants.

Lead

Lead is a potent, systemic poison that affects a variety of organ systems, including the nervous system, kidneys, reproductive system, blood formation, and gastrointestinal (GI) system. The most important way lead enters the body is through inhalation, but it can also be ingested when lead dust or unwashed hands contaminate food, drink, or cigarettes. Much of ingested lead passes through the body and is expelled in feces without absorption into the body. Adults may absorb only 5% to 15% of ingested lead; children may

absorb a much larger fraction. Once in the body, lead enters the bloodstream and circulates to various organs. Lead concentrates and remains in bone for many years. An acute, short-term dose could cause acute brain damage (encephalopathy) with seizures, coma, and death. However, short-term exposures of this magnitude are rare. Reversible kidney damage can also occur from acute exposure, as well as anemia.

Symptoms of chronic overexposure include appetite loss, nausea, metallic taste in the mouth, lead line on gingival (gum) tissue, constipation, anxiety, pallor of the face and the eye grounds, excessive tiredness, weakness, insomnia, headache, nervous irritability, fine tremors, numbness, muscle and joint pain, and abdominal pain. Kidney damage may also result from chronic overexposure, but few, if any symptoms appear until severe kidney damage has occurred. Reproductive damage is characterized by decreased sex drive, impotence, and sterility in men; and decreased fertility, abnormal menstrual cycles, and miscarriages in women. Lead is classified as a suspected carcinogen. The Occupational Safety and Health Administration (OSHA) and American Conference of Industrial Hygienists (ACGIH) have established an 8-hour Time Weighted Average (TWA) exposure limit of $50\mu g/m^3$ for occupational exposures to lead.

Based on previous analytical data for the site, the highest measured concentration of lead (189,000 mg/kg) was collected from a shallow soil sample obtained from Zone 7. The sample was collected from the boring for well 20MW6. The location of this well is shown on Figure 9-1 of the Background Review Report for Lower Subase Remedial Investigation (January, 1997). This maximum concentration was used to establish an action level for airborne particulates discussed in Section 7.4 of this HASP.

Total Petroleum Hydrocarbons

Workers have the potential to be exposed to petroleum based hydrocarbons primarily originating from No. 6 fuel oils and No. 2 diesel fuels. When high concentrations of petroleum vapors are inhaled, symptoms of intoxication may result. These symptoms, ranging from dizziness to excitement or unconsciousness, are similar to those produced by alcohol. If such effects occur, the victim should be removed to an area with fresh air which should result in complete recovery. Prolonged or repeated exposure to some petroleum products, especially those containing benzene soluble polycyclic aromatic hydrocarbons, may cause cancer. However, exposures of this magnitude and duration are not anticipated in the performance of the planned activities at the Lower Subase. As a precautionary measure, continuous air monitoring methods will be employed to assess potential exposures to airborne vapors. Repeated or prolonged skin contact with petroleum products may cause skin irritation and rashes. Some constituents of petroleum products may be absorbed through the skin.

6.2 PHYSICAL HAZARDS

The following is a list of physical hazards that may be encountered at the site or may present during the performance of site activities associated with the scope of work.

- Uneven or unstable terrain (slip, trip, and fall hazards)
- Strain/muscle pulls from manual lifting
- Exposure to pinch or compression points
- Entanglement or contact with moving or rotating equipment
- Contact with energized sources (aboveground and underground)
- Noise in excess of 85 dBA
- Inclement weather
- Water hazards
- Ambient temperature extremes

Many of these physical hazards are discussed in detail in Section 4.0 of the Health and Safety Guidance Manual. Additional information regarding physical hazards associated with the site is provided in Table 5-1 of this HASP.

6.2.1 Water Hazards When Working On Thames River

Surface water and sediment sampling activities conducted on the Thames River present a significant hazard to field crews. In particular, drowning and/or hypothermia concerns exists if personnel fall into the river or become wet as a result of sampling activities. Personnel performing sampling activities on the river must adhere to the requirements specified by the U.S. Coast Guard (USCG) for waterway safety. This shall include the use of USCG-approved personal floatation devices for all personnel working on the boat and/or while working on the river bank. Lifelines will also be required when working on the boat.

TABLE 6-1
CHEMICAL, PHYSICAL, AND TOXICOLOGICAL DATA
NSB-NLON, GROTON, CONNECTICUT

Substance	CAS No.	Air Monitoring/Sampling Information		Exposure Limits	Warning Property Rating	Physical Properties	Health Hazard Information
Benzene	71-43-2	PID: I.P 9.24 eV, 100% response with PID and 10.2 eV lamp. FID: 150% relative response ratio with FID.	Air sample using charcoal tube; carbon disulfide desorption; Sampling and analytical protocol in accordance with OSHA 07 or NIOSH Method #1500.	OSHA: 1 ppm ACGIH: 10 ppm NIOSH: 0.1 ppm IDLH: 500 ppm	Inadequate - Odor threshold 34-199 ppm. The use of air-purifying respirators with organic vapor cartridge up to 10 ppm is acceptable despite the inadequate warning properties, providing cartridges are changed at the beginning of each shift. **Recommended gloves:** Butyl/neoprene blend - >8.00 hrs; Silver shield as a liner - >8.00 hrs; Viton - >8.00 hrs	**Boiling Pt:** 176°F; 80°C **Melting Pt:** 42°F; 5.5°C **Solubility:** 0.07% **Flash Pt:** 12°F; -11°C **LEL/LFL:** 1.3% **UEL/UFL:** 7.9% **Vapor Density:** 2.77 **Vapor Pressure:** 75 mmHg **Specific Gravity:** 0.88 **Incompatibilities:** Strong oxidizers, fluorides, perchlorates, and acids **Appearance and Odor:** Colorless to a light yellow liquid with an aromatic odor	Overexposure may result in irritation to the eyes, nose, throat, and respiratory system. CNS effects include giddiness, lightheadedness, headaches, staggered gait, fatigue, and lassitude and depression. Additional effects may include nausea. Long duration exposures may result in respiratory collapse. Regulated as an OSHA carcinogen. May cause damage to the blood forming organs and may cause a form of cancer called leukemia.
Diesel Fuels including Fuel oil No.2-and No. 6 Diesel fuels Fuel Oil No. 2 resembles diesel fuel and is obtained from the middle distillate in petroleum separation - primarily used for heating fuel or for semidiesel engines. No. 6 diesel fuel is a heavier grade produced from the residual distillate fraction used - primarily for railroad and marine diesel engines.	Mixture	Components of this substance will be detected readily however no documentation exists as to the relative response ratio of either PID or FID.	Air sample using charcoal tube as a collection media; carbon disulfide desorption; GC/FID detection. Sampling and analytical protocol in accordance with NIOSH Method #1550.	OSHA; NIOSH; ACGIH: 5 mg/m³ as mineral oil mist. In addition NIOSH and ACGIH establish 10 mg/m³ as a STEL.	Kerosene odor **Recommended Air Purifying cartridges:** Organic vapor **Recommended gloves:** Nitrile	**Boiling Pt:** <170-400°F; 77-204°C **Melting Pt:** Not available **Solubility:** Negligible **Flash Pt:** 125°F; 52°C **LEL/LFL:** 0.6% **UEL/UFL:** 7.5% **Vapor Density:** >5 **Vapor Pressure:** <1 mmHg @ 70°F; 21°C **Specific Gravity:** 0.86 **Incompatibilities:** strong oxidizers, halogens, and hypochlorites **Appearance and odor:** Colorless to amber with a kerosene odor	Prolonged or repeated exposures to this product may cause skin and eye irritation. Due to the defatting capabilities this exposure may lead to a dermatitis condition. High vapor concentrations are irritating to the eyes and respiratory tract. Exposure to high airborne concentrations may result in narcotic effects including dizziness, headaches, and anesthetic to unconsciousness. High concentrations in a confined space may adequately displace oxygen thereby resulting in suffocation.
Toluene	108-88-3	PID: I.P 8.82 eV, High response with PID and 10.2 eV lamp. FID: 110% response with FID.	Air sample using charcoal tube; carbon disulfide desorption. Sampling and analytical protocol shall proceed in accordance with OSHA Method #07, or NIOSH Method #1500.	OSHA: 200 ppm 300 ppm (Ceiling) ACGIH: 50 ppm (skin) NIOSH: 100 ppm 150 ppm STEL IDLH: 500 ppm	Adequate - Odor threshold 1.6 ppm is considered good. Can use air-purifying respirator with organic vapor cartridge up to 1,000 ppm. **Recommended gloves:** Teflon >15.00 hrs; Viton >16.00 hrs; silver shield >6,00 hrs; supported nitrile (Useable time limit 0.5 hr. complete submersion for the nitrile selection); PV alcohol >25.00 hrs	**Boiling Pt:** 232°F; 111°C **Melting Pt:** -139°F; -95°C **Solubility:** 0.05% (61°F;16°C) **Flash Pt:** 40°F; 4°C **LEL/LFL:** 1.2% **UEL/UFL:** 7.1% **Vapor Density:** 3.14 **Vapor Pressure:** 20 mmHg @ 65°F; 18°C **Specific Gravity:** 0.87 **Incompatibilities:** Strong oxidizers **Appearance and odor:** Colorless liquid with a sweet pungent aromatic odor.	Overexposure to this substance may result in mild to moderate irritation at all points of contact, and CNS changes including euphoria, confusion, nervousness, and possibly paresthesia characterized by an abnormal burning sensation, pricking, or numbness. At 200-500 ppm exposure has resulted in headaches, nausea, eye irritation, loss of appetite, bad taste, impair coordination, fatigue, and weariness. Chronically, toluene overexposure may result in dermatitis, liver, and kidney damage.

TABLE 6-1
CHEMICAL, PHYSICAL, AND TOXICOLOGICAL DATA
NSB-NLON, GROTON, CONNECTICUT

Substance	CAS No.	Air Monitoring/Sampling Information		Exposure Limits	Warning Property Rating	Physical Properties	Health Hazard Information
Xylene All isomers o-,m-, p-	1330-20-7	PID: I.P. 8.56 eV, High response with PID and 10.2 eV lamp. FID: 110% response with FID.	Air sample using charcoal tube; carbon disulfide desorption; GC/FID detection. Sampling and analytical protocol shall proceed in accordance with OSHA 07, or NIOSH Method 1500.	ACGIH, & NIOSH: 100 ppm, 150 ppm STEL OSHA: 100 ppm IDLH: 900 ppm	Adequate - Odor thresholds for the following isomers: 0.6 m-; 5.4 p-; 20 o-ppm. Can use air-purifying respirator with organic vapor cartridge up to 1,000 ppm concentrations. **Recommended gloves:** PV Alcohol >12.67 hrs; Viton >8.00 hrs; CPE >1.00 hr; Butyl 0.87 hrs; Nitrile is acceptable for limited operations and contact (>0.20 hrs)	**Boiling Pt:** 269-281°F; 132-138°C **Melting Pt:** -13o/-54m/56p°F; -25o/-48m/13p °C **Solubility:** 0.02 % **Flash Pt:** 81-90°F;27-32°C **LEL/LFL:** 0.9% **UEL/UFL:** 7.0% **Vapor Density:** 3.66 **Vapor Pressure:** 7-9 mmHg @ 70°F; 21° C **Specific Gravity:** 0.86-0.88 **Incompatibilities:** Strong oxidizers and strong acids **Appearance and odor:** Colorless liquid with an aromatic odor.	Effects may of overexposure include irritation at all points of contact, CNS changes (i.e. dizziness, excitement, drowsiness, incoherent, staggering gait), difficulty in breathing, pulmonary edema, and possibly respiratory failure. Chronic effects may include dermatitis and cornea vacuolization.
Aluminum	7429-90-5	Particulate form - unable to be detected by PID/FID.	Air sample using a cellulose ester membrane filter (particulate filter); atomic absorption (Method #7013) or ICP (Method #7300). Sampling and analytical protocol shall proceed in accordance with NIOSH Methods #7013 and #7300 as applicable.	OSHA: 15 mg/m³ Total dust, 5 mg/m³ Respirable fraction NIOSH: 10 mg/m³ Total dust, 5 mg/m³ Respirable fraction ACGIH: 10 mg/m³	Particulate form - No identifiable warning properties to indicate presence and thereby detection. Employ air purifying respiratory protection suitable for dust and fume. Organic vapor acid gases with HEPA filter. **Recommended gloves:** This is in the particulate form. Therefore any glove suitable to prevent skin contact (Nitrile has been the one most widely used for the other substances).	**Boiling Pt:** 4452°F; 2450°C **Melting Pt:** 1220°F; 660°C **Solubility:** Insoluble **Flash Pt:** Nonflammable **LEL/LFL:** Nonflammable **UEL/UFL:** Nonflammable It should be noted that finely divided powders or dust when airborne becomes moderately flammable/explosive when exposed to heat, flame, or powerful oxidizers **Vapor Density:** Not available **Vapor Pressure:** 1 mmHg @ 2343°F; 1284°C **Specific Gravity:** 2.702 @ 77°F; 25°C **Incompatibles:** Acids, alkalis, oxidizers, halogens and halocarbons, alcohols **Appearance and odor:** silvery gray ductile, lustrous metal	Inhalation of finely divided powders or dusts may result in difficulty in breathing, coughing, and has been reported to cause pulmonary fibrosis. This malady known as "Shavers disease" is a form of benign pneumoconiosis.

TABLE 6-1
CHEMICAL, PHYSICAL, AND TOXICOLOGICAL DATA
NSB-NLON, GROTON, CONNECTICUT

Substance	CAS No.	Air Monitoring/Sampling Information		Exposure Limits	Warning Property Rating	Physical Properties	Health Hazard Information
Lead	7439-92-1	Particulate form - Unable to be detected by either PID or FID.	Air sample using a mixed cellulose ester filter; or HNO_3 or H_2O_2 desorption; or Atomic absorption detection. Sampling and analytical protocol shall proceed in accordance with NIOSH Method #7082 or #7300.	OSHA: 0.05 mg/m³ ACGIH: 0.15 mg/m³ NIOSH: 0.10 mg/m³ IDLH: 100 mg/m³ as lead	The use of a air purifying, full-face respirator with high efficiency particulate air filter for up to 2.5 mg/m³. **Recommended gloves:** This is in the particulate form. Therefore any glove suitable to prevent skin contact (Nitrile has been the one most widely used for the other substances).	**Boiling Pt:** 3164°F; 1740°C **Melting Pt:** 621°F; 327°C **Solubility:** Insoluble **Flash Pt:** Not applicable (Airborne dust may burn or explode when exposed to heat, flame, or incompatible chemicals) **LEL/LFL:** Not applicable **UEL/UFL:** Not applicable **Vapor Density:** Not available **Vapor Pressure:** 0 mmHg **Specific Gravity:** 11.34 **Incompatibilities:** Strong oxidizers, peroxides, sodium acetylide, zirconium, and acids **Appearance and Odor:** Metal: A heavy ductile, soft gray solid.	Overexposure to this substance via ingestion or inhalation may result in metallic taste in the mouth, dry throat, thirst, Gastrointestinal disorders (burning stomach pain, nausea, vomiting, possible diarrhea sometimes bloody or black, accompanied by severe bouts of colic), CNS effects (muscular weakness, pain, cramps, headaches, insomnia, depression, partial paralysis possibly coma and death. Extended exposure may result in damage to the kidneys, gingival lead line, brain, and anemia.
Manganese	7439-96-5 as Mn	Particulate form - This substance is unable to be detected by PID/FID.	Air sample using particulate filter; acid desorption, ICP detection. Sampling and analytical protocol shall proceed in accordance with NIOSH Method #7300.	OSHA: Ceiling 5 mg/m³ as a fume 1 mg/m³ NIOSH: 1 mg/m³ for dust and fume; 3 mg/m³ as a STEL ACGIH: 5 mg/m³ for dust; 1 mg/m³ for fume IDLH: 500 mg/m³	No identifiable warning properties to indicate presence and thereby detection. **Recommended APR Cartridge:** Suitable for dust and fume. Organic vapor acid gases with HEPA filter. **Recommended gloves:** This is in the particulate form. Therefore any glove suitable to prevent skin contact (Nitrile has been the one most widely used for the other substances).	**Boiling Pt:** 3452°F; 1900°C **Melting Pt:** 2300°F; 1260°C **Solubility:** Insoluble **Flash Pt:** Not available (Airborne dust may burn or explode when exposed to heat, flame, or incompatible chemicals. This substance is considered a combustible solid.) **LEL/LFL:** Not available **UEL/UFL:** Not available **Vapor Density:** Not available **Vapor Pressure:** 1 mmHg @ 2358°F; 1292°C **Specific Gravity:** 7.20 **Incompatibilities:** Strong oxidizers, halogens, and nitrates. Will react with water to produce hydrogen gas. **Appearance and odor:** Silvery solid or reddish-gray, odorless	Overexposure to this product may result in Central Nervous System and pulmonary effects by inhalation. Symptoms may include disturbances in gait and speech, sleepiness, mental confusion, stolid, masklike face, muscular twitching varying from tremors to coarse rhythmical movements of the extremities accompanied by cramps. Symptoms are described as postencephalitic Parkinsonism. Additionally dry throat, tightness in the chest, dyspnea, rales, flu-like symptoms low back pain, and vomiting.

7.0 AIR MONITORING

Monitoring devices such as Direct Reading Instruments (DRIs) will be employed at the site to detect and evaluate the presence of site contaminants and other potentially harmful agents. The specific type of monitoring and the associated instruments, frequency of use, and applicable action levels are dependent upon the specific scope of work and the contaminants of concern. As a result, specific air monitoring measures and requirements were established in Table 5-1 of this site specific HASP. Section 1.0 of the B&R Environmental Health and Safety Manual contains detailed information regarding direct reading instrumentation, personal and area air sampling procedures, as well as general calibration procedures of various instruments.

7.1 PHOTOIONIZATION DETECTOR (PID)

A photoionization detector (PID) with a 10.6 eV (or equivalent) lamp will be used to monitor potential source areas, to screen collected samples, and to monitor the breathing zones of employees during sampling and other intrusive activities. The PID has been selected because it is capable of detecting organic gases and vapors and some inorganic gases and vapors. When calibrated with isobutylene the PID has a one to one correspondence with benzene. Prior to the commencement of any field activities, the background level of the site must be determined and noted. Daily background readings must be taken away from areas of potential contamination to obtain accurate results. These readings, as well as any influencing conditions (i.e., weather, temperature, humidity) and location will be documented in the Health and Safety Logbook as a matter of reference.

7.2 FLAME IONIZATION DETECTOR (FID)

The use of a flame ionization detector (FID) may also be used to screen source areas and breathing zones of workers during sampling and other intrusive activities. The FID has been selected because it may detect the presence of long chain hydrocarbons better than a PID. The relative response factor for BTEX compounds range from 100% to 150%.

7.3 COLORMETRIC TUBES (DRAGER TUBES)

Colormetric tubes may be available onsite to provided semi-quantitative data regarding the concentrations of some potential site contaminants. These tubes can be employed to take samples at source areas or in worker breathing zones. Colormetric tubes operate by pulling a known quantity of air (using a hand actuated bellow) through a tube that contains a chemically treated media. A reaction between the

contaminant of concern and the treated media results in a color change. The length of the resultant stain (or in some cases the shade of the stain) indicates the concentration of the contaminant. Each tube contains a scale in parts per million. It should be noted that many tubes have interferences that may bias the results. Each type of sample tube includes a detailed set of directions that indicate the number of bellow strokes, the potential interferences, the appropriate color changes and other important information.

7.4 PARTICULATE MONITOR

If dusts are generated during site operations (particularly at Zones 5 and 7), and these emissions cannot be controlled by area wetting methods, direct reading particulate monitors (MIE PDM-3 Miniram, or equivalent) may be used to monitor dust emissions. This instrument will provide a real-time, as well as an 8-hour average measurement of total airborne particulates. Assuming a maximum concentration of lead at Zone 7 of 189,000 mg/kg and a safety factor of 1, a reading of 0.26 mg/kg on the Miniram would correlate to an exposure to lead of 50 $\mu g/m^3$. However, it should be noted that dusts are not anticipated to be generated as a result of site activities. Furthermore, this reading is based on the highest concentration observed at the site and is not representative of typical lead concentrations associated with the site.

8.0 TRAINING/MEDICAL SURVEILLANCE REQUIREMENTS

8.1 INTRODUCTORY/REFRESHER/SUPERVISORY TRAINING

8.1.1 Requirements for B&R Environmental Personnel

All B&R Environmental personnel must complete 40 hours of introductory hazardous waste site training in accordance with 29 CFR 1910.120(e) prior to performing work at NSB-NLON. Additionally, B&R Environmental 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. 8-hour Supervisory Training in accordance with 29 CFR 1910.120(e)(4) will be required for site supervisory personnel.

Documentation of B&R Environmental Health and Safety Training will be maintained at the project site. Copies of certificates or other official documentation will be used to fulfill this requirement.

8.1.2 Requirements for Subcontractors

All B&R Environmental 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 field work at NSB-NLON. B&R Environmental's subcontractors must certify that each employee has had such training by sending B&R Environmental a letter, on company letterhead, containing the information in the example letter provided as Figure 8-1 of this Health and Safety Plan.

8.2 SITE-SPECIFIC TRAINING

B&R Environmental will provide site-specific training to all B&R Environmental employees and subcontractor personnel who will perform work on this project. 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 to site contaminants
- The contents of the site-specific health and safety plan including the contents of Table 5-1 and 6-1.
- Emergency response procedures (evacuation and assembly points)

- Review the contents of relevant Material Safety Data Sheets

Figure 8-2 shall be used to document the provision of the site-specific training. All site personnel will be required to sign this form prior to commencement of site activities.

Additional training will be provided prior to the initiation of each new task being performed at the site. This training will highlight the hazards associated with the task and the appropriate control measures to be implemented to minimize these hazards. This training will be provided by the SSO and/or the FOL.

8.3 MEDICAL SURVEILLANCE

8.3.1 Medical Surveillance Requirements For B&R Environmental Personnel

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

Documentation for medical clearances will be maintained in B&R Environmental's Pittsburgh office and will be made available as necessary.

8.3.2 Medical Surveillance Requirements For Subcontractors

B&R Enviornmental 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" provided in Figure 8-3 shall be used to satisfy this requirement providing it is properly completed and signed by a licensed physician.

Subcontractors who have a company medical surveillance program meeting the requirements of paragraph (f) of OSHA 29 CFR 1910.120 can substitute "Subcontractor Medical Approval Form" with a letter, on company letterhead, containing all of the information in the example letter presented in Figure 8-4 of this document.

8.3.3 Requirements For All Field Personnel

Each field team member (including subcontractors) shall be required to complete and submit a copy of the Medical Data Sheet found in the B&R Environmental Health and Safety Guidance Manual. This shall be provided to the SSO prior to participating in site activities.

8.4 SUBCONTRACTOR EXCEPTION

Subcontractors who will not enter the exclusion zone during field operations, and whose activities involve no potential for exposure to site contaminants, will not be required to meet the requirements for training/medical surveillance, other than site-specific training as stipulated in Section 8-2.

FIGURE 8-1
TRAINING LETTER

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. Corey A. Rich, P.E.
Project Manager
B&R Environmental
Foster Plaza VII 661 Andersen Drive
Pittsburgh, Pennsylvania 15220

Subject: HAZWOPER Training for the Naval Submarine Base - New London Site

Dear Mr. Rich:

As an officer of XYZ Corporation, I hereby state that I am aware of potential hazardous nature of the subject project. I also understand that is out responsibility to comply with all applicable occupational safety and health regulations including those stipulated in Title 29 of the Code of Federal Regulations (CFR), Parts 1900 through 1910 and Part 126.

I also understand that Title 29 CFR 1910.120 entitled "Hazardous Waste Operations and Emergency Response" requires appropriate level of training for certain employees engaged in hazardous waste operations. In this regard, I hereby state that the following employees have had 40 hours of introductory hazardous waste site training or equivalent work experience as requested by 29 CFR 1910.120(e) and have had 8 hours of refresher training as required by 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)

FIGURE 8-2
SITE-SPECIFIC TRAINING DOCUMENTATION

My signature below indicates that I am aware of the potential hazardous nature of performing investigation activities at the NSB-NLON Site, and that I have received site-specific training which included the elements presented below:

- 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 including Table 5-1 and 6-1
- Emergency response procedures (evacuation and assembly points)
- Review contents of relevant Material Safety Data Sheets

I further state that I have been given the opportunity to ask questions and that all of my questions have been answered to my satisfaction.

I further state by the presence of my signature below the date of my training (introductory, refresher, and supervisory, as applicable), and my medical surveillance requirements are accurate and correct to the best of my knowledge.

Name	40-Hour General Site Worker Training (Date)	8-Hour Refresher Training (Date)	8-Hour Supervisory Training (Date)	Medical Surveillance	Signature

FIGURE 8-3

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 NSB-NLON work site
   ( ) not qualified to perform work at the NSB-NLON 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:

FIGURE 8-3
SUBCONTRACTOR MEDICAL APPROVAL FORM
PAGE TWO

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

   _____
   _____
   _____

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 of treatment.

Based on the information provided to me, and in view of the activities and hazard potentials involved at the NSB-NLON 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

FIGURE 8-4

MEDICAL SURVEILLANCE LETTER

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. Corey A. Rich, P.E.
Project Manager
B&R Environmental Corp.
Foster Plaza VII 661 Andersen Drive
Pittsburgh, Pennsylvania 15220

Subject: Medical Surveillance for Naval Submarine Base - New London Site

Dear Mr. Rich:

As an officer of XYZ Corporation, I hereby state that the persons listed below participate in a medical surveillance program meeting the requirements contained in paragraph (f) of Title 29 of the Code of Federal Regulations (CFR), Part 1910.120 entitled "Hazardous Waste Operations and Emergency Response" I further state that the persons listed below have had physical examinations under this program within the past 12 months and that they have been cleared, by a licensed physician, to perform hazardous waste site work and to wear positive and negative pressure respiratory protection. I also state that, to my knowledge, no person listed below has any medical restriction that would preclude him/her from working at the NSB-NLON Site.

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)

9.0 SPILL CONTAINMENT PROGRAM

9.1 SCOPE AND APPLICATION

It is anticipated that quantities of bulk potentially hazardous materials (greater than 55-gallons) will be handled during some of the field activities conducted as part of the scope of work. Significant quantities of decontamination, purge, and development waters may be generated as part of field activities. It is not anticipated that spillage of these stored fluids would constitute a significant danger to human health or the environment. As the job progresses, the potential for accumulating disposable PPE, decon, development, and purge fluids and various soils from drill cuttings exists. 55-gallon drums will be used to contain development and purge waters as well as soil cuttings generated during investigatory activities. These drums will be labeled with the facilities name and address, the type of contents, the boring or groundwater monitoring wells identifier, and the date the container was filled. Samples will be collected and analyzed to characterized the material and determine appropriate disposal measures. Once characterized they can be removed from the staging area and disposed of in accordance with Federal, State and local regulations. A plastic holding tank may be used to collect and store development and purge waters initially collected in 55-gallon drums. Because these fluids and soils will remain uncharacterized while in the staging area, a spill containment program will be developed and instituted as part of this HASP.

9.2 POTENTIAL SPILL AREAS

Potential spill areas will be monitored in an ongoing attempt to prevent and control further potential contamination of the environment. Currently, there are various areas vulnerable to this hazard including the areas used for central staging and decontamination activities. Additionally, areas designated for handling, loading, and unloading of potentially contaminated soils, waters, and debris present limited potential for leaks or spills. At this junction, it is anticipated that all decontamination fluids generated as a result of this scope of work will be containerized, labeled, and staged to await chemical analyses. The results of these analyses will determine appropriate disposal methods. During the turn around for the chemical analyses there exists a possibility to accumulate multiple containers of fluids, soils, and debris.

9.2.1 Site Containers

It is anticipated that all decontamination fluids will be contained in either 55-gallon drums or a plastic holding tank. All containers (drums, tanks, and other vessels) used for containing liquids will be sealed, labeled, and staged within a centralized area.

9.3 LEAK AND SPILL DETECTION

To establish an early detection of potential spills or leaks, a periodic walk around by the SSO will be conducted during working hours to visually determine that containers are not leaking. If a leak is detected, appropriate containment measures will be implemented. Provisions for the transfer of tank contents will be made and appropriate emergency contacts will be notified. In most instances, leaks will be collected and contained using absorbents such as Oil-dry, vermiculite, or sand, which will be stored at the staging area in a conspicuously marked drum. This material too, will be containerized for disposal pending analyses. All inspections will be documented in the Project Logbook.

9.4 PERSONNEL TRAINING AND SPILL PREVENTION

All personnel will be instructed on the procedures for spill prevention, containment, and collection of hazardous materials in the site-specific training. The FOL and/or the SSO will serve as the Spill Response Coordinator for this operation should the need arise.

9.5 SPILL PREVENTION AND CONTAINMENT EQUIPMENT

The following represents the minimum equipment which will be maintained at the staging area at all times for the purpose of supporting this Spill Prevention/Containment Program.

- Sand, clean fill, vermiculite, or other noncombustible absorbent (oil-dry);
- Drums (55-gallon U.S. DOT 17-E or 17-H)
- Portable storage tanks
- Shovels, rakes, and brooms
- Hand operated drum pump with hose
- Labels
- Drum Patch kit

9.6 SPILL CONTROL PLAN

This section describes the procedures the B&R Environmental field crew members will employ upon the detection of a spill or leak.

1) Notify the SSO or FOL immediately upon the detection of a leak or spill.

2) Employ the appropriate personnel protective equipment stored at the staging area. Take immediate actions to stop the leak or spill by plugging or patching the drum or raising the leak to the highest point. Spread the absorbent material in the area of the spill covering completely.

3) Transfer the material to a new container, collect and containerize the absorbent material. Label the new container appropriately. Await analyses for treatment or disposal options.

4) Solid spills will be recontainerized with 2-inches of top cover, and await test results for treatment or disposal options.

It is not anticipated that a spill will occur in which the field crews cannot handle. Should this occur notification of appropriate emergency response agencies will be carried out by the FOL or SSO.

10.0 SITE CONTROL

This section outlines the means by which B&R Environmental 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. It is anticipated that a three-zone approach will be used during work at this site. This three zone approach will utilize an exclusion zone, a contamination reduction zone, and a support zone. It is also anticipated that this control measure will be used to control access to site work areas. Use of such controls will restrict the general public, minimize the potential for the spread of contaminants, and protect individuals who are not cleared to enter work areas.

10.1 EXCLUSION ZONE

The exclusion zone will be considered those areas of the site of known or suspected contamination. It is not anticipated that significant amounts of surface contamination are present in the proposed work areas of this site. It is anticipated that this will remain so until/unless contaminants are brought to the surface by intrusive activities, such as soil boring or sampling operations. Furthermore, once intrusive 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 Lower Subase where active work is being performed plus a designated area surrounding the point of operation (see Table 5-1 for specific operation). The exclusion zone for this activity will be fragmented to represent the areas where the soil is disturbed through drilling or sampling activities. When possible, exclusion zones will be delineated using barrier tape, cones and/or drive poles, and postings to inform site personnel.

10.1.1 Exclusion Zone Clearance

Prior to the initiation of field activities, utility locations will be identified by utility companies contacted through the NSB-NLON Public Works Department (860) 449-4711. Additional utility surveys may be conducted by B&R Environmental through the use of available documentation provided by NSB-NLON and/or local utility companies. The positions of identified utilities will be field located and staked, to minimize the potential for damage during intrusive activities. Sample locations will be located to avoid buried utilities. In the event that a utility is struck during a subsurface investigative activity, the emergency numbers provided in Section 2.9, Table 2-1 will be notified.

Access to work areas will be controlled by B&R Environmental personnel. No personnel will be permitted to enter site exclusion zones without site-specific training. Site visitors will be provided site-specific training and will be escorted by B&R Environmental personnel at all times.

10.2 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. The personnel and equipment decontamination will not take place in this area, but will take place at a central location established for this project. Instead, this area will serve as a focal point in supporting exclusion zone activities. When applicable, this area will be delineated using barrier tape, cones and/or drive poles, and postings to inform and direct facility personnel.

10.3 SUPPORT ZONE

The support zone for this project 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.

10.4 SITE VISITORS

Site visitors for the purpose of this document are identified as representing the following groups of individuals:

- Personnel invited to observe or participate in operations by B&R Environmental
- Regulatory personnel (i.e., USEPA, OSHA, CTDEP)
- NSB-NLON Personnel
- Other authorized visitors

All personnel working on this project are required to gain initial access to the site by coordinating with the B&R Environmental FOL or designee and following established site access procedures.

Once access to the site is obtained, all personnel who require site access into areas of ongoing operations will be required to obtain permission from the FOL and SSO. Upon gaining access to the site, all site

visitors wishing to observe operations in progress will be escorted by a B&R Environmental representative (arranged for by the FOL) and shall be required to meet the minimum requirements discussed below:

- All site visitors will be routed to the FOL, who will sign them into the field logbook. Information to be recorded in the logbook will include the individual's name (proper identification required), the entity which they represent, and the purpose of the visit.

- All site visitors will be required to produce the necessary information supporting clearance to the site. This shall include information attesting to applicable training (40-hours of HAZWOPER training) and medical surveillance as stipulated in Section 8.0 of this document. In addition, to enter the site operational zones during planned activities, all visitors will be required to first go through site-specific training covering the topics stipulated in Section 8.2 of this HASP.

Once the site visitors have completed the above items, they will be permitted to enter the operational zone. All visitors are required to observe the protective equipment and site restrictions in effect at the site at the time of their visit. Any and all visitors not meeting the requirements, as stipulated in this plan, for site clearance will not be permitted to enter the site operational zones during planned activities. Any incidence of unauthorized site visitation will cause the termination of all onsite activities until the unauthorized visitor is removed from the premises. Removal of unauthorized visitors will be accomplished with support from the FOL, SSO or on-site security personnel.

10.5 SITE SECURITY

Site security will be accomplished using existing base security resources and procedures, supplemented by B&R Environmental or subcontractor personnel if or as necessary. B&R Environmental will retain complete control over active operational areas. The first line of security will take place at the site fences restricting the general public. The second line of security will take place at the work site referring interested parties to the FOL. The FOL will serve as a focal point for site personnel, and will serve and the final line of security and the primary enforcement contact.

10.6 SITE MAP

Once the areas of contamination, access routes, utilities, topography, and dispersion routes are determined, a site map will be generated and adjusted as site conditions change. These maps will show utility locations, potential points of contact with the public, roadways, and other significant characteristics that may impact site operations and safety. Site maps will be posted to illustrate up-to-date collection of contaminants and adjustment of zones and access points. A site map to the hospital will also be provided.

10.7 BUDDY SYSTEM

Personnel engaged in onsite activities will practice the "buddy system" to ensure the safety of all personnel involved in this operation.

10.8 MATERIAL SAFETY DATA SHEET (MSDS) REQUIREMENTS

B&R Environmental and subcontractor personnel will provide MSDSs for all chemicals brought on site. The contents of these documents will be reviewed by the SSO with the user(s) of the chemical substances prior to any actual use or application of the substances on site. A chemical inventory of all chemicals used on site will be developed using the Health and Safety Guidance Manual. The MSDSs will then be maintained in a central location and will be available for anyone to review upon request.

10.9 COMMUNICATION

As personnel may not always be working in proximity to one another during field activities, a supported means of communication between field crews will be used as necessary. As a result, two-way radio communication devices will be used by field personnel while at the site.

External communication will be accomplished by using provided telephones at the site. External communication will primarily be used for the purpose of resource and emergency resource communications.

10.10 SAFE WORK PERMITS

All exclusion zone work conducted in support of this project will be performed using Safe Work Permits to guide and direct field crews on a task by task basis. An example of the safe work permit to be used is illustrated in Figure 10-1. These work permits will be further supported by the daily meetings conducted

during their generation. This effort will ensure all site specific considerations and changing conditions are incorporated into the planning effort. All permits will require the signature of the FOL and SSO. All personnel engaged in onsite activities will be aware of the elements indicating levels of protection and precautionary measures to be used.

Use of these permits will provide the communication line for reviewing protective measures and hazards associated with each operation. This HASP will be used as the primary reference for selecting levels of protection and control measures. The work permit will take precedence over the HASP when more conservative measures are required based on specific site conditions.

FIGURE 10-1
SAFE WORK PERMIT

Permit No. _____ Date: _____ Time: From _____ to _____

SECTION I: General Job Scope (To be filled in by person performing work)

I. Work limited to the following (description, area, equipment used): _____

II. Names: _____

III. Onsite Inspection conducted ☐ Yes ☐ No Initials of Inspector _____ _____
B&RE

SECTION II: General Safety Requirements (To be filled in by permit issuer)

IV. Protective equipment required
Level D ☐ Level B ☐
Level C ☐ Level A ☐
Detailed on Reverse

Respiratory equipment required
Full face APR ☐
Half face APR ☐
SKA-PAC SAR ☐
Skid Rig ☐
Escape Pack ☐
SCBA ☐
Bottle Trailer ☐
None ☐

Modifications/Exceptions: _____

V. Chemicals of Concern | Action Level(s) | Response Measures

VI. Additional Safety Equipment/Procedures

Hardhat	☐ Yes	☐ No	Hearing Protection (Plugs/Muffs)	☐ Yes	☐ No
Safety Glasses	☐ Yes	☐ No	Safety belt/harness	☐ Yes	☐ No
Chemical/splash goggles	☐ Yes	☐ No	Radio	☐ Yes	☐ No
Splash Shield	☐ Yes	☐ No	Barricades	☐ Yes	☐ No
Splash suits/coveralls	☐ Yes	☐ No	Gloves (Type)	☐ Yes	☐ No
Steel toe/shank Workboots	☐ Yes	☐ No	Work/rest regimen	☐ Yes	☐ No

Modifications/Exceptions: _____

VII. Procedure review with permit acceptors

	Yes	NA		Yes	NA
Safety shower/eyewash (Location & Use)	☐	☐	Emergency alarms	☐	☐
Procedure for safe job completion	☐	☐	Evacuation routes	☐	☐
Contractor tools/equipment inspected	☐	☐	Assembly points	☐	☐

VII. Equipment Preparation

	Yes	NA
Equipment drained/depressured	☐	☐
Equipment purged/cleaned	☐	☐
Isolation checklist completed	☐	☐
Electrical lockout required/field switch tested	☐	☐
Blinds/misalignments/blocks & bleeds in place	☐	☐
Hazardous materials on walls/behind liners considered	☐	☐

VIII. Additional Permits required (Hot work, confined space entry, excavation etc.). ☐ Yes ☐ No
If yes, fill out appropriate section(s) on safety work permit addendum

IX. Special instructions, precautions: _____

Permit Issued by: _____ Permit Accepted by: _____
Job Completed by: _____ Date: _____

11.0 CONFINED SPACE ENTRY

Personnel under the provisions of this HASP are not allowed, under any circumstances, to enter confined spaces. A confined space is defined as an area which has one or more of the following characteristics:

- Is large enough and so configured that an employee can bodily enter and perform assigned work.
- Has limited or restricted means for entry or exit (for example, excavations, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
- Is not designed for continuous employee occupancy.
- Contains or has a potential to contain a hazardous atmosphere.
- Contains a material that has the potential to engulf an entrant.
- Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section.
- Contains any other recognized, serious, safety or health hazard.

For further information on confined space consult the Health and Safety Guidance Manual or call the B&R Environmental Health and Safety Manager. Any activity that may be considered a confined space entry shall require modifications of this HASP and shall result in the immediate notification of the Project Health and Safety Officer. This determination shall be made by the FOL or the SSO. If confined space operations are to be performed as part of the scope of work, detailed procedures and training requirements will be addressed in an addendum or the site specific health and safety plan.

12.0 MATERIALS AND DOCUMENTATION

The B&R Environmental PM shall ensure the following materials/documents are taken to the project site and used when required.

- A complete copy of this HASP
- Health and Safety Guidance Manual
- Incident Reports
- Medical Data Sheets
- Material Safety Data Sheets for all chemicals brought on site, including decon solutions, fuels, lime, sample preservatives, calibration gases, etc.
- Follow-up Reports
- A full-size OSHA Job Safety and Health Poster (posted in the site trailers)
- Training/Medical Surveillance Documentation Form (Blank)
- First-Aid Supply Usage Form
- Emergency Reference Form (Section 2.0, extra copy for posting)

12.1 MATERIALS TO BE POSTED AT THE SITE

The following documentation is to be posted at the site for quick reference purposes. In situations where posting of these documents is not feasible (such as no office trailer), these documents should be separated and immediately accessible.

Chemical Inventory Listing - This list represents all chemicals brought on site, including decontamination solutions, sample preservatives, fuel, calibration gases, etc.. This list should be posted in a central area.

Material Safety Data Sheets (MSDSs) - The MSDSs should also be in a central area accessible to all site personnel. These documents should match all the listings on the chemical inventory list for all substances employed on site. It is acceptable to have these documents within a central folder and the chemical inventory as the table of contents.

The OSHA Job Safety & Health Protection Poster - This poster, as directed by 29 CFR 1903.2 (a)(1), should be conspicuously posted in places where notices to employees are normally posted. Each FOL shall ensure that this poster is not defaced, altered, or covered by other material.

Site Clearance Posting - This list is found within the training section of the HASP (See Figure 8-1). The list identifies all site personnel, dates of training (including site-specific training), and medical surveillance. It also indicates not only clearance but also status. If personnel do not meet these requirements, they do not enter the site while site personnel are engaged in activities.

Emergency Phone Numbers and Directions to the Hospital(s) - This list of numbers and the directions will be maintained at all phone communications points and in each site vehicle.

Medical Data Sheets/Cards - Medical Data Sheets will be filled out by all onsite personnel and filed in a central location. The Medical Data Sheet will accompany any injury or illness requiring medical attention to the medical facility. A copy of this sheet or a wallet card will be given to all personnel to be carried on their person.

Hearing Conservation Standard (29 CFR 1910.95) - This standard will be posted anytime hearing protection or other noise abatement procedures are employed.

Personnel Monitoring - All results generated through personnel sampling (levels of airborne toxics, noise levels, etc.) will be posted to inform individuals of the results of that effort.

Placards and Labels - Where chemical inventories have been separated, because of quantities and incompatibilities, these areas will be conspicuously marked using Department of Transportation (DOT) placards and acceptable [Hazard Communication 29 CFR 1910.1200 (f)] labels.

APPENDIX E

SUPPLEMENTAL SAMPLING FOR REMEDIAL DESIGN OF AREA A DOWNSTREAM

APPENDIX E

1.0 INTRODUCTION

As indicated in Section 1.1 of this work plan, this appendix provides a field sampling plan for a supplemental sampling event which will be performed in the Thames River to aid in the remedial design of the Area A Downstream site.

2.0 SCOPE AND OBJECTIVES

The objective of this supplemental sampling effort is to collect additional sediment and surface water data in the vicinity of the outfall of Stream 5 that emanates from the Area A Downstream site. The additional sampling to be completed includes the collection and analysis of one sediment sample and the measurement of surface water quality parameters. The results of the sampling effort will provide an understanding of the baseline conditions (i.e., existing level of contamination) that exist at this location before remedial activities are completed at the Area A Downstream site.

3.0 LOCATION

This supplemental sampling effort will involve the collection of one grab sediment sample and the measurement of corresponding surface water quality parameters from the Thames River at the outfall of Stream 5. The location of this sampling point, which is approximately 15 feet from the shoreline and east of Buildings 355 and 397 at the DRMO site, is shown in Figure E-1. The location is designated SW/SD1-S5OAA. This location should be verified in the field prior to sampling.

4.0 COLLECTION, MEASUREMENT, AND ANALYSES

Sediment sampling and surface water quality measurements taken at SW/SD1-S5OAA in the Thames River will be conducted from a boat equipped with a GPS unit so that survey data may be obtained. The boat will be anchored and the engine will be shut off while sampling activities are being conducted.

In-situ surface water quality measurements will be taken prior to sampling of the river sediment. At this sampling location, the surface water at the surface (shallow) and near the sediment-water column interface (deep) will be field analyzed in-situ for temperature, pH, dissolved oxygen, specific conductivity, oxidation-reduction potential, turbidity, and salinity using a multi-parameter water quality meter (YSI or equivalent). The depth to the sediment-water interface will also be measured. Sampling will be conducted near low tide conditions and the level of the tide will be recorded at the time of sampling.

The sediment sample will be collected according to the procedures outlined in B&R Environmental's SOP SA-1.2 in Appendix B. The sediment sample will be collected using a stainless steel dredge, Ponar, or Van Veen sampler and stainless steel trowel. It will be collected from a sediment depth of approximately 0.0 to 0.5 feet below the bottom of the

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NOTES:

1. UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE.
2. BASE MAP AND UTILITY INFORMATION FROM MAPS OF NSB-NLON AND PHASE II RI WORK PLAN, (ATLANTIC, MAY 1993).
3. POTENTIOMETRIC SURFACE FOR WATER LEVELS MEASURED ON AUGUST 23-24, 1994.
4. MEAN HIGH WATER ELEVATION BASED ON FFS BY ATLANTIC, MARCH 1994.

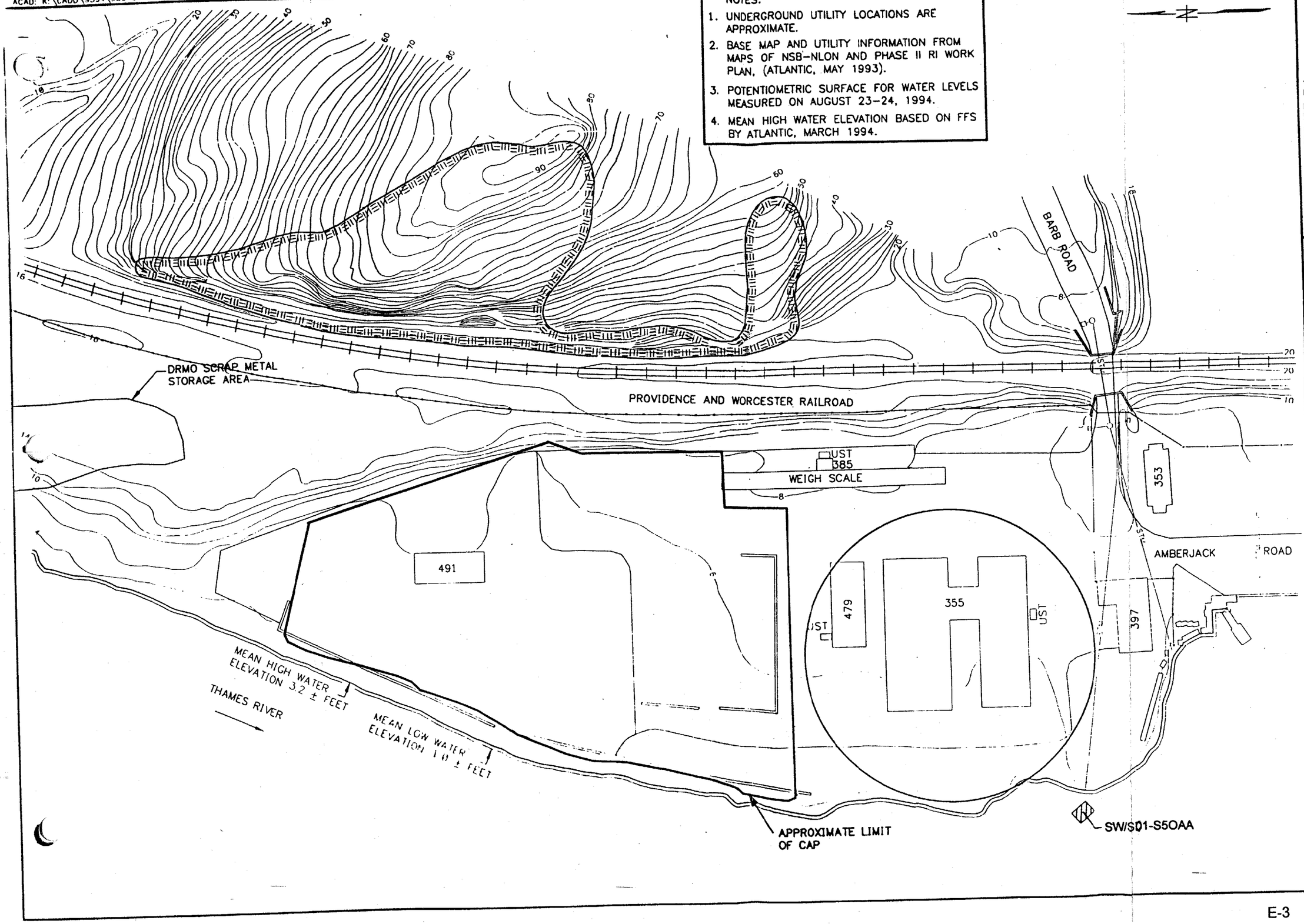

FIGURE E-1
SAMPLE LOCATION MAP
DRMO
Brown & Root Environmental

01328297

Thames River. A minor modification to this procedure, as discussed in Section 2.4.3 of this work plan, will be used for the collection of sediment samples for AVS/SEM and ammonia analyses. The sampling equipment will be decontaminated prior to the sampling activity and will follow decontamination procedures outlined in Section 2-7. Bottle and sample preservation requirements are presented in Table 2-3.

The sediment sample will be submitted to the BOA laboratory for the following analyses: TCL semivolatile organic compounds, TCL pesticides, TAL metals, acid volatile sulfide/simultaneously extracted metals (AVS/SEM), ammonia, pH, total organic carbon, and grain size analysis. All sample handling procedures, including packaging and shipping, chain of custody, quality control samples, and record keeping, that are discussed in Section 3.0 of this work plan should be followed.

APPENDIX F

Summary of Work Completed to Determine the Optimal Soil Sample Size for Lead

APPENDIX F

1.0 PURPOSE

To respond to USEPA's Comment No. 1 on the draft final Lower Subase RI WP/SAP, it is necessary to develop an appropriate method for determining the optimal soil sample size for lead for each zone at the Lower Subase. The reason for needing the optimal soil sample size is to justify that the number of samples in the proposed sampling program, along with the existing data, will provide sufficient information for the USEPA's model for evaluating risks to adults from lead. This model requires a representative mean concentration of lead. The exercise is also necessary to limit the additional samples that the Navy will have to collect in the future. By defining the decision making information prior to sampling and having the acceptance of the regulators, the Navy can eliminate unnecessary sampling at the Lower Subase in the future.

2.0 APPROACH

The approach selected by B&R Environmental (i.e., the Navy's contractor) for this task is summarized below. The method selected by B&R Environmental was used to determine if the Navy's combined analytical data set for soil (i.e., existing data and proposed data) will be adequate for human health risk assessment purposes.

Two common goals of the EPA and the regulated community are to minimize expenditures by eliminating unnecessary data and to collect data of sufficient quality and quantity to support defensible decision making. As an efficient method of accomplishing both goals, the EPA has developed the Data Quality Objectives (DQO) Process.

The DQO Process is a strategic planning approach based on the Scientific Method. Implementing this process assures that representative data is utilized to support effective decision-making. The EPA's DQO guidance [EPA QA / G-4 (Guidance for the Data Quality Objectives Process); September 1994] as well as the EPA's 'Methods for Evaluating the Attainment of Cleanup Standards: Volume 1: Soils and Solid Media' [EPA 230/02-89-042 (1989)] suggest standard formulas for determining the number of samples that are sufficient to meet the limits on decision errors that have been specified and the DQO constraints for comparing a mean against a regulatory threshold.

Soil samples have been collected and analyzed for lead in six of the seven zones. The sample size needed to characterize lead relative to its action level have been determined by using the sample size formula for testing mean of normal distribution versus an action level [Equation (8) from Appendix C of EPA's DQO Guidance].

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})\sigma^2}{\Delta^2} + 0.5\, Z_{1-\alpha}$$

where: n = sample size;

Z_p = p^{th} percentile of the standard normal distribution;

α = the false positive (Type I) error rate [deciding the site is contaminated when it truly is not];

β = the false negative (Type II) error rate [deciding the site is not contaminated when it truly is];

σ^2 = variance;

Δ = width of the 'gray region'; (U - AL); U is a constant value greater than the action level (AL).

An appropriate null hypothesis (H_0) for this situation is:

H_0: $\mu \leq AL$ *(The average concentration within the soil of the zone is less than the action level)*

The consequence of a Type I error [rejecting H_0 when it is true] is unnecessary remediation and the associated expenses. The consequence of a Type II error [accepting H_0 when it is false] is incomplete remediation which could possibly endanger human health and the environment.

Values are assigned to α, β, and Δ to reflect the tolerable probability for the occurrence of decision errors. The EPA's 'Soil Screening User's Guide' [EPA 540/R-96-01B (1996)] makes recommendations for these error rates. "Strive to achieve a false negative error rate of 5 percent...EPA also strives to achieve a 20 percent false positive error rate...EPA has defined the 'gray region' as one-half to two times the action level". These specifications give: $1-\beta = 0.95$, $1-\alpha = 0.80$, and U = 1.5xAL to 3.0xAL. The EPA's 'Guidance for Data Useability in Risk Assessment' [EPA 540/G-90/008 (1990)] reports minimum recommended performance measures of $1-\beta = 0.90$ and $1-\alpha = 0.80$.

For this exercise, ranges of $1-\beta$ of 0.50 to 0.99, $1-\alpha$ of 0.80 to 0.90, and U of 1.5xAL to 3.0xAL were used to estimate a range of required numbers of samples. One set of criteria was then selected (i.e., the USEPA's specifications of $1-\beta = 0.95$, $1-\alpha = 0.80$, and U = 1.5xAL) and the derived number of samples for these criteria were tabulated.

The action level selected for the calculations was the CTDEP's lead industrial remediation standard for soil which is 1,000 mg/kg. This criteria is appropriate because the Lower Subase is currently used for industrial purposes, and the Navy intends to maintain the industrial nature of the Lower Subase in the future.

3.0 RESULTS

The calculations performed for this task were completed by spreadsheet. All of the spreadsheets that were created are included in Attachment 1. The spreadsheets are grouped by Zone and data set {i.e., (validated) or (validated and unvalidated)}.

Table 1 summarizes the existing and proposed soil samples that have been or will be analyzed for lead. Table 2 summarizes the derived sample numbers using only

validated data. Table 3 summarizes the derived sample numbers using validated and unvalidated data. Table 4 summarizes the arithmetic average lead concentrations using two data sets {i.e., (validated) and (validated and unvalidated)}.

4.0 CONCLUSIONS

By comparing the results presented in Tables 2 and 3 with the number of samples provided in Table 1, the following conclusions can be made:

- The current sampling program is adequate for Zones 1, 2 and 5.
- There is a potential that additional sampling will be required at Zone 3, and it is likely that additional sampling will be required in Zones 4 and 7 because of the high levels of previously detected lead.
- No data is available for Zone 6, therefore no conclusions can be made in regard to the number of required samples at this time.

After evaluating the mean concentrations summarized in Table 4, the following conclusions can be made:

- The average concentrations of lead calculated for Zones 1, 2 and 5 are relatively consistent and independent of the data set {i.e., (validated) or (validated and unvalidated)}.
- The average concentrations of lead calculated for Zone 3 vary, but are of the same order of magnitude.
- The average concentrations of lead calculated for Zones 4 and 7 are variable with depth and indicate that high levels of contamination are present in the shallow soil of these zones and remediation of these hot spots will probably be necessary.

TABLES

TABLE 1
SUMMARY OF EXISTING AND PROPOSED SOIL SAMPLES - LEAD ANALYSIS
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

Zone	# of Existing Shallow Samples (1)	# of Existing Deep Samples (1)	Total # of Existing Samples	# of Proposed Shallow Samples (2)	# of Proposed Deep Samples (2)	Total # of Proposed Samples	Total Samples After Field Work
1	4	13	17	3	0	3	20
2	3	4	7	0	3	3	10
3	5	2	7	3	3	6	13
4	4	6	10	3	3	6	16
5	3	0	3	2	2	4	7
6	0	0	0	5	5	10	10
7	9	5	14	4	4	8	22

1 - Only analytical data for unexcavated, validated, grab samples are included in the data set
2 - From the draft final Lower Subase RI WP/SAP, July 1997

TABLE 2 - EXPOSURE SCENARIO = INDUSTRIAL
SUMMARY OF DERIVED NUMBER OF SOIL SAMPLES FOR LEAD - VALIDATED DATA ONLY
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

	VALIDATED DATA [1]			VALIDATED DATA WITH HOT SPOT(S) REMOVED [1]		
Zone	Derived Sample Size Shallow Sample Results [2]	Derived Sample Size Deep Sample Results [2]	Derived Sample Size - Shallow & Deep Sample Results [2,3]	Derived Sample Size Shallow Sample Results [2]	Derived Sample Size Deep Sample Results [2]	Derived Sample Size - Shallow & Deep Sample Results [2,3]
1	1	1	1	NA	NA	NA
2	1	2	1	NA	NA	NA
3	9	2	7	1[4]	NA	1[4]
4	541	9	320	NA	NA	NA
5	NA	NA	1	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	88203	5	55119	2[5]	NA	3[5]

1 - Only analytical data for unexcavated, validated, grab samples are included in the data set
2 - 1-a=0.80, 1-B=0.95, U=1.5xAL (Soil Screening User's Guide, USEPA, 1996); AL = 1000 mg/kg (CTDEP Industrial Scenario)
3 - Combined Sample Set of Shallow and Deep Samples
4 - Excludes Sample 13TB18-0103
5 - Excludes Sample 20MW6-0204

TABLE 3 - EXPOSURE SCENARIO = INDUSTRIAL
SUMMARY OF DERIVED NUMBER OF SOIL SAMPLES FOR LEAD - VALIDATED & UNVALIDATED DATA
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

	VALIDATED & UNVALIDATED DATA			VALIDATED & UNVALIDATED DATA WITH HOT SPOT(S) REMOVED		
Zone	Derived Sample Size Shallow Sample Results (2)	Derived Sample Size Deep Sample Results (2)	Derived Sample Size - Shallow & Deep Sample Results (2,3)	Derived Sample Size Shallow Sample Results (2)	Derived Sample Size Deep Sample Results (2)	Derived Sample Size - Shallow & Deep Sample Results (2,3)
1	1	1	1	NA	NA	NA
2	1	2	1	NA	NA	NA
3	15	27	20	NA	NA	NA
4	366	15	248	NA	NA	NA
5	1	1	1	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	63004	180	32613	2(4)	NA	92(4)

1 - All analytical data, except for excavated samples, are included in the data set
2 - 1-a=0.80, 1-B=0.95, U=1.5xAL (Soil Screening User's Guide, USEPA, 1996); AL = 1000 mg/kg (CTDEP Industrial Scenario)
3 - Combined Sample Set of Shallow and Deep Samples
4 - Excludes Sample 20MW6-0204

TABLE 4 - ARITHMETIC AVERAGE
LEAD ANALYTICAL RESULTS - VALIDATED & UNVALIDATED DATA
LOWER SUBASE REMEDIAL INVESTIGATION
NSB-NLON, GROTON, CONNECTICUT

	VALIDATED DATA			VALIDATED & UNVALIDATED DATA		
Zone	Average Shallow Sample Results (1)	Average Deep Sample Results (1)	Average - Shallow & Deep Sample Results (1)	Average Shallow Sample Results (2)	Average Deep Sample Results (2)	Average - Shallow & Deep Sample Results (2)
1	56.35	44.31	47.14	46.62	44.31	44.95
2	159.00	104.75	128.00	159.00	104.75	128.00
3	303.39	142.30	257.36	272.81	374.50	313.13
4	4816.25	295.32	2103.69	4237.14	428.32	2094.68
5	NA	NA	11.08	13.82	6.17	10.67
6	NA	NA	NA	NA	NA	NA
7	19032.62	188.43	11966.05	13635.62	969.28	7537.01

1 - Only analytical data for unexcavated, validated, grab samples are included in the data set
2 - All analytical data, except for excavated samples, are included in the data set

ATTACHMENT 1

ZONE 1

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 1 Shallow

LEAD (MG/KG)			
Sample Variance =	***1682.497***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	3

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	2	2	3

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	3	4

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	3	4	5

Boldface values are less than or equal to 4 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples	
σ^2=variance in concentration	
z_p=the pth percentile of the standard normal distribution	
Δ=width of gray region (U-AL)	

SITE	RESULT	QUAL	VALUE[2]	
13TB13-0305	26.7	J	26.7	**4 SAMPLES**
13TB15-0305	112		112	
13TB16-0204	24.2		24.2	
13TB17-0406	62.5	J	62.5	
Sample Variance =	***1682.497***			
Average Value =	56.350			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 1 Deep

LEAD (MG/KG)			
Sample Variance =	***10871.389***	***Action Level[1] =***	**1000**

$1-\beta = 0.50$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	3	5

$1-\beta = 0.75$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	3	5	8

$1-\beta = 0.90$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	2	3
U = 1.10 x AL	6	8	11

$1-\beta = 0.95$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	8	11	14

$1-\beta = 0.99$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	3	4	5
U = 1.10 x AL	12	15	19

Boldface values are less than or equal to 13 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
110590-13MW1(12-14)	4.2	J	4.2
110590-13MW2(10-12)	22.8	J	22.8
110790-13MW3(12-14)	3	J	3
110790-13MW4(6-8)	383	J	383
110790-13MW9(6-8)	23.3	J	23.3
110890-13MW5(10-12)	17.6	J	17.6
110790-13MW8(8-10)	15.3	J	15.3
110790-13MW7(8-10)	3.8	J	3.8
13TB13-0911	3.6		3.6
13TB15-0709	6.4		6.4
13TB16-0810	87		87
13TB17-0608	3.4		3.4
13MW18-0911	2.6		2.6
Sample Variance =	***10871.389***		
Average Value =	44.308		

13 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 1 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***8496.734***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	1	3	4

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	3	5	6

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	5	7	9

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	2	3
U = 1.10 x AL	6	9	11

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	9	12	15

Boldface values are less than or equal to 17 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
110590-13MW1(12-14)	4.2	J	4.2
110590-13MW2(10-12)	22.8	J	22.8
110790-13MW3(12-14)	3	J	3
110790-13MW4(6-8)	383	J	383
110790-13MW9(6-8)	23.3	J	23.3
110890-13MW5(10-12)	17.6	J	17.6
110790-13MW8(8-10)	15.3	J	15.3
110790-13MW7(8-10)	3.8	J	3.8
13TB13-0911	3.6		3.6
13TB15-0709	6.4		6.4
13TB16-0810	87		87
13TB17-0608	3.4		3.4
13MW18-0911	2.6		2.6
13TB13-0305	26.7		26.7
13TB15-0305	112		112
13TB16-0204	24.2		24.2
13TB17-0406	62.5		62.5
Sample Variance =	***8496.734***		
Average Value =	47.141		

17 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.

Action Level (AL): value that determines acceptance or rejection of H_0

α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**

β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**

Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 1 Shallow

LEAD (MG/KG)			
Sample Variance =	***1735.237***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	3

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	2	3

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	3	4

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	3	4	5

Boldface values are less than or equal to 5 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
13TB13-0305	26.7	J	26.7
13TB15-0305	112		112
13TB16-0204	24.2		24.2
13TB17-0406	62.5	J	62.5
Pipe Chase (94)	7.7		7.7
Sample Variance =	***1735.237***		
Average Value =	46.620		

5 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 1 Deep

LEAD (MG/KG)			
Sample Variance =	***10871.389***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	3	5

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	3	5	8

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	2	3
U = 1.10 x AL	6	8	11

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	8	11	14

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	3	4	5
U = 1.10 x AL	12	15	19

Boldface values are less than or equal to 13 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
110590-13MW1(12-14)	4.2	J	4.2
110590-13MW2(10-12)	22.8	J	22.8
110790-13MW3(12-14)	3	J	3
110790-13MW4(6-8)	383	J	383
110790-13MW9(6-8)	23.3	J	23.3
110890-13MW5(10-12)	17.6	J	17.6
110790-13MW8(8-10)	15.3	J	15.3
110790-13MW7(8-10)	3.8	J	3.8
13TB13-0911	3.6		3.6
13TB15-0709	6.4		6.4
13TB16-0810	87		87
13TB17-0608	3.4		3.4
13MW18-0911	2.6		2.6
Sample Variance =	***10871.389***		
Average Value =	44.308		

13 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 1 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***8083.349***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	1	3	4

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	3	4	6

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	4	7	9

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	2	3
U = 1.10 x AL	6	8	11

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	9	12	15

Boldface values are less than or equal to 18 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
110590-13MW1(12-14)	4.2	J	4.2
110590-13MW2(10-12)	22.8	J	22.8
110790-13MW3(12-14)	3	J	3
110790-13MW4(6-8)	383	J	383
110790-13MW9(6-8)	23.3	J	23.3
110890-13MW5(10-12)	17.6	J	17.6
110790-13MW8(8-10)	15.3	J	15.3
110790-13MW7(8-10)	3.8	J	3.8
13TB13-0911	3.6		3.6
13TB15-0709	6.4		6.4
13TB16-0810	87		87
13TB17-0608	3.4		3.4
13MW18-0911	2.6		2.6
13TB13-0305	26.7		26.7
13TB15-0305	112		112
13TB16-0204	24.2		24.2
13TB17-0406	62.5		62.5
Pipe Chase (94)	7.7		7.7
Sample Variance =	***8083.349***		
Average Value =	44.950		

18 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] 1/2 the detection limit is used to calculate value, average value, and sample variance for nc tects (samples with 'U' in QUAL column).

ZONE 2

VALIDATED DATA

Derived Sample Size (n) Based on Sample Variance and Action Level Zone 2 Shallow

LEAD (MG/KG)			
Sample Variance =	***271.000***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

Boldface values are less than or equal to 3 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]	3 SAMPLES
110890-13MW11(2-4)	178	J	178	
13TB8-0103	149		149	
13TB9-0103	150		150	
Sample Variance =	***271.000***			
Average Value =	159.000			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 2 Deep

LEAD (MG/KG)			
Sample Variance =	***39805.557***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	2	**2**
U = 1.25 x AL	1	2	**4**
U = 1.10 x AL	4	8	13

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	2	**3**
U = 1.25 x AL	2	4	**5**
U = 1.10 x AL	10	17	23

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	**2**
U = 1.50 x AL	2	2	**3**
U = 1.25 x AL	4	6	7
U = 1.10 x AL	19	27	36

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	**2**
U = 1.50 x AL	2	3	**4**
U = 1.25 x AL	5	7	9
U = 1.10 x AL	25	35	45

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	**2**
U = 1.50 x AL	2	3	**4**
U = 1.25 x AL	7	10	12
U = 1.10 x AL	41	53	65

Boldface values are less than or equal to 4 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]	4 SAMPLES
111290-13MW17(8-10)	5.4	J	5.4	
111390-13MW6(14-16)	2	J	2	
110890-13MW10(6-8)	7.6	J	7.6	
13TB11-0406	404		404	
Sample Variance =	***39805.557***			
Average Value =	104.750			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 2 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***20833.987***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	2	5	7

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	6	9	13

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	2	4	5
U = 1.10 x AL	10	15	20

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	3	4	5
U = 1.10 x AL	14	19	24

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	2
U = 1.50 x AL	2	2	3
U = 1.25 x AL	4	6	7
U = 1.10 x AL	22	28	35

Boldface values are less than or equal to 7 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples	
σ^2=variance in concentration	
z_p=the pth percentile of the standard normal distribution	
Δ=width of gray region (U-AL)	

SITE	RESULT	QUAL	VALUE[2]
111290-13MW17(8-10)	5.4	J	5.4
111390-13MW6(14-16)	2	J	2
110890-13MW10(6-8)	7.6	J	7.6
13TB11-0406	404		404
110890-13MW11(2-4)	178	J	178
13TB8-0103	149		149
13TB9-0103	150		150
Sample Variance =	***20833.987***		
Average Value =	128.000		

7 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 2 Shallow

LEAD (MG/KG)			
Sample Variance =	***271.000***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

Boldface values are less than or equal to 3 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]	
110890-13MW11(2-4)	178	J	178	**3**
13TB8-0103	149		149	**SAMPLES**
13TB9-0103	150		150	
Sample Variance =	***271.000***			
Average Value =	159.000			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample varian[illegible] non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 2 Deep

LEAD (MG/KG)			
Sample Variance =	***39805.557***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	1	2	4
U = 1.10 x AL	4	8	13

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	2	4	5
U = 1.10 x AL	10	17	23

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	2
U = 1.50 x AL	2	2	3
U = 1.25 x AL	4	6	7
U = 1.10 x AL	19	27	36

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	2
U = 1.50 x AL	2	3	4
U = 1.25 x AL	5	7	9
U = 1.10 x AL	25	35	45

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	2
U = 1.50 x AL	2	3	4
U = 1.25 x AL	7	10	12
U = 1.10 x AL	41	53	65

Boldface values are less than or equal to 4 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
111290-13MW17(8-10)	5.4	J	5.4
111390-13MW6(14-16)	2	J	2
110890-13MW10(6-8)	7.6	J	7.6
13TB11-0406	404		404
Sample Variance =	***39805.557***		
Average Value =	104.750		

4 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 2 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***20833.987***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**1**	**2**
U = 1.25 x AL	**1**	**2**	**3**
U = 1.10 x AL	**2**	**5**	**7**

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**2**	**2**
U = 1.25 x AL	**2**	**3**	**4**
U = 1.10 x AL	**6**	9	13

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**2**	**3**
U = 1.25 x AL	**2**	**4**	**5**
U = 1.10 x AL	10	15	20

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**2**	**3**
U = 1.25 x AL	**3**	**4**	**5**
U = 1.10 x AL	14	19	24

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**2**	**2**	**3**
U = 1.25 x AL	**4**	**6**	**7**
U = 1.10 x AL	22	28	35

Boldface values are less than or equal to 7 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
111290-13MW17(8-10)	5.4	J	5.4
111390-13MW6(14-16)	2	J	2
110890-13MW10(6-8)	7.6	J	7.6
13TB11-0406	404		404
110890-13MW11(2-4)	178	J	178
13TB8-0103	149		149
13TB9-0103	150		150
Sample Variance =	***20833.987***		
Average Value =	128.000		

7 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample varian[illegible] non-detects (samples with 'U' in QUAL column).

ZONE 3

VALIDATED DATA

Derived Sample Size (n) Based on Sample Variance and Action Level
Zone 3 Shallow — A

LEAD (MG/KG)			
Sample Variance =	***326597.215***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**3**
U = 1.50 x AL	**2**	**3**	**5**
U = 1.25 x AL	5	10	16
U = 1.10 x AL	24	55	90

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**2**	**3**	**4**
U = 1.50 x AL	**4**	6	9
U = 1.25 x AL	13	21	30
U = 1.10 x AL	76	126	178

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**2**	**3**	**5**
U = 1.50 x AL	7	10	13
U = 1.25 x AL	24	36	47
U = 1.10 x AL	148	216	282

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**3**	**4**	**5**
U = 1.50 x AL	9	13	16
U = 1.25 x AL	33	46	58
U = 1.10 x AL	203	281	355

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**4**	6	7
U = 1.50 x AL	14	18	22
U = 1.25 x AL	53	69	84
U = 1.10 x AL	329	426	517

Boldface values are less than or equal to 5 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]	
13TB18-0103	1320	J	1320	**5 SAMPLES**
13TB5A-1.5-3.5	151	J	151	
13TB7-0103	36.8	J	36.8	
SB14-2.0-TAL	3.1		3.1	
SB06-4.0-AVG	12.05	U	6.025	
Sample Variance =	***326597.215***			
Average Value =	303.385			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Shallow – B

VALIDATED DATA
(13TB18-0103 REMOVED)

LEAD (MG/KG)			
Sample Variance =	***4835.429***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	3

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	3	4

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	3	4	6

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	4	5	7

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	2	3
U = 1.10 x AL	6	8	9

Boldface values are less than or equal to 4 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]	
13TB5A-1.5-3.5	151	J	151	**4**
13TB7-0103	36.8	J	36.8	**SAMPLES**
SB14-2.0-TAL	3.1		3.1	
SB06-4.0-AVG	12.05	U	6.025	
Sample Variance =	***4835.429***			
Average Value =	49.231			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Deep

VALIDATED DATA

LEAD (MG/KG)			
Sample Variance =	*39032.180*	*Action Level[1] =*	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	**2**	**2**
U = 1.25 x AL	1	**2**	4
U = 1.10 x AL	4	8	12

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	2	3
U = 1.25 x AL	**2**	4	5
U = 1.10 x AL	10	16	23

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	**2**	**2**
U = 1.50 x AL	**2**	**2**	3
U = 1.25 x AL	4	5	7
U = 1.10 x AL	18	27	35

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	**2**	**2**
U = 1.50 x AL	**2**	3	4
U = 1.25 x AL	5	7	9
U = 1.10 x AL	25	35	44

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	**2**	**2**
U = 1.50 x AL	**2**	3	4
U = 1.25 x AL	7	9	12
U = 1.10 x AL	40	52	63

Boldface values are less than or equal to 2 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

SITE	RESULT	QUAL	VALUE[2]	
110890-13MW12(8-10)	2.6	J	2.6	**2 SAMPLES**
13TB12-0406	282	J	282	
Sample Variance =	***39032.180***			
Average Value =	142.300			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Shallow and Deep – A

LEAD (MG/KG)			
Sample Variance =	***230415.025***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	2
U = 1.50 x AL	2	3	4
U = 1.25 x AL	3	7	12
U = 1.10 x AL	17	39	64

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	3
U = 1.50 x AL	3	5	7
U = 1.25 x AL	9	15	22
U = 1.10 x AL	54	89	126

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	2	3	4
U = 1.50 x AL	5	7	10
U = 1.25 x AL	17	26	33
U = 1.10 x AL	105	153	199

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	2	3	4
U = 1.50 x AL	7	9	12
U = 1.25 x AL	24	33	42
U = 1.10 x AL	143	199	251

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	3	4	5
U = 1.50 x AL	10	13	16
U = 1.25 x AL	38	49	60
U = 1.10 x AL	232	301	365

Boldface values are less than or equal to 7 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
13TB18-0103	1320	J	1320
13TB5A-1.5-3.5	151	J	151
110890-13MW12(8-10)	2.6	J	2.6
13TB12-0406	282	J	282
13TB7-0103	36.8	J	36.8
SB14-2.0-TAL	3.1		3.1
SB06-4.0-AVG	12.05	U	6.025
Sample Variance =	***230415.025***		
Average Value =	257.361		

7 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sampl[illegible]riance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Shallow and Deep – B

VALIDATED DATA
(13TB18-0103 REMOVED)

LEAD (MG/KG)			
Sample Variance =	***13017.505***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	2	2
U = 1.10 x AL	2	3	5

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	1	2	3
U = 1.10 x AL	4	6	9

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	7	10	13

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	2
U = 1.25 x AL	2	3	4
U = 1.10 x AL	9	12	16

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	3	4	5
U = 1.10 x AL	14	18	22

Boldface values are less than or equal to 6 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
13TB5A-1.5-3.5	151	J	151
110890-13MW12(8-10)	2.6	J	2.6
13TB12-0406	282	J	282
13TB7-0103	36.8	J	36.8
SB14-2.0-TAL	3.1		3.1
SB06-4.0-AVG	12.05	U	6.025
Sample Variance =	***13017.505***		
Average Value =	80.254		

6 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Shallow

LEAD (MG/KG)			
Sample Variance =	*564266.677*	*Action Level[1] =*	1000

1-β = 0.70	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	3
U = 1.50 x AL	2	5	8
U = 1.25 x AL	7	16	26
U = 1.10 x AL	41	94	155

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	2	3	5
U = 1.50 x AL	6	10	14
U = 1.25 x AL	22	36	50
U = 1.10 x AL	131	217	305

1-β = 0.80	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	3	5	7
U = 1.50 x AL	11	16	21
U = 1.25 x AL	42	61	79
U = 1.10 x AL	255	372	485

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	4	6	8
U = 1.50 x AL	16	21	26
U = 1.25 x AL	57	79	100
U = 1.10 x AL	350	485	613

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	7	9	11
U = 1.50 x AL	24	31	37
U = 1.25 x AL	91	119	144
U = 1.10 x AL	567	736	892

Boldface values are less than or equal to 70 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_\alpha + z_\beta)^2}{\Delta^2} + (0.5)\, z_\alpha^2$$

VALIDATED & UNVALIDATE

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
2-EXWW-ALBACORE-06 (94)	4390		4390
EXSW-ALBACORE-06 (94)	4173		4173
EXWW-ALBACORE-06 (94)	1880		1880
13TB18-0103	1320	J	1320
13TB12-0204-X	567	J	567
SB13-2.0-D	463		463
EXWW01-07 (94)	437		437
SB30-2.0	413		413
SB25-2.0	369		369
EXSW02-06 (94)	364		364
3-EXSW09-06 (94)	351		351
SB25-4.0-D	351		351
EXSW-BULLHEAD-06 (94)	341		341
2-EXBE78-06 (94)	330		330
EXBE-BULLHEAD-07 (94)	285		285
EXSW03-07 (94)	264		264
SB29-4.0	238		238
2-EXNW78-09 (94)	233		233
SB20-2.0	229		229
SB13-2.0	186		186
EXSW01-07 (94)	184		184
SB30-4.0	163		163
13TB5A-1.5-3.5	151	J	151
EXEW-BULLHEAD-08 (94)	134		134
SB33-2.0	123		123
13TB5A-1.5-3.5-X	113	J	113
2-EXSW78-09 (94)	97.9		97.9
EXEW02-06 (94)	92.4		92.4
2-EXNW09-06 (94)	72.7		72.7
SB21-2.0	69.8		69.8
SB15-2.0	69.2		69.2
EXNW04-06 (94)	67.4		67.4
SB15-4.0	44.5		44.5
13TB7-0103	36.8	J	36.8
SB13-4.0	32.6		32.6
SB32-2.0	31.4		31.4
SB26-2.0	30.1		30.1
SB09-2.0	27.5		27.5
SB25-4.0	26.8		26.8
SB20-4.0	26.4		26.4
SB20-4.0-D	25.8		25.8
EXNW03-07 (94)	24.3		24.3
4-EXEW03-07 (94)	21.4		21.4
EXNW02-06 (94)	19.9		19.9
SB27-2.0	19.8		19.8
SB06-4.0	19.3	U(b)	19.3
SB19-4.0	15.7		15.7
SB07-2.0	13.7		13.7
SB10-4.0	13.7		13.7
EXSW04-06 (94)	10.9		10.9
SB09-4.0	9.8		9.8
SB19-2.0	9.7		9.7
SB21-4.0	9.3		9.3
2-EXWW09-06 (94)	8.4		8.4
SB22-4.0	8.1		8.1
SB10-2.0	7.9		7.9
EXWW02-06 (94)	7.4		7.4
SB23-4.0	6.7		6.7
SB14-4.0	6.3		6.3
SB06-2.0	5.9		5.9
SB22-2.0	5.4		5.4
SB06-4.0-D	4.8	U(b)	4.8
SB27-4.0	4		4
SB14-2.0-TAL	3.1		3.1
SB07-4.0	3.1		3.1
SB14-2.0	3.1		3.1
SB26-4.0	3		3
SB12-4.0	2.9		2.9
SB12-2.0	2.8		2.8
SB23-2.0	2.8		2.8
Sample Variance =	*564266.677*		
Average Value =	272.807		

70 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Deep

LEAD (MG/KG)			
Sample Variance =	*1075711.505*	*Action Level[1] =*	1000

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	2	3	5
U = 1.50 x AL	4	8	13
U = 1.25 x AL	13	30	48
U = 1.10 x AL	77	178	293

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	3	5	8
U = 1.50 x AL	11	18	25
U = 1.25 x AL	40	67	94
U = 1.10 x AL	248	413	581

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	6	8	11
U = 1.50 x AL	20	30	39
U = 1.25 x AL	78	114	149
U = 1.10 x AL	486	708	923

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	8	11	13
U = 1.50 x AL	27	38	48
U = 1.25 x AL	107	149	188
U = 1.10 x AL	666	923	1166

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	12	15	19
U = 1.50 x AL	44	57	70
U = 1.25 x AL	174	225	273
U = 1.10 x AL	1080	1402	1698

Boldface values are less than or equal to 46 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_\alpha + z_\beta)^2}{\Delta^2} + (0.5)\, z_\alpha^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
2-EXBE-ALBACORE-04 (94)	6060		6060
EXBE-ALBACORE-03 (94)	3330		3330
EXBE-ALBACORE-04-D (94)	1870		1870
EXBE05-04 (94)	1290		1290
EXNW08-07 (94)	1030		1030
2-EXWW06-06 (94)	429		429
SB16-6.0	339		339
EXBE02-04 (94)	322		322
SB17-6.0	302		302
13TB12-0406	282	J	282
EXSW08-07 (94)	234		234
EXSW07-04 (94)	213		213
EXBE06-07 (94)	162		162
SB19-6.0	144		144
EXWW06-07 (94)	142		142
SB06-6.0	134		134
EXBE03-04 (94)	134		134
SB29-6.0	127		127
13TB12-0608-X	107	J	107
SB30-6.0	57.2		57.2
SB20-6.0	49.8		49.8
EXBE01-04 (94)	49.6		49.6
SB13-6.0	42.9		42.9
SB15-6.0	40		40
SB07-6.0	39.5		39.5
EXEW07-05 (94)	33.3		33.3
SB22-6.0	32.6		32.6
SB22-6.0-TAL	32.6		32.6
SB08-6.0	30		30
EXEW07-05-D (94)	27.6		27.6
SB26-6.0	25.4		25.4
EXBE07-03 (94)	15.2		15.2
SB09-6.0	14.6		14.6
EXWW08-07 (94)	14.4		14.4
SB10-6.0	9.1		9.1
SB12-6.0	8.8		8.8
SB10-6.0-D	8.76		8.76
SB23-6.0	7.7		7.7
SB25-6.0	7		7
SB21-6.0	6.8		6.8
SB14-6.0	5.1		5.1
SB24-6.0	4.9		4.9
EXNW07-05 (94)	4.3		4.3
SB27-6.0	3.5		3.5
110890-13MW12(8-10)	2.6	J	2.6
EXWW07-05 (94)	2.6		2.6
Sample Variance =	*1075711.505*		
Average Value =	374.497		

46 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.
(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	*761986.655*	*Action Level[1] =*	1000

$1-\beta = 0.50$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**1**	**3**	**4**
U = 1.50 x AL	**3**	**6**	**10**
U = 1.25 x AL	**9**	**21**	**35**
U = 1.10 x AL	**55**	126	208

$1-\beta = 0.75$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**3**	**4**	**6**
U = 1.50 x AL	**8**	**13**	**18**
U = 1.25 x AL	**29**	**48**	**67**
U = 1.10 x AL	176	293	412

$1-\beta = 0.90$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**4**	**6**	**8**
U = 1.50 x AL	**15**	**21**	**28**
U = 1.25 x AL	**56**	**81**	**106**
U = 1.10 x AL	344	502	654

$1-\beta = 0.95$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**6**	**8**	**10**
U = 1.50 x AL	**20**	**27**	35
U = 1.25 x AL	**76**	**106**	134
U = 1.10 x AL	472	654	826

$1-\beta = 0.99$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**9**	**11**	**14**
U = 1.50 x AL	**31**	**41**	**50**
U = 1.25 x AL	123	160	194
U = 1.10 x AL	766	993	1204

Boldface values are less than or equal to 116 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
110890-13MW12(8-10)	2.6	J	2.6
13TB12-0406	282	J	282
13TB12-0608-X	107	J	107
13TB12-0204-X	567	J	567
13TB18-0103	1320	J	1320
13TB5A-1.5-3.5	151	J	151
13TB5A-1.5-3.5-X	113	J	113
13TB7-0103	36.8	J	36.8
2-EXBE-ALBACORE-04 (94)	6060		6060
2-EXBE78-06 (94)	330		330
2-EXNW09-06 (94)	72.7		72.7
2-EXNW78-09 (94)	233		233
2-EXSW78-09 (94)	97.9		97.9
2-EXWW-ALBACORE-06 (94)	4390		4390
2-EXWW06-06 (94)	429		429
2-EXWW09-06 (94)	8.4		8.4
3-EXSW09-06 (94)	351		351
4-EXEW03-07 (94)	21.4		21.4
EXBE-ALBACORE-03 (94)	3330		3330
EXBE-ALBACORE-04-D (94)	1870		1870
EXBE-BULLHEAD-07 (94)	285		285
EXBE01-04 (94)	49.6		49.6
EXBE02-04 (94)	322		322
EXBE03-04 (94)	134		134
EXBE05-04 (94)	1290		1290
EXBE06-07 (94)	162		162
EXBE07-03 (94)	15.2		15.2
EXEW-BULLHEAD-08 (94)	134		134
EXEW02-06 (94)	92.4		92.4
EXEW07-05 (94)	33.3		33.3
EXEW07-05-D (94)	27.6		27.6
EXNW02-06 (94)	19.9		19.9
EXNW03-07 (94)	24.3		24.3
EXNW04-06 (94)	67.4		67.4
EXNW07-05 (94)	4.3		4.3
EXNW08-07 (94)	1030		1030
EXSW-ALBACORE-06 (94)	4173		4173
EXSW-BULLHEAD-08 (94)	341		341
EXSW01-07 (94)	184		184
EXSW02-06 (94)	364		364
EXSW03-07 (94)	264		264
EXSW04-06 (94)	10.9		10.9
EXSW07-04 (94)	213		213
EXSW08-07 (94)	234		234
EXWW-ALBACORE-06 (94)	1880		1880
EXWW01-07 (94)	437		437
EXWW02-06 (94)	7.4		7.4
EXWW06-07 (94)	142		142
EXWW07-05 (94)	2.6		2.6
EXWW08-07 (94)	14.4		14.4
SB14-2.0-TAL	3.1		3.1
SB22-6.0-TAL	32.6		32.6
SB06-2.0	5.9		5.9
SB06-4.0	19.3	U(b)	19.3
SB06-4.0-D	4.8	U(b)	4.8
SB06-6.0	134		134
SB07-2.0	13.7		13.7
SB07-4.0	3.1		3.1
SB07-6.0	39.5		39.5

116 SAMPLES

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 3 Shallow and Deep

SB08-6.0	30		30
SB09-2.0	27.5		27.5
SB09-4.0	9.8		9.8
SB09-6.0	14.6		14.6
SB10-2.0	7.9		7.9
SB10-4.0	13.7		13.7
SB10-6.0	9.1		9.1
SB10-6.0-D	8.76		8.76
SB12-2.0	2.8		2.8
SB12-4.0	2.9		2.9
SB12-6.0	8.8		8.8
SB13-2.0	186		186
SB13-2.0-D	463		463
SB13-4.0	32.6		32.6
SB13-6.0	42.9		42.9
SB14-2.0	3.1		3.1
SB14-4.0	6.3		6.3
SB14-6.0	5.1		5.1
SB15-2.0	69.2		69.2
SB15-4.0	44.5		44.5
SB15-6.0	40		40
SB16-6.0	339		339
SB17-6.0	302		302
SB19-2.0	9.7		9.7
SB19-4.0	15.7		15.7
SB19-6.0	144		144
SB20-2.0	229		229
SB20-4.0	26.4		26.4
SB20-4.0-D	25.8		25.8
SB20-6.0	49.8		49.8
SB21-2.0	69.8		69.8
SB21-4.0	9.3		9.3
SB21-6.0	6.8		6.8
SB22-2.0	5.4		5.4
SB22-4.0	8.1		8.1
SB22-6.0	32.6		32.6
SB23-2.0	2.8		2.8
SB23-4.0	6.7		6.7
SB23-6.0	7.7		7.7
SB24-6.0	4.9		4.9
SB25-2.0	389		389
SB25-4.0	26.8		26.8
SB25-4.0-D	351		351
SB25-6.0	7		7
SB26-2.0	30.1		30.1
SB26-4.0	3		3
SB26-6.0	25.4		25.4
SB27-2.0	19.8		19.8
SB27-4.0	4		4
SB27-6.0	3.5		3.5
SB29-4.0	238		238
SB29-6.0	127		127
SB30-2.0	413		413
SB30-4.0	163		163
SB30-6.0	57.2		57.2
SB32-2.0	31.4		31.4
SB33-2.0	123		123
Sample Variance =	***761936.655***		
Average Value =	313.132		

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

ZONE 4

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 4 Shallow

VALIDATED DATA

LEAD (MG/KG)			
Sample Variance =	***21834256.250***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	16	37	61
U = 1.50 x AL	63	145	238
U = 1.25 x AL	248	575	947
U = 1.10 x AL	1547	3587	5909

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	51	85	119
U = 1.50 x AL	202	335	472
U = 1.25 x AL	804	1338	1881
U = 1.10 x AL	5020	8355	11747

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	99	145	189
U = 1.50 x AL	395	575	750
U = 1.25 x AL	1576	2296	2994
U = 1.10 x AL	9843	14345	18700

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	136	188	238
U = 1.50 x AL	541	749	947
U = 1.25 x AL	2161	2993	3783
U = 1.10 x AL	13500	18700	23631

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	220	286	346
U = 1.50 x AL	877	1138	1379
U = 1.25 x AL	3507	4549	5511
U = 1.10 x AL	21914	28423	34435

Boldface values are less than or equal to 4 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples	
σ^2=variance in concentration	
z_p=the pth percentile of the standard normal distribution	
Δ=width of gray region (U-AL)	

SITE	RESULT	QUAL	VALUE[2]	
13TB2A-0406	1880	J	1880	**4 SAMPLES**
13TB3A-2.5-4.5-AVG	6505	J	6505	
13TB4A-0002	280	J	280	
13WE4A-0002	10600	J	10600	
Sample Variance =	***21834256.250***			
Average Value =	4816.250			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 4 Deep

VALIDATED DATA

LEAD (MG/KG)			
Sample Variance =	***331662.874***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**3**
U = 1.50 x AL	**2**	**4**	**5**
U = 1.25 x AL	**5**	10	16
U = 1.10 x AL	24	56	92

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**2**	**3**	**4**
U = 1.50 x AL	**4**	**6**	9
U = 1.25 x AL	13	22	30
U = 1.10 x AL	77	128	180

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**2**	**4**	**5**
U = 1.50 x AL	7	10	13
U = 1.25 x AL	25	36	47
U = 1.10 x AL	150	219	286

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**3**	**4**	**5**
U = 1.50 x AL	9	13	16
U = 1.25 x AL	34	47	59
U = 1.10 x AL	206	285	361

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**4**	**6**	7
U = 1.50 x AL	14	19	23
U = 1.25 x AL	54	70	86
U = 1.10 x AL	334	433	525

Boldface values are less than or equal to 6 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples	
σ^2=variance in concentration	
z_p=the pth percentile of the standard normal distribution	
Δ=width of gray region (U-AL)	

SITE	RESULT	QUAL	VALUE[2]
QW-1 (94)	1470		1470
111290-13MW15(12-14)	55.3		55.3
111390-13MW13(8-10)-AVG	37.7	J	37.7
111390-13MW14(12-14)-AVG	68.7		68.7
111290-13MW16(10-12)	41.3		41.3
13TB6-0507	98.9	J	98.9
Sample Variance =	***331662.874***		
Average Value =	295.317		

6 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 4 Shallow and Deep

VALIDATED DATA

LEAD (MG/KG)			
Sample Variance =	***12912699.423***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**10**	23	37
U = 1.50 x AL	37	86	142
U = 1.25 x AL	147	341	561
U = 1.10 x AL	915	2122	3495

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	31	51	71
U = 1.50 x AL	120	199	280
U = 1.25 x AL	476	792	1113
U = 1.10 x AL	2969	4942	6948

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	59	86	112
U = 1.50 x AL	234	341	444
U = 1.25 x AL	932	1359	1771
U = 1.10 x AL	5822	8484	11060

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	81	112	142
U = 1.50 x AL	320	444	561
U = 1.25 x AL	1278	1771	2238
U = 1.10 x AL	7984	11060	13976

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	130	169	205
U = 1.50 x AL	519	674	816
U = 1.25 x AL	2074	2691	3260
U = 1.10 x AL	12960	16810	20366

Boldface values are less than or equal to 10 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
13TB2A-0406	1880	J	1880
13TB3A-2.5-4.5-AVG	6505	J	6505
13TB4A-0002	280	J	280
13WE4A-0002	10600	J	10600
QW-1 (94)	1470		1470
111290-13MW15(12-14)	55.3		55.3
111390-13MW13(8-10)-AVG	37.7	J	37.7
111390-13MW14(12-14)-AVG	68.7		68.7
111290-13MW16(10-12)	41.3		41.3
13TB6-0507	98.9	J	98.9
Sample Variance =	***12912699.423***		
Average Value =	2103.690		

10 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor.

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 4 Shallow

LEAD (MG/KG)			
Sample Variance =	***14758690.476***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	11	26	42
U = 1.50 x AL	43	98	162
U = 1.25 x AL	168	389	641
U = 1.10 x AL	1046	2425	3995

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	35	58	81
U = 1.50 x AL	137	227	319
U = 1.25 x AL	544	905	1272
U = 1.10 x AL	3393	5648	7941

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	67	98	128
U = 1.50 x AL	267	389	507
U = 1.25 x AL	1065	1553	2024
U = 1.10 x AL	6654	9697	12641

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	92	128	162
U = 1.50 x AL	366	507	641
U = 1.25 x AL	1461	2024	2557
U = 1.10 x AL	9125	12640	15974

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	149	193	235
U = 1.50 x AL	593	770	933
U = 1.25 x AL	2371	3075	3726
U = 1.10 x AL	14813	19213	23277

Boldface values are less than or equal to 7 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
13TB2A-0406	1880	J	1880
13TB2A-0406-X	2080	J	2080
13TB3A-2.5-4.5	8240	J	8240
13TB3A-2.5-4.5-D	4770	J	4770
13TB4A-0002	280	J	280
13TB4A-0002-X	1810	J	1810
13WE4A-0002	10600	J	10600
Sample Variance =	***14758690.476***		
Average Value =	4237.143		

7 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.

Action Level (AL): value that determines acceptance or rejection of H_0

α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**

β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**

Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sampl riance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 4 Deep

LEAD (MG/KG)			
Sample Variance =	***562026.517***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**3**
U = 1.50 x AL	**2**	**5**	**8**
U = 1.25 x AL	**7**	16	26
U = 1.10 x AL	41	94	154

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**2**	**3**	**5**
U = 1.50 x AL	**6**	**10**	14
U = 1.25 x AL	22	36	50
U = 1.10 x AL	130	216	304

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**3**	**5**	**7**
U = 1.50 x AL	11	16	21
U = 1.25 x AL	41	60	79
U = 1.10 x AL	254	371	483

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**4**	**6**	**8**
U = 1.50 x AL	15	21	26
U = 1.25 x AL	56	78	99
U = 1.10 x AL	348	483	610

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**6**	**9**	11
U = 1.50 x AL	23	31	37
U = 1.25 x AL	91	118	144
U = 1.10 x AL	565	733	888

Boldface values are less than or equal to 9 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
QW-1 (94)	1470		1470
111290-13MW15(12-14)	34.4		34.4
111390-13MW13(8-10)	50.2	J	50.2
111390-13MW14(12-14)	68.7		68.7
111290-13MW16(10-12)	41.3		41.3
111390-13MW14(12-14)-D	76.2		76.2
111390-13MW13(8-10)-D	25.2	J	25.2
13TB3A-0608-X	1990	J	1990
13TB6-0507	98.9	J	98.9
Sample Variance =	***562026.517***		
Average Value =	428.322		

9 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 4 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***10011341.256***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**8**	18	29
U = 1.50 x AL	29	67	110
U = 1.25 x AL	114	264	435
U = 1.10 x AL	710	1646	2710

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	24	40	56
U = 1.50 x AL	93	155	217
U = 1.25 x AL	369	614	864
U = 1.10 x AL	2302	3832	5387

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	46	67	88
U = 1.50 x AL	181	264	345
U = 1.25 x AL	723	1054	1374
U = 1.10 x AL	4514	6578	8575

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	63	87	110
U = 1.50 x AL	248	344	435
U = 1.25 x AL	991	1373	1735
U = 1.10 x AL	6190	8575	10836

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	101	132	160
U = 1.50 x AL	403	523	633
U = 1.25 x AL	1608	2086	2528
U = 1.10 x AL	10048	13033	15790

Boldface values are less than or equal to 16 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^4$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
QW-1 (94)	1470		1470
111290-13MW15(12-14)	34.4		34.4
111390-13MW13(8-10)	50.2	J	50.2
111390-13MW14(12-14)	68.7		68.7
111290-13MW16(10-12)	41.3		41.3
111390-13MW14(12-14)-D	76.2		76.2
111390-13MW13(8-10)-D	25.2	J	25.2
13TB3A-0608-X	1990	J	1990
13TB6-0507	98.9	J	98.9
13TB2A-0406	1880	J	1880
13TB2A-0406-X	2080	J	2080
13TB3A-2.5-4.5	8240	J	8240
13TB3A-2.5-4.5-D	4770	J	4770
13TB4A-0002	280	J	280
13TB4A-0002-X	1810	J	1810
13WE4A-0002	10600	J	10600
Sample Variance =	***10011341.256***		
Average Value =	2094.681		

16 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for detects (samples with 'U' in QUAL column).

ZONE 5

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 5 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***28.936***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

Boldface values are less than or equal to 3 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 [z_{1-\alpha} + z_{1-\beta}]^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]	
19TB4-0406 (93)	12.3		12.3	
19TB4-0002 (93)	10.4	U	5.2	**3**
19TB4-0204 (93)	31.5	U	15.75	**SAMPLES**
Sample Variance	***28.936***			
Average Value =	11.083			

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 5 Shallow

LEAD (MG/KG)			
Sample Variance =	***171.830***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	2	2

Boldface values are less than or equal to 10 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
19MW2-0204 (93)	6.6	S	6
19MW3-0002 (93)	13.3	S	13.3
19MW4-0004 (93)	12.5		12.5
19SS1 (93)	48.4		48.4
19TB1-0004 (93)	13.7		13.7
19TB2-0002 (93)	6.1	S	6.1
19TB3-0204 (93)	1.7	J	1.7
19TB4-0002 (93)	10.4	U	5.2
19TB4-0204 (93)	31.5	U	15.75
19MW1-0.252.25 (93)-AVG	15.55		15.55
Sample Variance =	***171.830***		
Average Value =	13.820		

10 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sampl[illegible]iance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 5 Deep

LEAD (MG/KG)			
Sample Variance =	***27.632***	***Action Level[1] =***	**1000**

$1-\beta = 0.50$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

$1-\beta = 0.75$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

$1-\beta = 0.90$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

$1-\beta = 0.95$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

$1-\beta = 0.99$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	1	2
U = 1.25 x AL	1	1	2
U = 1.10 x AL	1	1	2

Boldface values are less than or equal to78 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
19MW2-0406 (93)-AVG	6	S	6
19MW3-0406 (93)	14.6		14.6
19MW4-0608 (93)	4.4	S	4.4
19TB1-0608 (93)	1.3	S	1.3
19TB2-0608 (93)	2.7	S	2.7
19TB3-1012 (93)	1.9	S	1.9
19TB4-0406 (93)	12.3		12.3
Sample Variance =	***27.632***		
Average Value =	6.171		

7 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 5 Shallow and Deep

LEAD (MG/KG)			
Sample Variance =	***122.072***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	1	**2**
U = 1.25 x AL	1	1	**2**
U = 1.10 x AL	1	1	**2**

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	1	**2**
U = 1.25 x AL	1	1	**2**
U = 1.10 x AL	1	1	**2**

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	1	**2**
U = 1.25 x AL	1	1	**2**
U = 1.10 x AL	1	1	**2**

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	1	**2**
U = 1.25 x AL	1	1	**2**
U = 1.10 x AL	1	1	**2**

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	**2**
U = 1.50 x AL	1	1	**2**
U = 1.25 x AL	1	1	**2**
U = 1.10 x AL	1	1	**2**

Boldface values are less than or equal to 17 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
19MW2-0406 (93)-AVG	6	S	6
19MW3-0406 (93)	14.6		14.6
19MW4-0608 (93)	4.4	S	4.4
19TB1-0608 (93)	1.3	S	1.3
19TB2-0608 (93)	2.7	S	2.7
19TB3-1012 (93)	1.9	S	1.9
19TB4-0406 (93)	12.3		12.3
19MW2-0204 (93)	6.6	S	6
19MW3-0002 (93)	13.3	S	13.3
19MW4-0004 (93)	12.5		12.5
19SS1 (93)	48.4		48.4
19TB1-0004 (93)	13.7		13.7
19TB2-0002 (93)	6.1	S	6.1
19TB3-0204 (93)	1.7	J	1.7
19TB4-0002 (93)	10.4	U	5.2
19TB4-0204 (93)	31.5	U	15.75
19MW1-0.252.25 (93)-AVG	15.55		15.55
Sample Variance =	***122.072***		
Average Value =	10.671		

17 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] 1/2 the detection limit is used to calculate value, average value, and sample variance for n[illegible]tects (samples with 'U' in QUAL column).

ZONE 7

VALIDATED DATA

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow — A

LEAD (MG/KG)			
Sample Variance =	***3566577721.764***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	2527	5859	9651
U = 1.50 x AL	10106	23432	38600
U = 1.25 x AL	40422	93724	154394
U = 1.10 x AL	**252631**	585766	964954

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	8199	13647	19188
U = 1.50 x AL	32793	54586	76745
U = 1.25 x AL	131171	218338	306976
U = 1.10 x AL	819813	1364609	1918590

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	16078	23432	30545
U = 1.50 x AL	64311	93724	122176
U = 1.25 x AL	**257243**	**374891**	**488699**
U = 1.10 x AL	1607764	2343061	3054362

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	22051	30545	38600
U = 1.50 x AL	88203	122176	154394
U = 1.25 x AL	352810	488699	617571
U = 1.10 x AL	2205057	3054361	3859811

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	35795	46427	56248
U = 1.50 x AL	143177	185704	224987
U = 1.25 x AL	572707	742813	899943
U = 1.10 x AL	3579415	4642576	5624634

Boldface values are less than or equal to 10 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples	
σ^2=variance in concentration	
z_p=the pth percentile of the standard normal distribution	
Δ=width of gray region (U-AL)	

SITE	RESULT	QUAL	VALUE[2]
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW6-0204 (93)	189000	J	189000
20MW7-0204 (93)	6.3	J	6.3
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
Sample Variance	***3566577721.764***		
Average Value =	19032.620		

10 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.

Action Level (AL): value that determines acceptance or rejection of H_0

α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**

β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**

Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow – B

VALIDATED DATA
(20MW6-0204 REMOVED)

LEAD (MG/KG)			
Sample Variance =	***51289.198***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**2**	**2**
U = 1.25 x AL	**1**	**3**	**4**
U = 1.10 x AL	**4**	10	16

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**1**	**2**	**3**
U = 1.25 x AL	**3**	**4**	**6**
U = 1.10 x AL	13	21	29

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**2**	**3**	**4**
U = 1.25 x AL	**5**	**7**	**9**
U = 1.10 x AL	24	35	46

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**2**	**3**	**4**
U = 1.25 x AL	**6**	**8**	11
U = 1.10 x AL	33	45	57

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**3**
U = 1.50 x AL	**3**	**4**	**5**
U = 1.25 x AL	**9**	12	15
U = 1.10 x AL	52	68	83

Boldface values are less than or equal to 9 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW7-0204 (93)	6.3	J	6.3
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
Sample Variance	***51289.198***		
Average Value =	147.356		

9 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Deep

VALIDATED DATA

LEAD (MG/KG)			
Sample Variance =	***174244.627***	***Action Level[1] =***	**1000**

$1-\beta = 0.50$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**1**	**2**	**4**
U = 1.25 x AL	**3**	**6**	9
U = 1.10 x AL	13	30	49

$1-\beta = 0.75$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**1**	**2**	**3**
U = 1.50 x AL	**2**	**4**	**6**
U = 1.25 x AL	7	12	17
U = 1.10 x AL	41	68	96

$1-\beta = 0.90$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**2**	**2**	**3**
U = 1.50 x AL	**4**	**6**	8
U = 1.25 x AL	13	20	26
U = 1.10 x AL	79	116	151

$1-\beta = 0.95$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**2**	**3**	**4**
U = 1.50 x AL	**5**	7	9
U = 1.25 x AL	18	25	32
U = 1.10 x AL	109	151	190

$1-\beta = 0.99$	$1-\alpha = 0.80$	$1-\alpha = 0.90$	$1-\alpha = 0.95$
U = 2.00 x AL	**3**	**4**	**5**
U = 1.50 x AL	8	10	13
U = 1.25 x AL	29	38	46
U = 1.10 x AL	176	228	277

Boldface values are less than or equal to 6 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2 + (0.5)\, z_{1-\alpha}^2}{\Delta^2}$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-1416 (93)	2.3	J	2.3
20MW3-0810 (93)	38.3	J	38.3
20MW4-0406 (93)	12	J	12
20MW5-0608 (93)	1040	J	1040
20MW7-0406 (93)	6.2	J	6.2
20TB5-0406 (93)	31.8	J	31.8
Sample Variance	***174244.627***		
Average Value =	188.433		

6 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow and Deep – A

VALIDATED DATA

LEAD (MG/KG)			
Sample Variance =	***2228780557.383***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1580	3662	6032
U = 1.50 x AL	6316	14643	24122
U = 1.25 x AL	25260	58569	96483
U = 1.10 x AL	157871	366050	603008

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	5124	8529	11991
U = 1.50 x AL	20493	34111	47959
U = 1.25 x AL	81970	136442	191832
U = 1.10 x AL	512307	852754	1198942

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	10048	14643	19089
U = 1.50 x AL	40189	58569	76350
U = 1.25 x AL	160753	234273	305393
U = 1.10 x AL	1004704	1464196	1908694

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	13780	19088	24122
U = 1.50 x AL	55119	76349	96483
U = 1.25 x AL	220474	305392	385926
U = 1.10 x AL	1377957	1908693	2412025

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	22369	29013	35151
U = 1.50 x AL	89473	116048	140597
U = 1.25 x AL	357889	464190	562382
U = 1.10 x AL	2236803	2901180	3514876

Boldface values are less than or equal to 16 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2 + (0.5)\, z_{1-\alpha}^2}{\Delta^2}$$

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-1416 (93)	2.3	J	2.3
20MW3-0810 (93)	38.3	J	38.3
20MW4-0406 (93)	12	J	12
20MW5-0608 (93)	1040	J	1040
20MW7-0406 (93)	6.2	J	6.2
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW7-0204 (93)	6.3	J	6.3
20MW6-0204 (93)	189000	J	189000
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
20TB5-0406 (93)	31.8	J	31.8
Sample Variance	***2228780557.383***		
Average Value =	11966.050		

16 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor.

(1) = Action Level based on Industrial Risk Criteria.

(2) 1/2 the detection limit is used to calculate value, average value, and sample variance non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow and Deep – B

VALIDATED DATA
(20MW6-0204 Removed)

LEAD (MG/KG)			
Sample Variance =	*91972.236*	*Action Level[1] =*	1000

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	1	2
U = 1.50 x AL	1	2	3
U = 1.25 x AL	2	4	6
U = 1.10 x AL	7	16	27

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	2
U = 1.50 x AL	2	3	4
U = 1.25 x AL	4	7	10
U = 1.10 x AL	22	37	51

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	3
U = 1.50 x AL	3	4	5
U = 1.25 x AL	7	11	14
U = 1.10 x AL	42	62	81

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1	2	3
U = 1.50 x AL	3	4	6
U = 1.25 x AL	10	14	18
U = 1.10 x AL	58	80	101

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	2	3	3
U = 1.50 x AL	5	6	8
U = 1.25 x AL	16	20	25
U = 1.10 x AL	93	121	147

Boldface values are less than or equal to 15 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

SITE	RESULT	QUAL	VALUE[2]
20MW2-1416 (93)	2.3	J	2.3
20MW3-0810 (93)	38.3	J	38.3
20MW4-0406 (93)	12	J	12
20MW5-0608 (93)	1040	J	1040
20MW7-0406 (93)	6.2	J	6.2
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW7-0204 (93)	6.3	J	6.3
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
20TB5-0406 (93)	31.8	J	31.8
Sample Variance	*91972.236*		
Average Value =	163.787		

15 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow – A

LEAD (MG/KG)			
Sample Variance =	***2547601047.734***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	1805	4185	6894
U = 1.50 x AL	7219	16738	27572
U = 1.25 x AL	28873	66947	110284
U = 1.10 x AL	180454	418412	689266

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	5857	9749	13706
U = 1.50 x AL	23424	38991	54820
U = 1.25 x AL	93695	155959	219273
U = 1.10 x AL	585591	974738	1370447

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	11485	16738	21819
U = 1.50 x AL	45938	66947	87271
U = 1.25 x AL	183749	267784	349078
U = 1.10 x AL	1148424	1673645	2181726

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	15752	21819	27572
U = 1.50 x AL	63004	87270	110284
U = 1.25 x AL	252012	349077	441131
U = 1.10 x AL	1575069	2181726	2757058

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	25569	33163	40179
U = 1.50 x AL	102272	132649	160708
U = 1.25 x AL	409084	530591	642828
U = 1.10 x AL	2556771	3316186	4017668

Boldface values are less than or equal to 14 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW6-0204 (93)	189000	J	189000
20MW7-0204 (93)	6.3	J	6.3
20TB1-0204 (93)	35.5		35.5
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
20TB6-0002 (93)	476		476
20TB7-3242 (93)	47.7		47.7
20MW1-0.52.5 (93)-AVG	13.3		13.3
Sample Variance =	***2547601047.734***		
Average Value =	13635.621		

14 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.

Action Level (AL): value that determines acceptance or rejection of H_0

α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**

β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**

Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow – B

(20MW6-0204 REMOVED)

LEAD (MG/KG)			
Sample Variance =	***46559.376***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**2**	**2**
U = 1.25 x AL	**1**	**3**	**4**
U = 1.10 x AL	**4**	**9**	14

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**1**	**2**
U = 1.50 x AL	**1**	**2**	**3**
U = 1.25 x AL	**3**	**4**	**6**
U = 1.10 x AL	**12**	19	27

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**2**	**3**	**3**
U = 1.25 x AL	**4**	**6**	**8**
U = 1.10 x AL	22	32	42

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**2**
U = 1.50 x AL	**2**	**3**	**4**
U = 1.25 x AL	**5**	**8**	**10**
U = 1.10 x AL	30	41	52

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**1**	**2**	**3**
U = 1.50 x AL	**3**	**4**	**5**
U = 1.25 x AL	**8**	**11**	14
U = 1.10 x AL	48	62	75

Boldface values are less than or equal to 13 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5) z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW7-0204 (93)	6.3	J	6.3
20TB1-0204 (93)	35.5		35.5
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
20TB6-0002 (93)	476		476
20TB7-3242 (93)	47.7		47.7
20MW1-0.52.5 (93)-AVG	13.3		13.3
Sample Variance =	***46559.376***		
Average Value =	146.054		

13 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Deep

LEAD (MG/KG)			
Sample Variance =	***7225449.034***	***Action Level[1] =***	**1000**

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	**6**	**13**	21
U = 1.50 x AL	21	49	80
U = 1.25 x AL	83	191	315
U = 1.10 x AL	513	1188	1957

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	17	29	41
U = 1.50 x AL	67	112	157
U = 1.25 x AL	267	444	624
U = 1.10 x AL	1662	2766	3889

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	33	49	64
U = 1.50 x AL	131	191	249
U = 1.25 x AL	522	761	992
U = 1.10 x AL	3258	4748	6190

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	46	63	80
U = 1.50 x AL	180	249	315
U = 1.25 x AL	716	991	1253
U = 1.10 x AL	4468	6189	7821

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	73	95	116
U = 1.50 x AL	291	378	458
U = 1.25 x AL	1161	1506	1825
U = 1.10 x AL	7252	9407	11397

Boldface values are less than or equal to 13 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-1416 (93)	2.3	J	2.3
20MW3-0810 (93)	38.3	J	38.3
20MW4-0406 (93)	12	J	12
20MW5-0608 (93)	1040	J	1040
20MW7-0406 (93)	6.2	J	6.2
20TB1-0608 (93)-AVG	4.15	N	4.15
20TB7-4856 (93)-AVG	94.2		94.2
20TB2-1416 (93)	20.7	S	20.7
20TB3-1012 (93)	16.6		16.6
20TB4-1416 (93)	9770		9770
20TB5-0406 (93)	31.8	J	31.8
20TB6-0810 (93)	24.4		24.4
20MW6-1214 (93)	1540		1540
Sample Variance =	***7225449.034***		
Average Value =	969.281		

13 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

(1) = Action Level based on Industrial Risk Criteria.

(2) = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow and Deep — Pb

LEAD (MG/KG)			
Sample Variance =	*1318729913.161*	*Action Level[1] =*	1000

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	935	2167	3570
U = 1.50 x AL	3737	8665	14273
U = 1.25 x AL	14946	34655	57088
U = 1.10 x AL	93410	216586	356790

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	3032	5047	7096
U = 1.50 x AL	12126	20184	28378
U = 1.25 x AL	48500	80731	113504
U = 1.10 x AL	303123	504560	709393

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	5946	8665	11295
U = 1.50 x AL	23779	34655	45175
U = 1.25 x AL	95115	138615	180696
U = 1.10 x AL	594466	866340	1129341

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	8154	11295	14273
U = 1.50 x AL	32613	45175	57088
U = 1.25 x AL	130451	180696	228346
U = 1.10 x AL	815313	1129340	1427153

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	13236	17167	20799
U = 1.50 x AL	52940	68664	83189
U = 1.25 x AL	211757	274654	332752
U = 1.10 x AL	1323477	1716578	2079690

Boldface values are less than or equal to 27 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-1416 (93)	2.3	J	2.3
20MW3-0810 (93)	38.3	J	38.3
20MW4-0406 (93)	12	J	12
20MW5-0608 (93)	1040	J	1040
20MW7-0406 (93)	6.2	J	6.2
20TB1-0608 (93)-AVG	4.15	N	4.15
20TB7-4856 (93)-AVG	94.2		94.2
20TB2-1416 (93)	20.7	S	20.7
20TB3-1012 (93)	16.6		16.6
20TB4-1416 (93)	9770		9770
20TB5-0406 (93)	31.8	J	31.8
20TB6-0810 (93)	24.4		24.4
20MW6-1214 (93)	1540		1540
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW6-0204 (93)	189000	J	189000
20MW7-0204 (93)	6.3	J	6.3
20TB1-0204 (93)	35.5		35.5
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
20TB6-0002 (93)	476		476
20TB7-3242 (93)	47.7		47.7
20MW1-0.52.5 (93)-A	13.3		13.3
Sample Variance =	***1318729913.161***		
Average Value =	7537.013		

27 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
α: probability that a Type I (false positive) error will be made. That is rejecting H_0 when it is True. **Confidence Interval**
β :probability that a Type II (false negative) error will be made. That is failing to rejecting H_0 when it is False. **Power**
Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

[1] = Action Level based on Industrial Risk Criteria.

[2] = 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples with 'U' in QUAL column).

Derived Sample Size (n) Based on
Sample Variance and Action Level
Zone 7 Shallow and Deep ~ B

(20MW6-0204 Removed)

LEAD (MG/KG)			
Sample Variance =	*3666766.704*	*Action Level[1] =*	1000

1-β = 0.50	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	3	7	12
U = 1.50 x AL	11	25	42
U = 1.25 x AL	42	98	161
U = 1.10 x AL	261	604	994

1-β = 0.75	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	9	15	22
U = 1.50 x AL	35	57	81
U = 1.25 x AL	136	226	317
U = 1.10 x AL	844	1404	1974

1-β = 0.90	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	17	25	33
U = 1.50 x AL	67	98	127
U = 1.25 x AL	265	387	504
U = 1.10 x AL	1654	2410	3142

1-β = 0.95	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	24	33	42
U = 1.50 x AL	92	127	161
U = 1.25 x AL	364	504	637
U = 1.10 x AL	2268	3141	3970

1-β = 0.99	1-α = 0.80	1-α = 0.90	1-α = 0.95
U = 2.00 x AL	38	49	60
U = 1.50 x AL	148	192	233
U = 1.25 x AL	590	765	927
U = 1.10 x AL	3681	4774	5784

Boldface values are less than or equal to 26 samples already taken.

Probability	*z-Score*
0.50	0.00000
0.75	0.67449
0.80	0.84162
0.90	1.28155
0.95	1.64485
0.99	2.32634

$$n = \frac{\sigma^2 (z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + (0.5)\, z_{1-\alpha}^2$$

VALIDATED & UNVALIDATED

n=required # of samples
σ^2=variance in concentration
z_p=the pth percentile of the standard normal distribution
Δ=width of gray region (U-AL)

SITE	RESULT	QUAL	VALUE[2]
20MW2-1416 (93)	2.3	J	2.3
20MW3-0810 (93)	38.3	J	38.3
20MW4-0406 (93)	12	J	12
20MW5-0608 (93)	1040	J	1040
20MW7-0406 (93)	6.2	J	6.2
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20TB7-4856 (93)-AVG	94.2		94.2
20TB2-1416 (93)	20.7	S	20.7
20TB3-1012 (93)	16.6		16.6
20TB4-1416 (93)	9770		9770
20TB5-0406 (93)	31.8	J	31.8
20TB6-0810 (93)	24.4		24.4
20MW6-1214 (93)	1540		1540
20MW2-0002 (93)	65.1	J	65.1
20MW3-0204 (93)	60.7	J	60.7
20MW4-0204 (93)	20.4	J	20.4
20MW5-0002 (93)	128	J	128
20MW7-0204 (93)	6.3	J	6.3
20TB1-0204 (93)	35.5		35.5
20TB2-0204 (93)	33.6	J	33.6
20TB3-0204 (93)	66.1		66.1
20TB4-0002 (93)	726		726
20TB5-0002 (93)	220	J	220
20TB6-0002 (93)	476		476
20TB7-3242 (93)	47.7		47.7
20MW1-0.52.5 (93)-A	13.3		13.3
Sample Variance =	*3666766.704*		
Average Value =	557.667		

26 SAMPLES

Null Hypothesis (H_0): the true mean is less than the action level.
Action Level (AL): value that determines acceptance or rejection of H_0
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Gray Region: A range of values of the mean concentration where consequences of making a decision error are relatively minor. The gray region is bounded on the lower side by the action level and on the upper side by the other bound (U).

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[2] 1/2 the detection limit is used to calculate value, average value, and sample variance for non-detects (samples in QUAL column).