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Monitoring Well Installation and Free Product Recovery Test Work Plan

for

Plant No. 3 - Former Underground Storage Tanks (03-01-1, 2, and 3 - AOC 22)

Naval Weapons Industrial Reserve Plant
Bethpage, New York

DEPARTMENT OF THE NAVY * UNITED STATES OF AMERICA *

Northern Division
Naval Facilities Engineering Command
Contract No. N62472-90-D-1298
Contract Task Order 0283

May 1999

TETRA TECH NUS, INC.

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE NAVY
NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
10 INDUSTRIAL HIGHWAY
MAIL STOP, #82
LESTER, PA 19113-2090

IN REPLY REFER TO

5090
Code 1821/JC

23 APR 1999

MEMORANDUM

FOR THE MEMBERS OF THE TECHNICAL REVIEW COMMITTEE (TRC) FOR THE INSTALLATION RESTORATION PROGRAM AT NAVAL WEAPONS INDUSTRIAL RESERVE PLANT (NWIRP) BETHPAGE, NEW YORK

Enclosed is the Navy's Workplan to Conduct Free Product Recovery Tests at a former Underground Storage Tank (UST) site known as AOC 22 located at NWIRP Bethpage, New York. Implementation of this workplan is scheduled to begin on or near May 24, 1999. Any comments pertinent to this workplan should be submitted prior to that date for incorporation. In addition, the Navy will also incorporate comments or concerns generated at the upcoming May 29, 1999 meeting at the EPA Region II offices in Manhattan, New York.

AOC 22 was discovered during a Phase 1 and 2 Site Assessment process conducted by the Northrop Grumman Corporation as part of their effort to vacate the Navy's property at Bethpage. The Navy is pursuing the additional investigation and remediation, if required, at the request of Northrop Grumman.

The additional work that is to be conducted by the Navy will include additional environmental investigations to determine if a free product layer is present and, if so, to offer remedial alternatives for its removal.

If you have any questions or would like additional information, please feel free to call me at (610) 595-0567, extension 163. If you would like to fax your comments, my fax number is (610) 595-0555.

Sincerely,

James L Colter

JAMES L. COLTER
Remedial Project Manager
By direction of the
Commanding Officer

Enclosure

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MONITORING WELL INSTALLATION AND FREE PRODUCT RECOVERY TEST WORK PLAN

PLANT NO. 3 - FORMER
UNDERGROUND STORAGE TANKS
(03-01-1, 2, AND 3 – AOC 22)
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

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

Submitted to:
Northern Division
Environmental Branch, Code 1812BJH
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop No. 82
Lester, Pennsylvania 19113-2090

Submitted by:
Tetra Tech NUS, Inc.
600 Clark Avenue, Suite 3
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Contract No. N62472-90-D-1298
Contract Task Order 0283

May 1999

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TETRA TECH NUS

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

SECTION **PAGE**

APPENDICES

FIGURES

NUMBER **PAGE**

TABLES

NUMBER **PAGE**

1.0 INTRODUCTION

This Monitoring Well Installation And Free Product Recovery Test Work Plan for Contract Task Order (CTO) No. 0283 has been prepared by Tetra Tech NUS, Inc. (TtNUS) for the Northern Division (NORTHDIV) Naval Facilities Engineering Command (NAVFAC) under the Comprehensive Long-Term Environmental Action - Navy (CLEAN) Contract Number N62472-90-D-1298. The purpose of this plan is to describe field activities to be performed as part of a Resource Conservation and Recovery Act Facility Investigation (RFI) of former underground storage tanks located south of Plant No. 3 (AOC 22) at the Naval Weapons Industrial Reserve Plant (NWIRP) Bethpage, New York, (See Figures 1-1 and 1-2). The scope of work is to install soil boring and groundwater monitoring wells, collect soil and groundwater samples, determine if a floating free petroleum product is present, and if free product is present, evaluate the effectiveness of recovering free product from this area.

Environmental concerns for this area are based on a Northrop Grumman investigation of Plant No. 3 former underground storage tanks (USTs) conducted in 1997. This investigation found evidence of petroleum in the soils from near the bottom of the former USTs to depths near the water table (UST Nos. 03-01-1, 2, and 3). Based on the detected concentrations and depth of petroleum hydrocarbons in soil, groundwater contamination may be present. In addition, a free petroleum product may be present on the water table. The UST's were reportedly removed sometime between 1980 – 1984.

1.1 PRINCIPAL INVESTIGATORS AND RESPONSIBILITIES

TtNUS will be responsible for the management and conduct of the field investigation activities presented in this work plan. The following key personnel will be involved with site characterization activities for this CTO:

- Navy remedial project manager (RPM)
- NWIRP facilities representative
- TtNUS project manager
- CLEAN program manager
- CLEAN program quality assurance (QA) manager
- CLEAN program health and safety (H&S) manager
- TtNUS project H&S officer

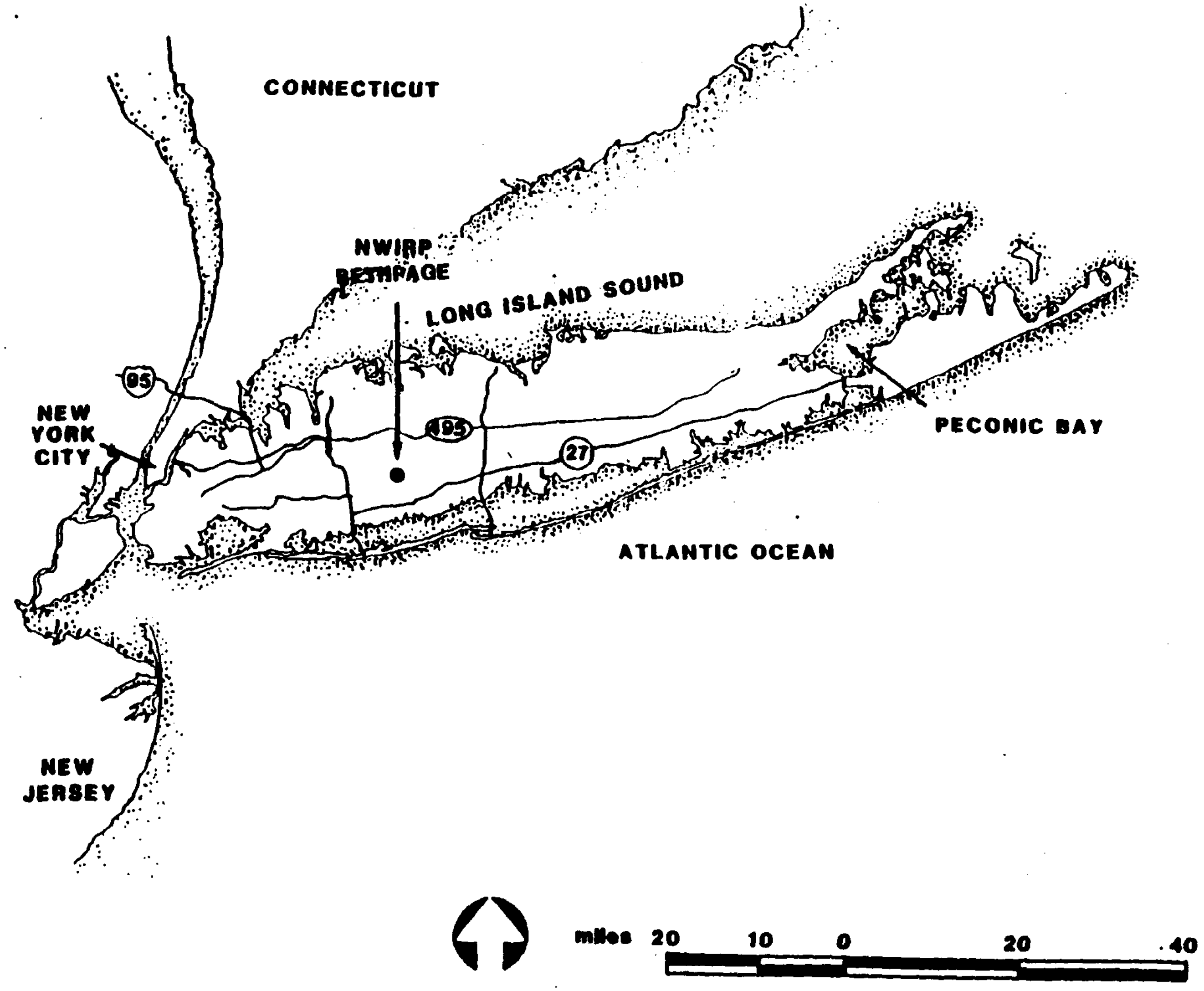

FIGURE 1-1

SITE LOCATION MAP

Naval Weapons Industrial
Reserve Plant
Bethpage
Long Island, New York

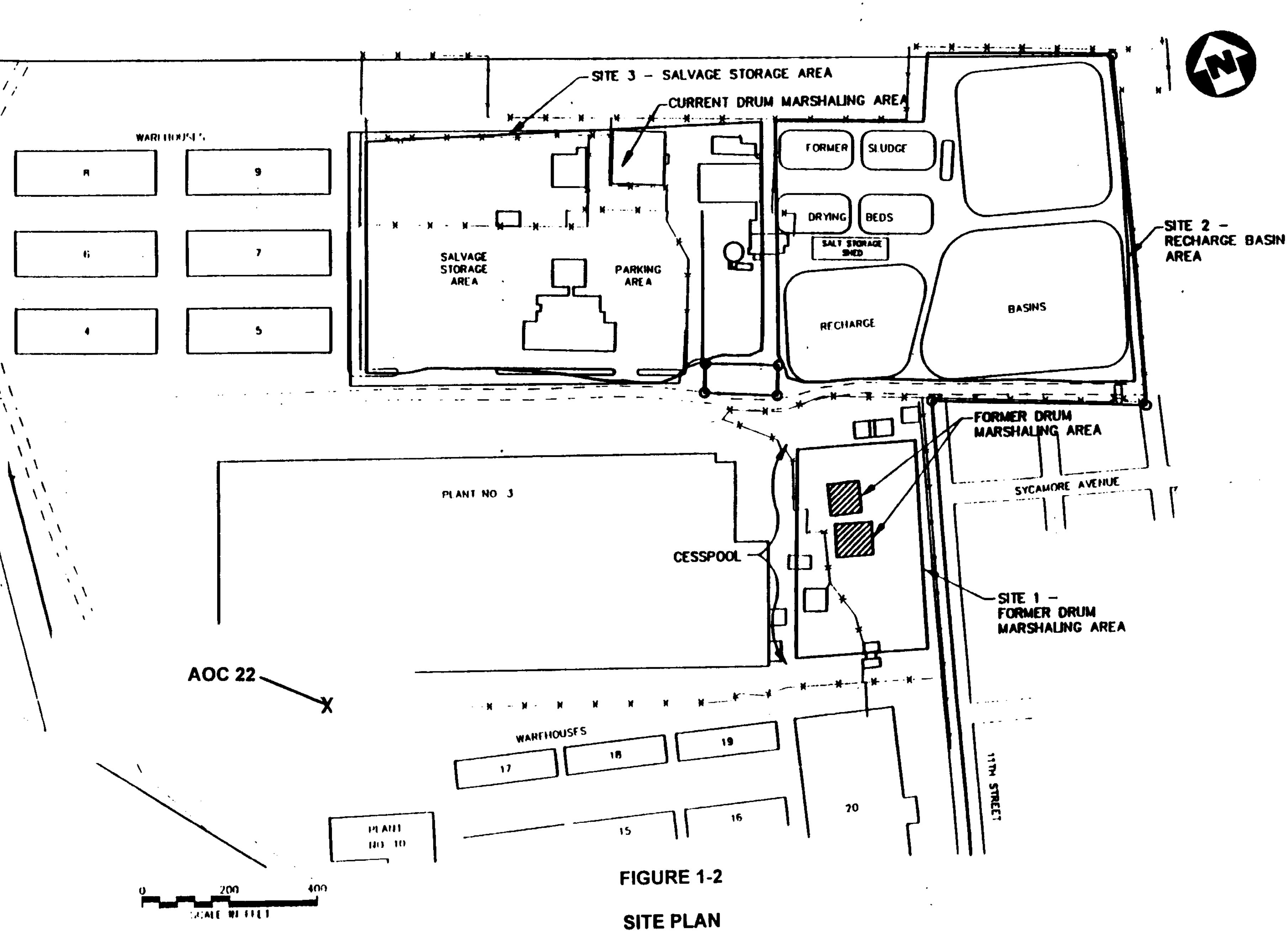

FIGURE 1-2

SITE PLAN
NWIRP BETHPAGE, NEW YORK

The Navy RPM for CTO No. 0283 is Mr. Jim Colter, NORTHDIV AVFAC; he can be contacted at (610) 595 -0567. As RPM, Mr. Colter is responsible for the following:

- Provide logistical assistance
- Review results and recommendations and provide management and technical oversight

The NWIRP facility representative is Mr. Al Taormina, NWIRP; he can be contacted at (516)-345-0344. As Facility Representative, Mr. Taormina is responsible for the following:

- Provide logistical assistance
- Review results and recommendations and provide technical oversight

The CLEAN program manager is John Trepanowski, of TtNUS; he can be contacted at (610) 491-9688. As program manager, Mr. Trepanowski is responsible for the following:

- Ensure that contract requirements are met.
- Provide necessary resources to the project team to meet requirements of this Work Plan.
- Maintain consistency in procedures and work products with other CTOs.
- Establish and maintain communication among the Navy RPM, CLEAN program contracting officer, CLEAN program QA manager, CLEAN program H&S manager, and TtNUS project manager.

The CLEAN program QA manager is Paul Frank, of TtNUS; he can be contacted at (412)-921-8950. As QA manager, Mr. Frank is responsible for the following:

- Review laboratory QA plans, work plans, audit reports, and site data.
- Identify nonconformance situations to management and provide guidance in the correction of nonconformances.
- Ensure deliverables meet the requirements of the Navy QA/quality control (QC) QA/QC program.
- Make recommendations to the program manager and the PM regarding corrective action.

The CLEAN program H&S manager is Matt Soltis, of TtNUS; he can be contacted at (412) 921-8912. As H&S manager, Mr. Soltis is responsible for the following:

- Ensure that the site-specific health and safety plan (HASP) is in accordance with Federal and state regulations and contract specifications.
- Provide technical safety and industrial hygiene oversight for all fieldwork performed under the CLEAN contract.
- Provide clearance to the Navy for all personnel on the site in accordance with federal and state regulations and contract specifications.
- Perform audits to evaluate program effectiveness.
- Provide assistance and guidance to the project H&S officer.
- Maintain communication with the program manager, PM, and the project H&S officer.

The project manager is David Brayack, of TtNUS; he can be contacted at (412) 921-8375 by telephone and (412) 921-4040 by telecopy. As project manager, Mr. Brayack is responsible for the following:

- Complete the project in a timely manner and maintain the project's scope, budget, and schedule.
- Coordinate and implement all tasks indicated in the approved site-specific work plan and quality assurance project plan (QAPP).
- Supervise data collection, reporting, and document control process.
- Approve deliverables and associated documents before transmittal.
- Implement programs and protocols related to the project.
- Establish and maintain communication among technical staff, Navy RPM, CLEAN program manager, program QA coordinator, program H&S managers, and regulatory agencies.

The project H&S officer is Michelle Gillie, of TtNUS; she can be contacted at (610) 491-9688. As project H&S officer, Ms. Gillie is responsible for the following:

- Prepare the site specific HASP.
- Establish and maintain communication among the site safety officer (SSO), the PM, and the CLEAN program H&S manager.
- Verify that site personnel adhere to the site safety requirements.
- Provide guidance about appropriate corrective action procedures to PM and support personnel.
- Perform other responsibilities as specified in the site-specific HASP.

Subcontracts for the drilling and laboratory analytical services will be procured and awarded by CLEAN program subcontracting officers before commencement of field activities.

2.0 BACKGROUND INFORMATION

2.1 PHYSICAL SETTING

2.1.1 Surface Features

The NWIRP Bethpage is located on Long Island, New York. It is located on a relatively flat, featureless, glacial outwash plain. The site and nearby vicinity are highly urbanized. Because of this, most of the natural physical features have been reshaped or destroyed. The topography of the activity is relatively flat with a gentle slope toward the south. Elevations range from greater than 140 feet (above mean sea level, MSL) in the north to less than 110 feet (above MSL) at the southwest corner.

The NWIRP is about 108 acres in size. The dominant features at the activity are Plant No. 3, (the manufacturing plant) and three groundwater recharge basins. The recharge basins are each approximately 1.5 to 2.5 acres in area and about 30 feet deep.

1.4.2 Geology

The Upper Glacial Formation (commonly referred to as glacial deposits) forms the surface deposits across the entire NWIRP. The glacial deposits beneath the site consist of coarse sands and gravels. These deposits are generally about 30 to 45 feet thick; local variations in thickness are common due to the irregular and undulating contact of the glacial deposits with the underlying Magothy Formation. The contact between the two formations was defined in the field as the horizon where gravel becomes very rare to absent, and finer sands, silts, and clays predominate. The generally coarse nature of both formations near their contact, however, may make this differentiation either difficult or rather subjective.

The results of the drilling program at location HN-24 (near AOC 22) and surrounding well locations appear to confirm the regional observation that there is no singular, areally extensive clay units beneath the NWIRP. Clay units encountered at any particular location do not persist along strike or in either direction of dip. The stratigraphic section at and below subsurface depths of about 100 feet may be considered "clay-prone" because the number of individual clay units significantly increases below this depth, but none of these clays are laterally persistent.

2.1.3 Hydrogeology

The Upper Glacial Formation and the Magothy Formation comprise the aquifer of concern at the NWIRP. Regionally, these formations are generally considered to form a common, interconnected aquifer as the coarse nature of each unit near their contact and the lack of any regionally confining clay unit allows for the unrestricted flow of groundwater between the formations.

Although the water table beneath the NWIRP occurs below the glacial deposits, they are hydrogeologically important because their high permeability allows for the rapid recharge of precipitation to the underlying Magothy Formation. In addition, the large quantities of groundwater withdrawn daily from the Magothy passes back through part of the glacial deposits via the recharge basins to the Magothy Formation.

The Magothy aquifer is the major source of public water in Nassau County. The most productive water-bearing zones are the discontinuous lenses of sand and gravel that occur within the generally siltier matrix. The major water-bearing zone is the basal gravel.

The Magothy aquifer is commonly regarded to function overall as an unconfined aquifer at shallow depths and a confined aquifer at deeper depths. The drilling program on the NWIRP has revealed that clay zones beneath the facility are common but laterally discontinuous. No confining clay units of facility-wide extent were encountered.

The degree of confinement within the Magothy aquifer is reported to generally increase with depth due to the cumulative effect of the silts and clays. The lack of a singular, continuous confining unit beneath the NWIRP and the dependence of confinement on the occurrence of multiple fine-grained units should make the relationship of confinement to depth laterally inconsistent due to the extreme lithologic heterogeneity of the formation. The response of the Magothy aquifer to production well pumping suggests that groundwater occurs under at least semi-confined conditions in deeper portions of the aquifer.

The groundwater flow dynamics beneath the NWIRP and Northrop Grumman are complex. A total of 16 deep production wells (7 on the NWIRP and 9 on Northrop Grumman property) are located on the facility. Throughout the year, these wells are pumped in various combinations. Depending on facility demand, any particular well may be turned on and off at frequent intervals, or may be turned on or off for extended periods. The resultant cones of depression formed by the possible well-usage combinations make local variations in the overall groundwater pattern difficult to predict.

Recharge basins have the potential to greatly affect local water elevations and hence, local groundwater flow patterns. The dominant direction of shallow groundwater flow beneath the NWIRP appears to be dominantly to the southwest and, to a lesser extent, to the south.

2.2 Site History

2.2.1 Previous Investigations

In 1997, Northrop Grumman conducted a soil investigation at the former underground storage tank location (AOC 22). During this investigation soil borings were installed around and under the former tanks. Approximately 144 soil samples were collected in 8 areas from depths of 8 to 65 feet below ground surface. This range represents soils from the bottom of the former USTs to the approximate water table. The samples were analyzed for petroleum-based volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) in accordance with the NYSDEC STARS Memorandum No. 1 – Petroleum-Contaminated Soil Guidance Policy (August 1992) and for total petroleum hydrocarbons.

VOCs were detected infrequently in the soil samples, and none of the detected results exceeded STARS Memorandum Guidance Values (Table 2 of the guidance). SVOCs were detected more frequently and approximately 23% of the soil samples had one or more STARS Memorandum SVOC parameters (polynuclear aromatic hydrocarbons) at a concentration greater than the STARS Memorandum Guidance Values. STARS Memorandum Guidance Value exceedances were noted in all of the soil boring locations and for most sample depths from shallow soils (8 feet below ground surface) to deeper soils near the water table. However, the maximum SVOC concentration detected that exceeded a STARS Memorandum criteria was only 4.3 mg/kg, indicating that although petroleum hydrocarbons are wide spread, concentrations are relatively low.

Total petroleum hydrocarbon testing was conducted to evaluate general fuel oil contamination. This testing found petroleum in soils at concentrations up to 18,000 mg/kg and at depths near the water table, (see Appendix B). The petroleum hydrocarbons were of the diesel range organics that are consistent with No. 4 and No. 6 fuel oils reportedly used at this location.

3.0 FIELD SAMPLING PLAN

3.1 SAMPLING OBJECTIVES

The sampling objectives of this sampling program are as follows.

- Determine if a floating free product layer is present at AOC 22.
- Collect groundwater data from the area to determine if groundwater has been impacted.
- If free product is present, conduct recovery tests to characterize physical properties of free product and conduct chemical testing of free product for disposal purposes.
- Collect additional soil data to help characterize the horizontal spread of petroleum. Note that based on the relatively large area (0.2 acres) and depth of petroleum contamination (65 feet) determined during the Northrop Grumman investigation, excavation of petroleum-contaminated soils is not considered to be practicable.

3.2 FIELD INVESTIGATIVE TASK DESCRIPTIONS

Field activities are presented by task in the following paragraphs. All field activities will be conducted in accordance with procedures referenced in TtNUS Standard Operating Procedures (SOPs), and in accordance with the health and safety procedures established in the site HASP.

3.2.1 Soil Boring and Permanent Groundwater Monitoring Wells

Soil boring and monitoring wells will be installed in areas where free petroleum product may be present. Initially five soil borings will be installed as indicated on Figure 3-1. As the soil borings are being installed, if evidence of free product is detected, one to three of the soil borings will be converted into permanent monitoring wells to test for free product formation in the well. The permanent monitoring wells will be flush mounts.

After the first five soil borings are installed, approximately five additional soil borings will be installed to better delineate the extent of floating free product. Two to four of these soil borings may also be converted into permanent monitoring wells to monitor free product formation. A total of five monitoring wells are planned for this area. The location of the additional soil borings will be dependent on field observations of floating free product, soil staining at the water table, and PID/FID readings of split spoon samples.

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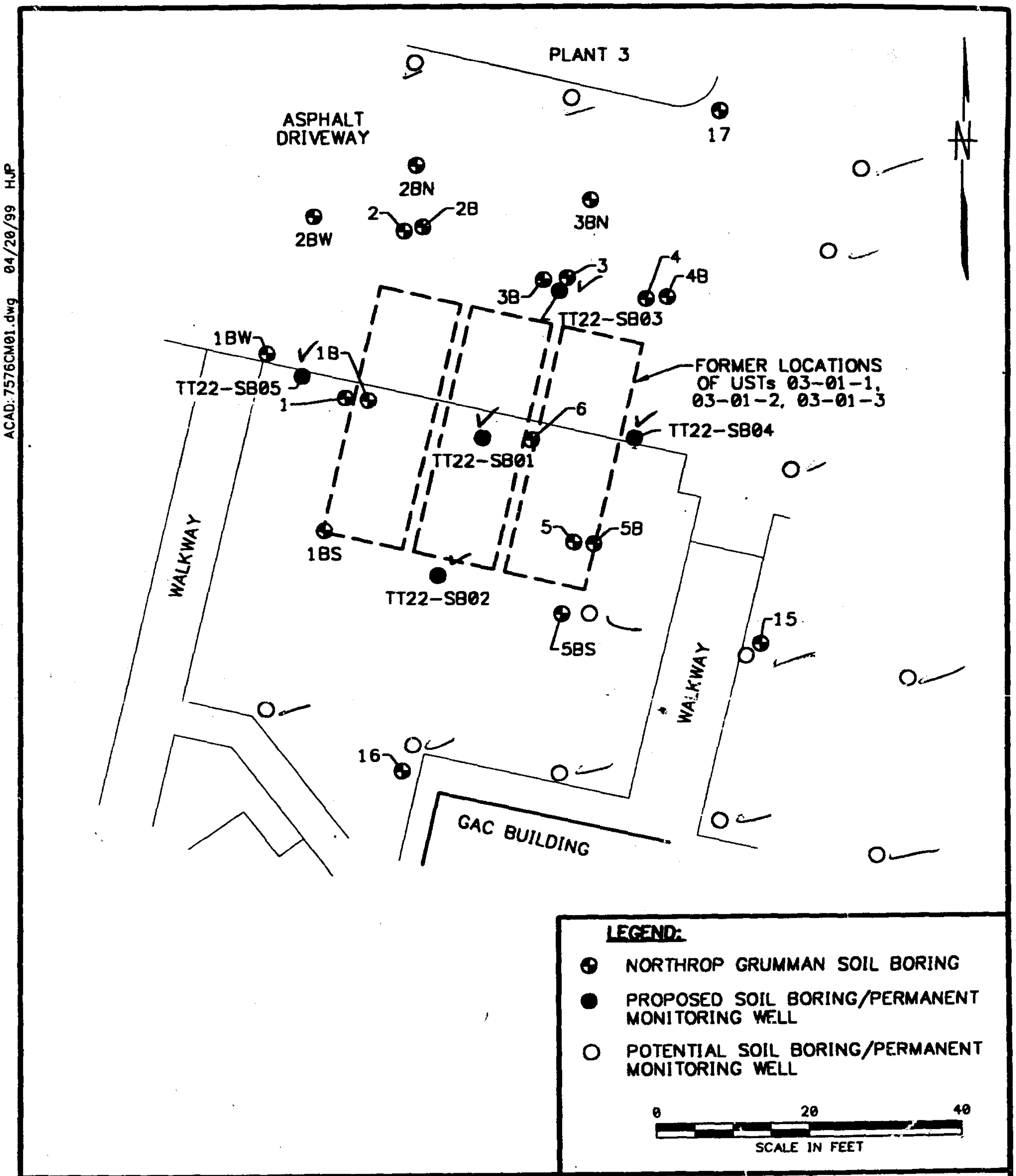


DRAWN BY MF DATE 3/10/99	Tetra Tech NUS, Inc.	CONTRACT NO. 7576	OWNER NO.
CHECKED BY DATE	SOIL BORING/MONITORING WELL LOCATION AOC 22 NWIRP BETHPAGE, NEW YORK	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 3-1	REV. 0

FORM CADD NO. TtNUS_AV.DWG - REV 0 - 1/22/98

During installation of the soil borings, split spoon samples will be collected on 10-foot centers from 10 feet below ground surface to a depth of approximately 5 feet above the water table. Nearby existing groundwater monitoring wells can be used to estimate the depth to water table in this area for the first soil boring. At a depth of approximately 5 feet above the water table, split spoon samples will be collected continuously to a depth of approximately 8 feet below the water table. Soil samples from 5 feet above the water table to 8 feet below the water table will be evaluated in the field for evidence of free product. One soil sample from each soil boring will be analyzed for TPH diesel range organics (DRO) and gasoline range organics (GRO) by method number SW 846-8015B. In addition, soil samples from 3 of the 10 soil borings will be analyzed for VOCs and SVOCs by EPA Methods 8260B and 8270. A summary of the analytical plan is presented in Table 3-1. Samples for TPH and VOC/SVOC analysis will be biased toward contamination under the following guidelines.

1. Oil stained soils near the water table.
2. The sample interval near the water table with the highest PID/FID readings.
3. If oil stained soils or elevated PID/FID readings are not observed, then the sample interval at the water table.

One round of groundwater samples will be collected for standard turnaround laboratory analysis from the permanent groundwater monitoring wells a minimum of 2 weeks after well completion. Groundwater samples will be analyzed for TCL VOCs by method SW 846-8260B.

3.2.2 Aquifer Tests

Rising-head slug tests will be conducted for all newly installed permanent monitoring wells in order to define aquifer characteristics such as hydraulic conductivity (K), transmissivity (T), and storativity (S).

3.2.3 Free Product Thickness Measurements

The thickness of the free petroleum product in each monitoring well will be measured with an interface probe. Based on the field measurements, two wells will be selected for free product recovery testing. The selection will target the wells with the thickest layer of free product and most remote from each other. These wells will also be used to collect free product samples.

In addition, free product measurements will be conducted three times over a 6-month period to determine if there is seasonal variation in the free product thickness measurements.

TABLE 3-1

ANALYTICAL SUMMARY
FREE PRODUCT INVESTIGATION
NWIRP BETHPAGE, NEW YORK

Media	TPH – DRO & GRO	TCL VOCs	TCL SVOCS	PCBs/ pesticides	RCRA Metals (8)	Flash point/BTU Value	Chloride
Soils	10	3	3	0	0	0	0
Groundwater	0	5	5	0	0	0	0
Free Product	0	2	2	2	2	2	2
QA/QC Samples	0	TB, DU, MS/MSD	TB, DU, MS/MSD	0	0	0	0

TB:	Trip Blank (one per day)
DU:	Duplicate (one per ten per matrix)
MS/MSD:	Matrix Spike/Matrix Spike Duplicate (one per twenty per matrix)

3.2.4 Free Product Samples

Free product samples will be collected from two of the new wells. The samples will be collected during the Free Product Recovery Tests. If necessary, water will be decanted from the free product prior to sample collection. The free product samples will be analyzed for TCL VOCs by Method 8260, TCL SVOCs by Method 8270, PCBs by Method 8082, Pesticides by Method 8081, RCRA Metals by Method 6010/7470, Flash point by Method 1010, BTU by ASTM D240, and Chloride by Method 325.2. If necessary, samples from more than one free product recovery test at a given well will be used to generate sufficient volume. However, both free product samples will be shipped to the laboratory at the same time. If necessary, the samples will be held at the facility on ice until sample shipment. Samples will be shipped to the laboratory for analysis via high hazard shipping containers.

3.2.5 Free Product Recovery Tests

Free product recovery tests will be conducted on two of the new groundwater monitoring wells. The free product test consists of removing the free product and then monitoring the free product thickness over time. A hand bailer will be used to remove free product from the monitoring wells. Ideally, all free product should be removed from the well prior to the start of the test. However, based on the free product recovery rate and initial thickness of the free product layer, some free product may be present in the wells at the start of the tests.

An interface probe is used to measure the free product thickness. Free product thickness measurements are to be conducted over a 24 to 48 hour period as indicated on the Free Product Recovery Test Field Sheet located in Appendix A. Once the recovered product thickness reaches 50% or more of the original thickness, the test should be repeated. If possible based on the time available, the test should be repeated a third time.

The quantity of free product recovered is measured in a graduated cylinder. The results are to be recorded. The volume of water collected should not be considered in the measurements. The free product collected is to be used for analytical testing.

3.3 SAMPLE DESIGNATION SYSTEM

Each sample collected for analysis will be assigned a unique sample tracking number. This number will consist of a two-segment alphanumeric code that identifies the sample type or QC sample designation, and the station or QC sample number. The alphanumeric coding system to be used is explained in the following diagram and subsequent definitions.

TTNUS-22-AA-NN-NNNN

Sample Type/Station number

Character Type: A = Alpha N = Numeric

Site Designation:

TTNUS-22 = AOC 22 South of Plant 003

Sample Type:

MW = Monitoring Well
SB = Soil Boring

QC Sample Designation:

TB = Trip Blank
DU = Duplicate

Station Sample Number:

All sample stations will be assigned a consecutive, two digit station numbers per sample type in the order of installation. For example, a groundwater sample collected in the first monitoring well installed would be assigned the tracking number TTNUS-22-MW-01. Monitoring well and soil boring numbers will be independent of each other.

All QC samples will be assigned a unique sample number.

For soils boring samples, the last four digits will be used to indicate top and bottom of sample interval in feet below ground surface.

All pertinent information regarding sample identification will be recorded in the field logbooks and on sample logsheets where appropriate.

4.0 QUALITY ASSURANCE AND QUALITY CONTROL

The Quality Assurance Project Plan (QAPP) identifies specific parameters and procedures that are applicable to the investigation:

- Project scope and complexity
- Project organization and responsibilities
- QA objectives for analytical data
- Sampling methods
- Field decontamination procedures
- Custody protocol
- Analytical parameters and sample frequency
- Identification of analytical methods
- Calibration procedures
- Data reduction, validation, and reporting procedures
- Data assessment procedures
- Handling of investigation-derived waste

4.1 PROJECT SCOPE AND COMPLEXITY

This project will include the installation and sampling of test borings and the installation and sampling of permanent monitoring wells to further define the nature and extent of petroleum contamination at the site.

4.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

Overall project coordination personnel and responsibilities are as discussed in Section 1.3 of this work plan.

4.3 QUALITY ASSURANCE OBJECTIVES

The QA objective is to ensure that the data generated as part of this investigation are of known and acceptable quality and are suitable for the intended use. The data quality objectives (DQOs) are established by identifying the end use of the data and the degree of certainty necessary to satisfy that end use. The data will be used to determine if free product on the water table is present, if groundwater quality exceeds current NYSDEC guidance values, and to supplement the existing soil data base.

The overall quality assurance (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 that are legally defensible in a court of law. 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.

4.3.1 Precision

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.

4.3.1.1 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 analytical samples.

4.3.1.2 Laboratory Precision Objectives

Laboratory precision quality control samples will be analyzed with a frequency of five percent (i.e., one quality control sample per 20 environmental samples) for organic analyses. Laboratory precision is measured via comparison of calculated Relative Percent Difference (RPD) values and Precision Control Limits specified in the analytical method or by the laboratory's QA/QC Program.

Precision for organic analysis will be measured via the RPDs for matrix spike/matrix spike duplicate samples.

4.3.2 Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference value.

4.3.2.1 Field Accuracy Objectives

Accuracy in the field is assessed through the use of trip blanks and is ensured through the adherence to all sample handling, preservation, and holding times. Accuracy and precision requirements for field measurements (e.g., pH) are ensured through calibration as discussed in Section 4.9.1.

4.3.2.2 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 analysis) or into actual samples (i.e., surrogate or matrix spike analysis). These analyses measure the accuracy of laboratory operations as affected by matrix. Laboratory control sample analyses are performed with a frequency of one per 20 associated samples of like matrix. Matrix spike analyses will be performed with a frequency of one per 20 associated samples of like matrix for organic analyses and with a frequency of one per 10 associated samples of like matrix for inorganic analyses. Surrogate spike analysis is performed for all organic analyses. Laboratory accuracy is assessed via comparison of calculated percent recovery (%R) values with accuracy control limits specified in the analytical method or by the laboratory's QA/QC program.

Accuracy for organic analysis will be measured via the percent recoveries for surrogate spikes and matrix spike/matrix spike duplicates.

4.3.3 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 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. Completeness will be calculated for the RI as a whole since it is anticipated that all samples will be collected within a 4-month period. If critical data points are lost, resampling and/or re-analysis may be required.

4.3.3.1 Field Completeness Objectives

Field completeness is a measure of the amount of valid field measurements obtained from all the field measurements taken in the project. Field completeness for this project is expected to be greater than 90 percent.

4.3.3.2 Laboratory Completeness Objectives

Laboratory completeness is a measure of the amount of valid laboratory measurements obtained from all the laboratory measurements taken in the project. Laboratory completeness for this project is expected to be greater than 95 percent.

4.3.4 Representativeness

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.

4.3.4.1 Measures to Ensure Representativeness of Field Data

Representativeness is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the field-sampling plan (FSP) in Section 3.0 of this RI work plan is followed and that proper sampling technique are used.

4.3.4.2 Measures to Ensure Representativeness of Laboratory Data

Using the proper analytical procedures, meeting sample-holding times, and analyzing and assessing field duplicate samples ensures representativeness in the laboratory. The sampling network for this activity was designed to provide data representative of facility conditions. During development of this network, consideration was given to existing analytical data, physical setting and processes. The rationale of the sampling network is discussed in detail in Section 3.0 of the FSP.

4.3.5 Comparability

Comparability is defined as the confidence with which one data set can be compared to another (e.g., between sampling points; between sampling events). 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) achieve comparability. Additionally, consideration is given to seasonal conditions and other environmental variations that could exist to influence data results.

4.3.5.1 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 FSP is followed and that proper sampling techniques are used. It is also dependent on recording field measurements using the correct units. Field measurements for this project include pH, specific conductance, temperature, turbidity, and dissolved oxygen. The units used for the field measurements for this project are as follows:

- pH is measured to the nearest 0.1 standard pH unit.
- Specific conductance is measured in μmhos (the inverse of the ohm).
- Temperature is measured in degrees Celsius.
- Turbidity is measured in nephelometric turbidity units (NTU).

4.3.5.2 Measures to Ensure Comparability of Lab 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. Organic chemicals will be reported in μg/L for aqueous samples and μg/kg for solid samples.

4.4 QUALITY ASSURANCE PROCEDURES

QA/QC samples are intended to provide control over the collection of environmental data and subsequent validation, review, and interpretation of the analytical results. Various types of blank samples and other related QA/QC concerns such as packaging, handling, and shipping of samples from the site are discussed in this section.

External QC measures (i.e., field quality control samples) consist of field duplicates, trip blanks, rinsate blanks, and field 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.

4.4.1 Trip Blank

The trip blank is used exclusively for the monitoring of volatile organic analysis. The purpose of the trip blank is to measure cross contamination of the samples during shipment to and from the site. The trip blanks must travel to the site with the empty bottleware and from the site with the collected samples. At no time should the trip blank be opened in the field. The rate at which this sample is taken is one per cooler containing volatile organic samples. The trip blank must be analyzed for volatile organic parameters.

4.4.2 Field Blank

The field blank is prepared in the field, from analyte-free water used during equipment decontamination activities. The field blanks will be preserved in the same manner as the aqueous field samples and will be analyzed for the same parameters as the field samples collected that day. Field blanks will be prepared at the rate of one per sampling event. Since disposable sample equipment will be used, field blanks are not anticipated for this project.

4.4.3 Rinsate Blank

The rinsate blank is prepared in the field, from analyte-free water supplied by the laboratory, by pouring the water over dedicated or decontaminated sampling devices into clean sample bottles. The rinsate blanks will be preserved in the same manner as the aqueous field samples and will be analyzed for the same parameters as the field samples collected that day. Rinsate blanks will be prepared at the rate of one per day per matrix.

Field blanks are not required for potable well sampling events or when an aqueous sample is collected directly from the source into a sampling container. Since disposable sample equipment will be used, field blanks are not anticipated for this project.

4.4.4 Field Duplicate Samples

The field duplicate is collected to monitor the precision and reproducibility of the sampling and analytical activities. The sample is prepared by collecting two samples from the same location. These samples are collected at a rate of one for every 10 samples per matrix for the event. Field duplicates are further discussed in Section 4.4.9.

4.4.5 Matrix Spike/Matrix Spike Duplicate

The matrix spike (MS) samples are collected as monitoring controls for the laboratory and are addressed under the analytical protocols. These samples are collected at a rate of five percent of the total number of organic analyses to be conducted for the event. MS/matrix spike duplicate (MSD) analyses are performed for organic fraction analysis. The preparation of the organic fraction laboratory QC samples requires supplying triple volume of the designated sample.

4.4.6 Method Blanks

Method blank samples are generated within the laboratory and are used to assess contamination resulting from laboratory procedures.

4.4.7 Other Laboratory QC Analyses

The level of QC effort for testing of organics (volatiles and semivolatiles) will conform to the analytical methods.

4.5 SAMPLING METHODS

Sampling during field operations will include the collection of subsurface soil, groundwater, and QA/QC samples. General field sampling and sample documentation procedures to be implemented are described in TtNUS Standard Operating Procedures (SOPs). The specific sampling procedures for each task are detailed in the following sections. A summary of the proposed sampling and analysis program is presented in Table 3-1.

4.5.1 Soil Borings

Soil borings will be installed. A subcontracted drilling company will complete the soil borings using methods specified in accordance with TtNUS SOPs. The subcontracted drilling company will be responsible for obtaining all necessary permits.

Standard-penetration test and split-spoon sampling will be conducted using 2-foot long, nominal 2-inch outside diameter (O.D.) split-spoon samplers, according to methods presented in American Society for Testing and Materials (ASTM) D-1586-84. During the advancement of the borings at each location, soils will be inspected from each split-spoon sampler to provide a lithologic record of the subsurface materials. The field geologist in accordance with TtNUS SOPs will maintain a complete boring log for the borings at each location. Each log will describe lithologies encountered, depth of contacts, water levels, sample depths, and sample numbers and will include data from standard penetration tests. Soil samples will be described using the Unified Soil Classification System.

Upon the opening of each split-spoon sampler, the soils will be monitored for organic vapors using a Photoionization detector (PID) or a Flame Ionization Detector (FID). Discrete soil samples will be collected in all borings using methods in accordance with TtNUS SOPs.

Split-spoon samples/drill cuttings and samples that are visibly contaminated with hydrocarbons, if any, will be containerized and stored on site in 55-gallon Department of Transportation (DOT)-approved steel drums (DOT 17-H). Soils that are visibly clean and odor free will be placed back into the soil boring or spread around the monitoring well.

All disposable sampling equipment will be dedicated and disposed properly. All non-disposable sampling equipment will be decontaminated before use and between each soil boring using methods in accordance with TtNUS SOPs.

4.5.2 Permanent Groundwater Monitoring Well Installation

The subcontracted drilling company will install permanent monitoring wells using methods specified in accordance with TtNUS SOPs. The monitoring wells will be constructed of 4-inch internal diameter (ID), threaded, flush joint, National Sanitary Foundation (NSF)-certified, Schedule 40 PVC well casing and screen. The well screen will have a length of 13 feet and a 0.010 slot size. The top of the screen will extend 5 feet above the top of the water table encountered during drilling.

A filter pack, consisting of clean silica sand; will be placed by freefall from the bottom of the well screen to a minimum of 2 feet above the top of the well screen. A minimum of 2 feet of bentonite pellets will be placed on top of the filter pack. The bentonite pellets will be activated by potable water before the addition of a bentonite/cement grout. The bentonite cement grout will be placed by tremie pipe from the top of the bentonite pellets to approximately 10 inches below grade. Steel guard casing will be centered around the well casing, cemented in place, and fitted with a flush-mounted cap. The wells will be developed after the grout has been placed.

4.5.3 Groundwater Sampling of Permanent Groundwater Monitoring Wells

Groundwater samples will be collected using methods in accordance with TtNUS SOPs from each of the monitoring wells a minimum of 14 days after well completion for laboratory chemical analysis. Each well will be purged a minimum of three well volumes. Field testing of pH, temperature, and conductivity will be performed using methods in accordance with TtNUS SOPs before sampling. Samples will be poured directly from bailers into appropriately pre-preserved sample containers. The samples will include applicable field QA/QC samples (i.e., blanks and duplicates).

All purge water and decontamination fluids generated during groundwater sampling activities will be handled in accordance with Section 4.7.

Sampling equipment will be handled in accordance with Section 4.7. Disposable sampling equipment will be dedicated and disposed properly. All non-disposable sampling equipment will be decontaminated before use and between each well using methods in accordance with TtNUS SOPs.

4.5.4 Groundwater-Level Measurement in Permanent Groundwater Monitoring Wells

One round of static-water-level measurements will be collected prior to sampling. The water level will be measured from the top of the casing and from the top of the ground surface and will be measured to 0.01-foot accuracy.

4.5.5 Aquifer Tests

Slug tests conducted during field operations will be in accordance with methods specified in TtNUS SOP GH-2.4. A rising-head slug test will be performed during field operations in at least one of the permanent groundwater monitoring wells installed in order to provide approximate K values for that portion of the soil that surrounds the screened interval in the permanent groundwater monitoring well. Water-level measurements will be obtained during the test using a pressure transducer.

4.5.6 Duplicate and Split Samples

Duplicate samples will be obtained during field activities to monitor sampling techniques in the field and in the laboratory. These samples will be collected at a rate of one duplicate for each 10 field samples. The laboratory will receive them as "blind" samples. Details regarding the field duplicate sampling process are further described below.

Aqueous duplicates are collected by alternatively filling sample containers from the same sampling device for each parameter. Samples for volatile organic analysis will be taken from the same bailer and will be the first samples filled.

Soil samples (non-aqueous) will be collected from the same sample location. The sample material will be homogenized in a stainless-steel mixing bowl before sample containers are filled. Sample material for volatile organic analysis will be collected prior to homogenizing to prevent loss of volatile constituents and to preserve the physical integrity of the volatile fraction.

Split samples are not proposed for this field activity. If field conditions change or the scope of work for this activity change to include the collection of split samples, this work plan will be amended to reflect the change.

4.6 FIELD DECONTAMINATION PROCEDURES

An important aspect of quality control is the decontamination of field sampling equipment. Improperly cleaned and prepared equipment can lead to misinterpretation of environmental data due to interference from cross contamination.

All non-disposable sampling equipment that comes in contact with sample medium will be decontaminated using methods in accordance with TtNUS SOPs. Specifically, the following decontamination requirements will be met:

- Potable water and detergent rinse (Alconox/Liquinox)
- Tap water rinse
- Distilled/deionized water rinse
- Methanol rinse
- Distilled/ deionized water rinse
- Air dry

4.7 HANDLING AND DISPOSAL OF INVESTIGATION-DERIVED WASTES

Waste that is generated during field activities must be disposed in a manner that will not further the potential for contamination. Waste materials routinely generated from an investigation of this type consist of Geoprobe® and drill cuttings, excess sample, well development and purge water, decontamination water, dedicated disposable sampling equipment, and general refuse.

At locations where the cuttings are considered to be contaminated based on visual staining and/or petroleum odors, the drill cuttings and disposable sampling equipment will be placed in drums and stored in a secure area. The need to perform analyses of the secured IDW for waste characterization and disposal approvals will be evaluated and performed as necessary based on the sample results.

At locations where the groundwater is considered to be contaminated above NYSDEC groundwater quality standards, the groundwater and decontamination water will be collected in a drum and stored in a secure area.

If sample results exceed NYSDEC action levels, the IDW will be transported and disposed off site at a licensed disposal facility. TtNUS will be responsible for procuring and managing the subcontract disposal services for IDW during this project.

In the event that the sample results are below the action levels, the Navy plans to dispose of these materials on site. Purge water will be poured onto unpaved ground surfaces. Decontamination waters will be poured onto a paved surface to allow natural evaporation and runoff to the storm water collection system. Disposable sampling equipment will be placed in plastic garbage bags and disposed as general refuse.

4.8 SAMPLE CUSTODY

Chain-of-custody (COC) procedures in accordance with TtNUS SOPs. will be followed.

As explained in the procedure, a sample is under custody if it is in

- The possession of the sampler/analyst
- View after being in the possession of the sampler/analyst
- The possession of the sampler/analyst and then placed in a secured location
- A designated secure area

4.8.1 Sample Collection Custody Procedures

The person doing the actual field sampling is responsible for the care and custody of the samples collected until the samples are properly transferred or dispatched.

Sample labels shall be completed for each sample container, using waterproof ink. Appropriate sample description and other pertinent information must be recorded in the field logbook.

4.8.2 Field Documentation/Logbooks

A summary of all field activities will be properly recorded in a bound logbook with consecutively numbered pages that cannot be removed. Logbooks will be assigned to field personnel but will be stored in a secured area when not in use. A unique number will identify each logbook.

At a minimum, the following information will be recorded in the site logbook:

- The name of the person to whom the logbook is assigned.
- The logbook number.
- The project name.
- The project start date.
- The names and responsibilities of on-site project personnel including subcontractor personnel.
- The arrival/departure of site visitors.
- The arrival/departure of equipment.
- Sampling activities and sample logsheet references.
- A description of subcontractor activities.
- Sample pick-up information including COC numbers, air-bill numbers, carrier, time, and date.
- A description of borehole, trench, or monitoring well installation activities.
- Health and safety issues.
- A description of photographs including the date, time, photographer, roll and picture number, location, and direction of the photograph.

All entries will be written in black ink and no erasures will be made. If an incorrect entry is made, the correction will be made by striking a single line through the incorrect information; the person making the correction will initial and date the change.

Samples will be collected following procedures outlined in Section 4.4. The equipment used to collect the sample will be noted in the logbook along with time of sampling, sampler's name, sample description, depth at which the sample was collected, and the volume and number of containers collected. QC sample information will be appropriately recorded.

Field Changes

Changes in proposed project activities may be necessary as a result of altered field conditions or unanticipated events. Amendments or revisions to approved project plans will undergo the same level of review as the original planning document. A summary of the sequence of events associated with field changes is as follows:

- The FOL notifies the project manager of the need for a change in scheduled activities.
- The project manager will discuss the change with the appropriate individuals and will provide verbal approval or denial for the proposed change.
- The FOL will document the change on a Task Modification Request Form and forward the form to the project manager immediately.
- The project manager will review and sign the form and distribute copies to the program contracting officer, program QA manager, FOL, and the project file.
- A copy of the completed Task Modification Request Form will also be attached to the field copy of the affected document (i.e., project work plan, safety plan).

Sample Documentation

A sample logsheet will be filled out for each sample collected. A sample logsheet is used to record specific types of data pertaining to the samples. Sample-specific data include such information as the sample identification number, container type and lot number, sample volume, preservative information, medium, sample description, any problems encountered during sampling, shipping information (airbill), date and time of sample, and sampler's signature. Sample logsheets are sequentially numbered and stored in a notebook. The notebook is included in the project file at the completion of field activities. Copies of these pages will be included as an appendix to rough draft, draft, and final project deliverables.

Daily Activities Record

The Daily Activities Record is designed for schedule and budget tracking and progress reporting. This record documents the pay items involved with daily activities and progress for each subcontractor. These sheets summarize the work performed and are used to check the subcontractor's request for payment.

The FOL supervising a subcontractor activity must complete a Daily Activities Record Form. The subcontractor's signature is required at the end of each day to verify work accomplished and the various pay items (e.g., hours worked, delay time, and materials used).

Equipment Calibration Log Form

Each TtNUS instrument requiring calibration will have a separate equipment calibration log form that documents that the manufacturer's instructions and the SOPs were followed for calibration of the equipment.

This information should include the frequency and type of standard or calibration device. This record documents the accuracy, precision, or sensitivity of the measurement. If necessary, it will be used to determine if corrections should be applied to the readings. A separate form will be established and maintained for each field instrument.

These forms will be maintained in a binder and, at the completion of the field activities, will be stored in the project file.

4.8.3 Custody Transfer and Shipment Procedures

A properly completed chain-of-custody (COC) form will accompany samples. When transferring the possession of samples, the individuals relinquishing and receiving the samples will sign, date, and note the time of transfer on the record. The original form and one copy will be sealed inside the cooler for shipment; the sampler will retain another carbon copy.

Samples will be properly packaged for shipment and secured with strapping tape and custody seals.

If the samples are sent by common carrier, a bill of lading will be used. A receipt or a bill of lading will be retained as permanent project documentation. Commercial carriers are not required to sign the custody form as long as the forms are sealed inside the shipping container and the custody forms remain intact. If the samples are sent by mail, the package will be registered with a return receipt requested.

4.8.4 Laboratory Custody Procedures

The laboratory will follow proper custody procedures. When the laboratory receives the samples, the bill of lading or shipping manifest will be signed and dated to document sample receipt. The laboratory will keep a copy of the manifest that will be included in the data package. The sample custodian will verify the integrity of the custody seals and the condition of the shipping containers. When the containers are opened, the temperature of the cooler will be measured and documented and the enclosed sample paperwork will be removed.

The samples will be removed from the coolers, and the condition of the bottles will be noted. All pertinent sample paperwork and labels will be inspected for discrepancies. Breakage or discrepancies will be resolved through the TtNUS project manager. Sample preservation will be noted and any improper preservation will be documented on an Out-Of-Control Form; corrective action will be taken. Laboratory tracking procedures will be followed as discussed in the laboratory QA plan provided by the contracted laboratory.

4.9 CALIBRATION PROCEDURES

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 to fixed laboratory instruments.

4.9.1 Field Calibration And Preventative Maintenance Procedures

It is the FOL's responsibility to ensure that field team members are trained in the calibration, use, and maintenance of all applicable field instruments and equipment.

Equipment used during field activities and sample collection will be calibrated in accordance with SOPs and manufacturers' instructions.

Equipment will be inspected at the beginning of each day to ensure that it is in operable condition and calibrated. All calibration activities will be documented on equipment calibration log sheets. Instruments in need of repair will be removed from service and clearly marked to ensure against further use.

The field logbook will clearly identify the specific instruments used for each task.

4.9.2 Laboratory Instrument Calibration

The laboratory is responsible for properly calibrating and maintaining analytical instrumentation. The laboratory's approved QA plan and method-specific QC activities must be in compliance with method and NFESC requirements. Sufficient documentation of compliance will be provided by the laboratory and will be included as part of the data package. Method- and instrument-specific calibration and tuning criteria for particular analyses are described briefly below. The frequency of calibration will be performed according to the requirements of the specific methods.

4.9.2.1 Volatile Organic Compound Analyses

For volatile organic compounds, the GC/MS system will be tuned and calibrated in accordance with the SW-846 method 8260 for groundwater and free product samples and EPA method 8021 for soil samples, with the exception noted as follows: 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 methods. However, 5 μg/L standards will be used in place of 10 μg/L standards in the aqueous volatile initial calibration for benzene. 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.

4.9.2.2 Semivolatile Organic Compound Analyses

For semivolatile organic compounds, the GC/MS system will be calibrated in accordance with the SW-846 method 8270, with the exception noted as follows: Initial calibration is required before any samples are analyzed and must include a blank plus five different concentrations as specified in the method. However, 5 μg/L standards will be used in place of 10 μg/L standards in the initial calibration for Benzo (a) pyrene. 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.

4.10 ANALYTICAL PROCEDURES

All sampling and monitoring activities conducted in the field will be documented including calibration and use records for field instrumentation. All data generated will be reviewed by the FOL and approved before accepted.

Off-site analytical support will be provided by a NYSDEC-certified analytical laboratory. This laboratory is responsible for compliance to all applicable NYSDEC and NFESC requirements. The analytical data package(s) is required to meet deliverable requirements to include documentation of QC results for calibration and method QC compliance as listed on laboratory QC summary sheets and raw analytical data (chromatograms, quantitation lists, and spectra) for field samples and laboratory and field blanks. Non-target compound reporting (tentatively identified compounds) will not be required, nor will raw data for calibration standards, matrix spikes, or instrument tuning. These requirements are further addressed in Section 4.9.2. All method-specific QA/QC requirements will be met. Upon approval of this QAPP, a NYSDEC certified laboratory will be procured.

4.10.1 Laboratory Sample Storage Procedures

The laboratory is required to follow the sample storage procedures outlined in the laboratory's approved QA plan. Specifically, the samples will be maintained under custody and will be stored in compliance with all applicable method-specific and program QA/QC requirements.

4.10.2 Laboratory Data Deliverable Format

Samples from investigation that are submitted to the laboratory for volatile and semivolatile analyses will require partial laboratory data deliverables for submission by the laboratory to include the raw data and QC forms described above. Submission of electronic data records pertaining to analyses conducted under the investigation will also be required. The format of the electronic data records will meet TtNUS requirements.

4.11 DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction will be performed by the laboratory in accordance with the laboratory's approved QA plan, laboratory SOPs, and NFESC and NYSDEC requirements. Documentation to support the data review will be included in the data package. The content and format of the analytical data packages are discussed in the preceding section.

Analytical data will not be formally validated but will be reviewed to evaluate usability (false positives, false negatives, and any severe accuracy problems) by a senior chemist. The analytical data review process includes the following tasks:

- Check analytical data for completeness to determine if all samples were analyzed and reported for the parameters requested in the chain-of-custody. Contact the laboratory to retrieve any missing information. Verify that the correct methods were followed in the laboratory narrative and QC summary forms.

- Check the data report for accuracy of sample identification, sample location, date of collection, and units.

- Organize the data tables by sample matrix, sample location. Consolidate the results of any multiple sample results (i.e., re-runs or dilutions) into one set of results.

- Check all summary forms for blank contamination and field/laboratory precision. Method non-compliance or anomalous results for blanks or field duplicates will be checked in the raw data to ensure against reporting error. Any findings will be summarized in an internal memorandum, but the data will not be qualified.

- In field samples, check selected large positive hits against the raw data to ensure against false positive or incorrectly calculated results.

- Check laboratory QC summary forms to ensure against those problems that would trigger data rejection (extremely low response factors or severe tuning problems).

- Submit the data review results to the project manager as an internal memorandum summarizing problems and resolutions.

4.12 DATA ASSESSMENT PROCEDURES

Precision and accuracy will be assessed through data review procedures as discussed above. Compliance with the completeness objectives for field and laboratory data/measurement will be verified. Information necessary to document acceptable precision and accuracy will be provided in electronic and hard-copy form by the subcontract laboratory. Procedures to be used for the precision, accuracy, and completeness assessment are as earlier outlined in Sections 4.3.1 through 4.3.5.

5.0 HEALTH AND SAFETY

5.1 PROJECT ORGANIZATION AND RESPONSIBILITIES

The H&S manager at each TtNUS office is responsible for ensuring that the site-specific HASP is in accordance with federal and state regulations and contract specifications. The site-specific HASP is provided in Appendix C. The H&S manager also provides technical safety and industrial hygiene oversight for all fieldwork performed for all projects and provides assistance and guidance to the project H&S officer. The project H&S officer is responsible for preparing the site-specific HASP and for verifying that site personnel adhere to the site safety requirements. The project H&S officer also provides guidance about appropriate corrective action procedures and maintains communication among the project staff, project manager, and office H&S manager.

5.2 HEALTH AND SAFETY OBJECTIVES

TtNUS has established a comprehensive health, safety, and training program for all field activities, particularly those that have the potential for chemical exposures. The program is intended to provide adequate procedures, protective gear, monitoring, and follow-up to protect the health of TtNUS, subcontractor, and client personnel, as well as the public near the work sites.

This program is driven by the requirement to comply with federal and state Occupational Safety and Health Administrative (OSHA) regulations, the need to minimize the risk of adverse health effects from exposure to work hazards, and the savings inherent in safe work activities. In this regard, our objective is to comply with all standards, training requirements, medical monitoring, and employee protection requirements for workers engaged in hazardous waste operations, as required by 29 CFR 1910.120, March 6, 1989.

APPENDIX A

TETRA TECH NUS STANDARD OPERATING PROCEDURES

APPENDIX A
FREE PRODUCT RECOVERY TEST FIELD SHEET
NWIRP BETHPAGE

Site: AOC 22 South of Plant 3

Well No.: ____________________

Well Size/Type: ____________________

Total Well Depth: ____________________

Initial Free Product Thickness: ________

Total Volume of Free Product Recovered: ________________

Date: ________________

Depth to Water: __________

Odor: ________________

Color: ________________

Temperature: ___________

Target Time (hours)[1]	Actual Time	Thickness Measurement (feet)	Notes/Observations
0			
1			
2			
4			
8			
16			
24			
48			

1. Times are approximate. If the well recovers faster, then shorter time intervals will be used.

General Notes/Observations: ____

Test Performed By: ____________________

TETRA TECH NUS	STANDARD OPERATING PROCEDURES	Number SA-6.3	Page 1 of 32
		Effective Date 03/01/96	Revision 0
		Applicability TETRA TECH NUS	
		Prepared Earth Sciences Department	
Subject	FIELD DOCUMENTATION	Approved D. Senovich	

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

ATTACHMENTS (EXAMPLES) **PAGE**

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 <u>Site Notebooks</u>

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

	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD
Date: ____________ Time: ____________ Method: ____________								

Purge Data

	Volume	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD
Date: ____________ Method: ____________	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: ______________________

Project No.: ______________________

☐ Spring
☐ Stream
☐ Other ______________________
☐ QA Sample Type: ______________________

☐ Pond
☐ Lake

Sample ID No.: ______________________

Sample Location: ______________________

Sampled By: ______________________

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:

Depth Sampled:

Sample Date and Time:

Type of Sample
- ☐ **Grab**
- ☐ **Composite**
- ☐ **Grab-Composite**
- ☐ **High Concentration**
- ☐ **Low Concentration**

[illegible]		
Sample	**Time**	**Color/Description**

[illegible]	
Color	**Description:** (Sand, Clay, Dry, Moist, Wet, etc.)

[illegible]	[illegible]	[illegible]

Map:

Observations/Notes:

[illegible]	
MS/MSD	**Duplicate ID No:**

Signature(s):

Subject FIELD DOCUMENTATION	Number SA-6.3	Page 13 of 32
	Revision 0	Effective Date 03/01/96

ATTACHMENT B-4
CONTAINER SAMPLE LOG SHEET FORM

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	Phase	☐Sol. ☐Liq.	☐Sol. ☐Liq.	☐Sol. ☐Liq
☐ Container opened but not sampled. Reason: ______ ______	Color	______	______	______
	Viscosity	☐L ☐M ☐H	☐L ☐M ☐H	☐L ☐M ☐H
☐ Container not opened. Reason: ______ ______	% of Total Volume	______	______	______
	Other ______	______	______	______

Monitor Reading:	Type of Sample ☐ Low Concentration ☐ High Concentration ☐ Grab ☐ Composite ☐ Grab-composite
Sample Method:	

		Organic	Inorganic
Sample Date & Time:	Sample Identification		
Sampled by:			
Signature(s):			
	Date Shipped		
Analysis:	Time Shipped		
	Lab		
	Volume		

ATTACHMENT B-5

SAMPLE LABEL

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

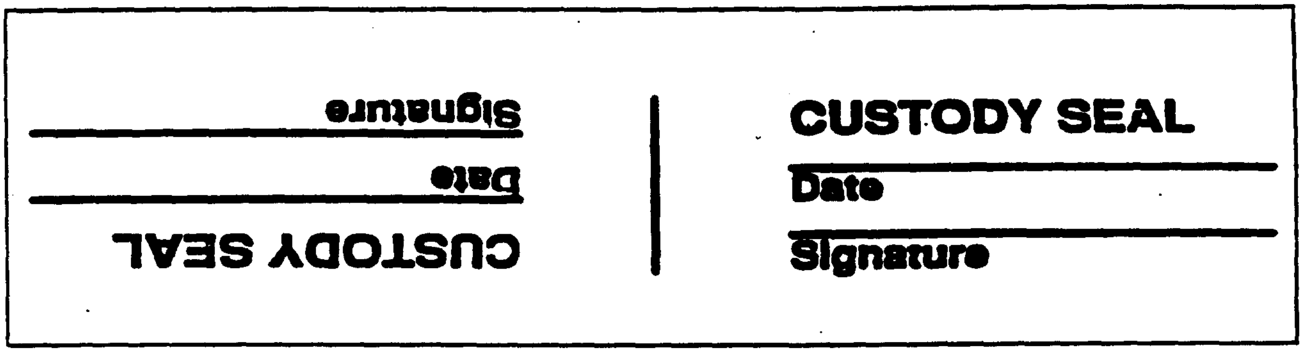
CHAIN-OF-CUSTODY RECORD FORM
(Original is 8.5 x 11")

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

Date

Signature

CUSTODY SEAL

Date

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** ____________

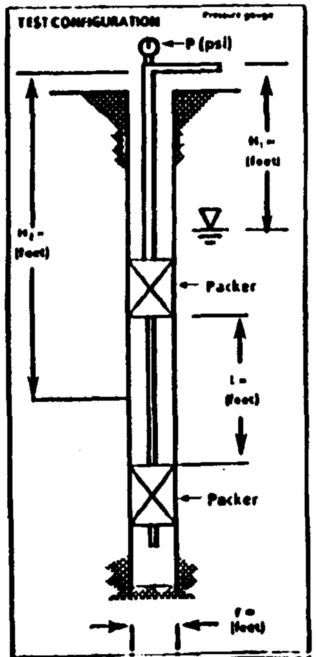
TEST INTERVAL: ____________ **BY:** ____________________ **CHECKED:** ____________________ **PACKER PRESSURE** ____________

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) = Cp Q/H	K (cm/sec) = 9.67 x 10^{-7} K (ft/yr)

$CP = (1/(2\pi L))\ \ln(L/r)\ (70{,}315\ S)$
7.48 Gallons = 1 Ft^3
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: ____
____
____



Length of test section in feet, l	Cp			
	EX (1 ½")	AX (1 7/8")	BX (2 3/8")	NX (3")
1	31,000	28,100	25,300	23,300
2	19,400	18,100	16,800	15,500
5	9,000	8,500	8,000	7,600
8	6,000	5,400	[illegible]	5,000
10	5,700	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]

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			* U S C S	Remarks	PID or FID Reading (ppm)
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			

*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 MCL)	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)				GROUP SYMBOL	TYPICAL NAMES
	Identification Procedures on Fraction Smaller than No. 40 Sieve Size				
	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-NX (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

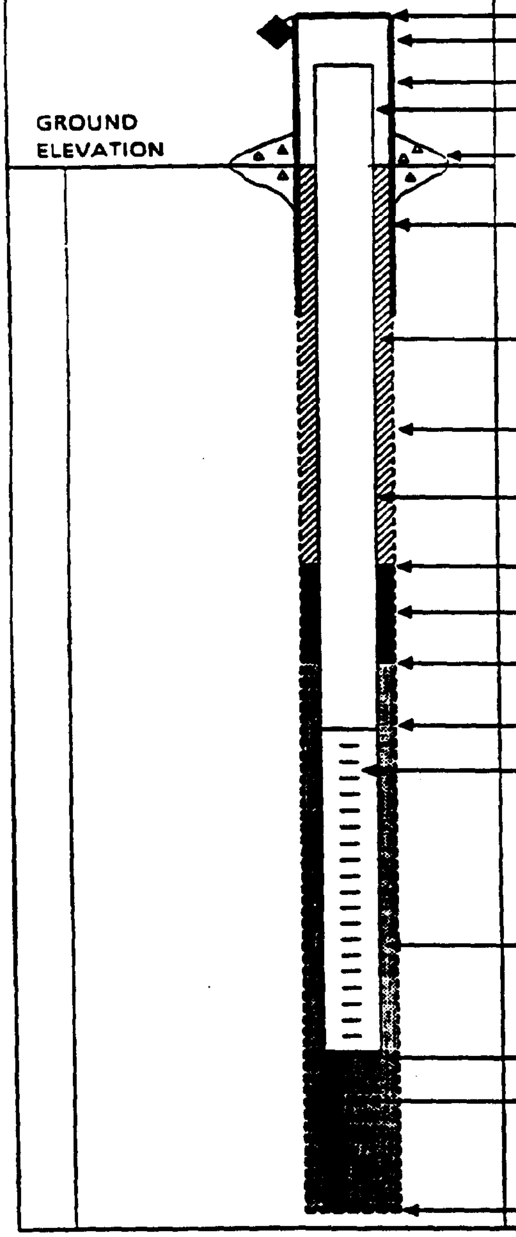
ATTACHMENT C-5
EXAMPLE OVERBURDEN MONITORING WELL SHEET

BORING NO.: ______

OVERBURDEN
MONITORING WELL SHEET

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

DRILLER ______
DRILLING METHOD ______
DEVELOPMENT METHOD ______



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: ___/___

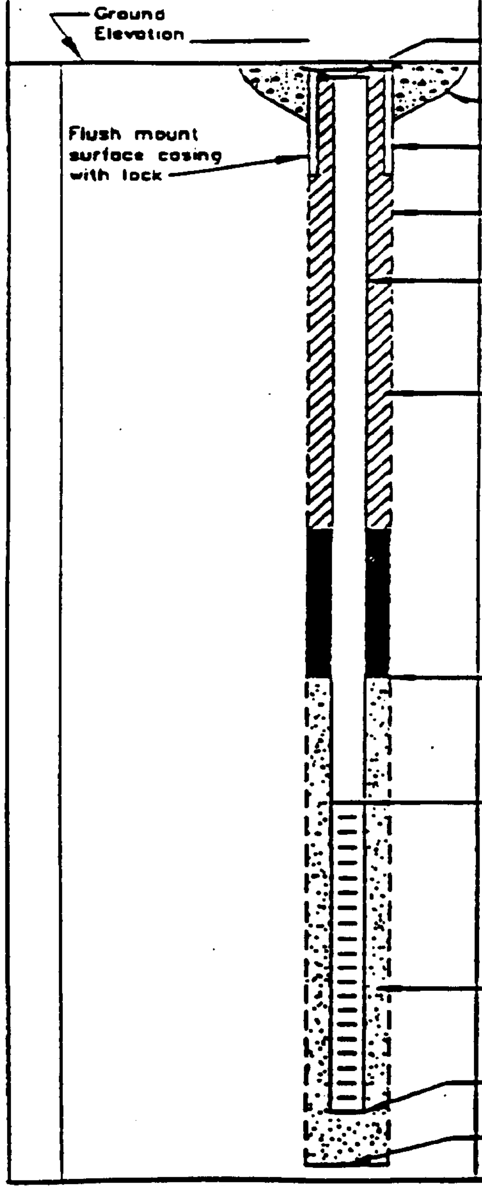
ATTACHMENT C-5A
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)

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: ______

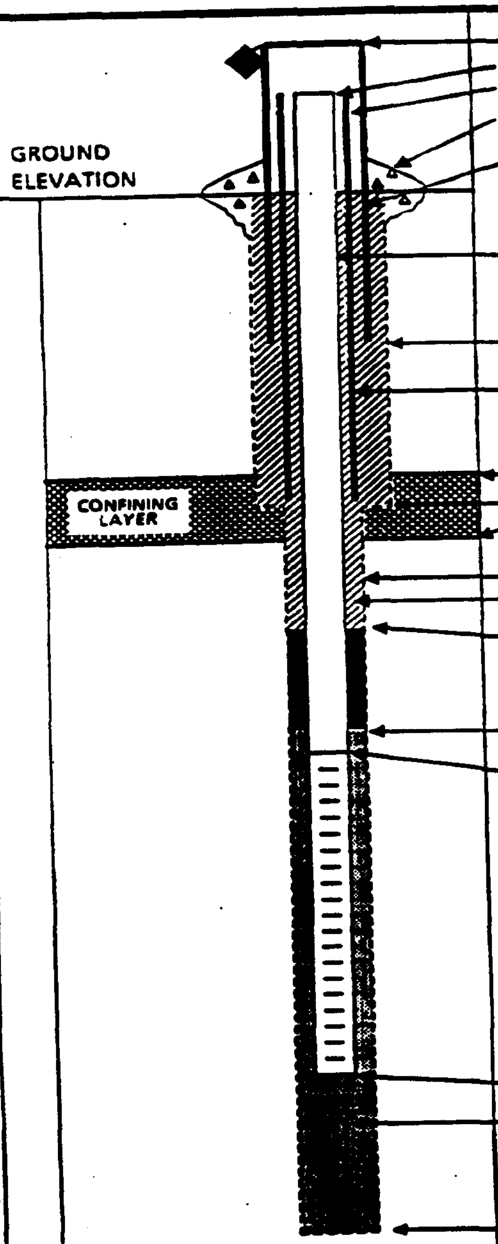
[illegible]

ATTACHMENT C-6
EXAMPLE CONFINING LAYER MONITORING WELL SHEET

BORING NO.: ____________

CONFINING LAYER MONITORING WELL SHEET

PROJECT ____________
PROJECT NO. ____________
ELEVATION ____________
FIELD GEOLOGIST ____________
LOCATION ____________
BORING ____________
DATE ____________
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: ____________

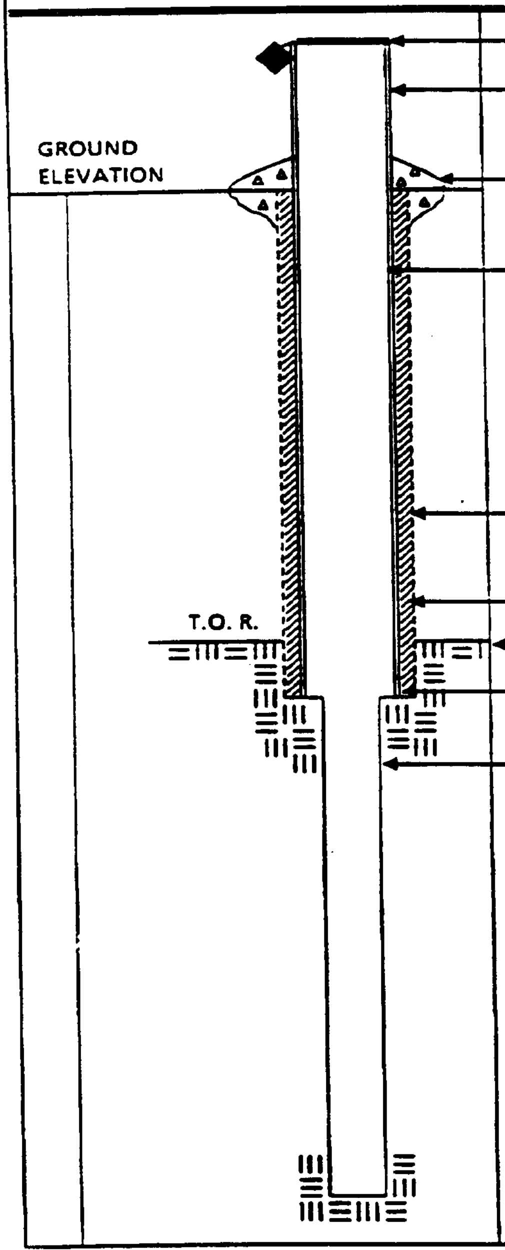
ATTACHMENT C-7
EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL

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: ______ / ______

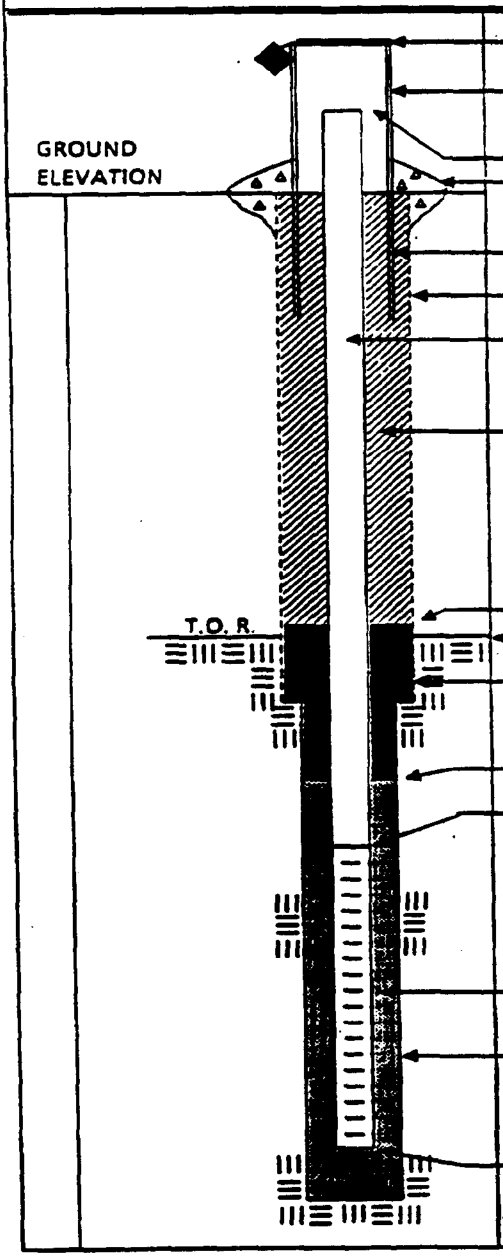
ATTACHMENT C-8
EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK

BORING NO.: ____________

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

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

DRILLER ____________
DRILLING METHOD ____________
DEVELOPMENT METHOD ____________



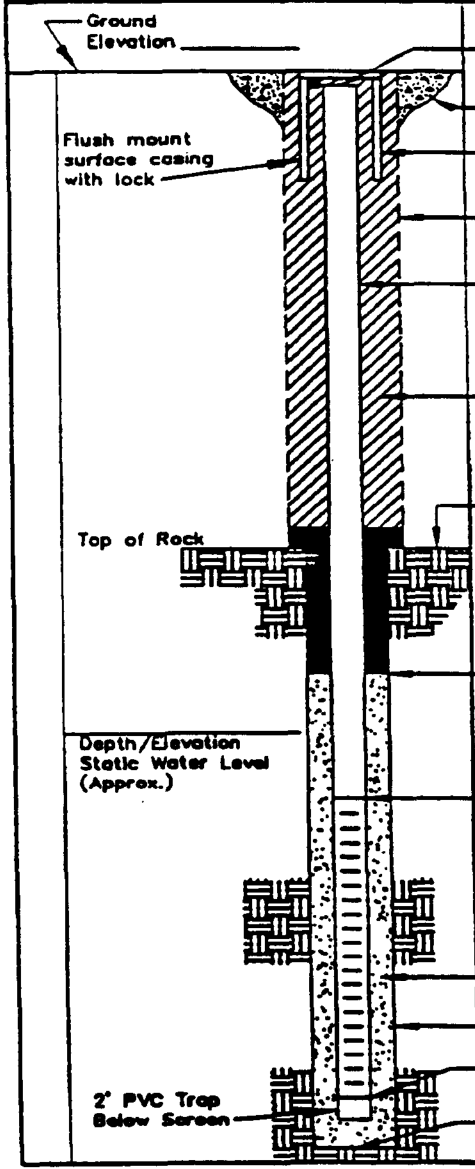
ELEVATION OF TOP OF SURFACE CASING: ____________
STICK UP OF CASING ABOVE GROUND SURFACE: ____________
ELEVATION TOP OF RISER: ____________
TYPE OF SURFACE SEAL: ____________
____
I.D. OF SURFACE CASING: ____________
DIAMETER OF HOLE: ____________
RISER PIPE I.D.: ____________
TYPE OF RISER PIPE: ____________
____
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

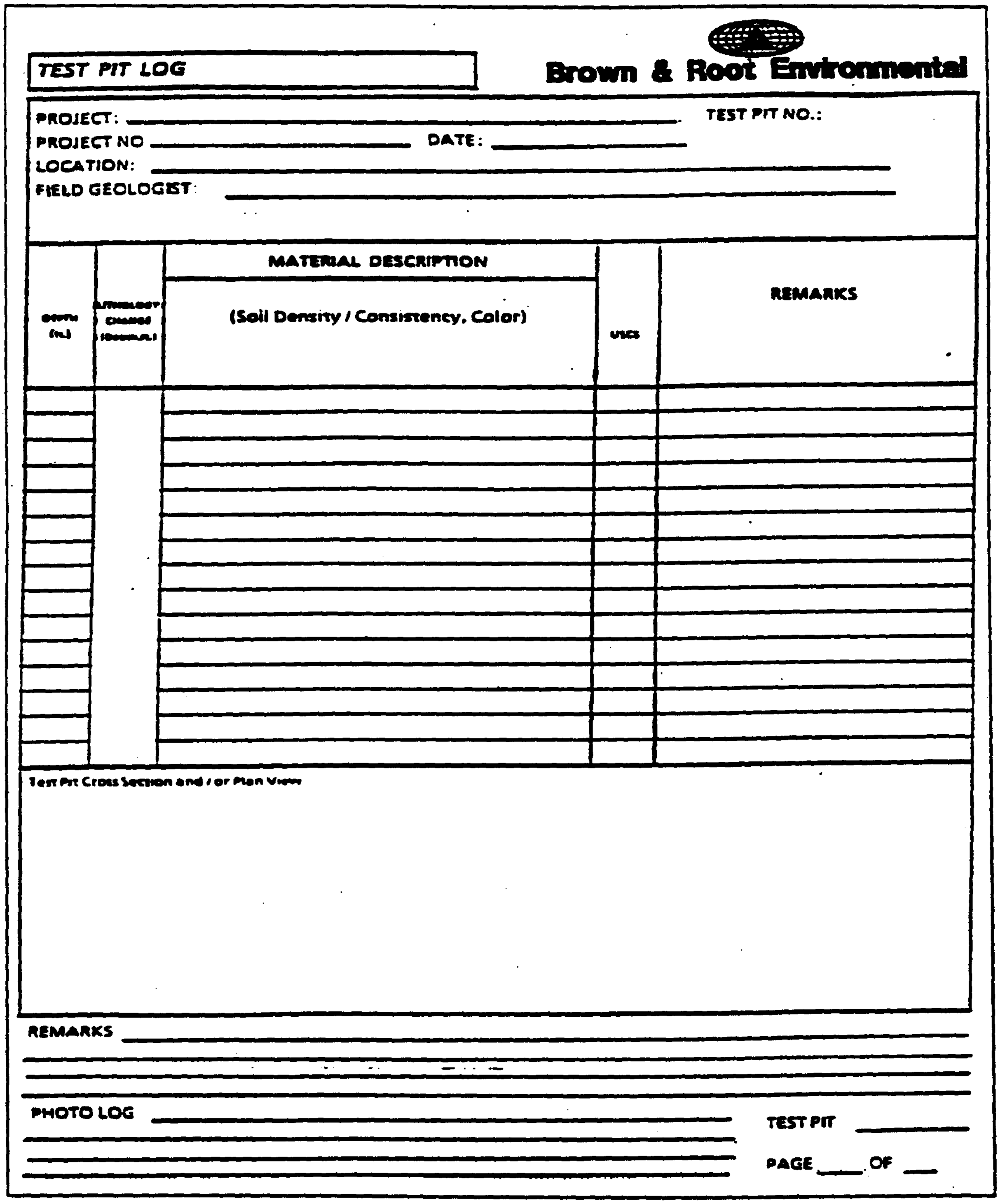
PROJECT: ____________ LOCATION: ____________
PROJECT NO.: ____________ BORING: ____________
ELEVATION: ____________ DATE: ____________
FIELD GEOLOGIST: ____________
DRILLER: ____________
DRILLING METHOD: ____________
DEVELOPMENT METHOD: ____________



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 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: [illegible]

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 : ____________________

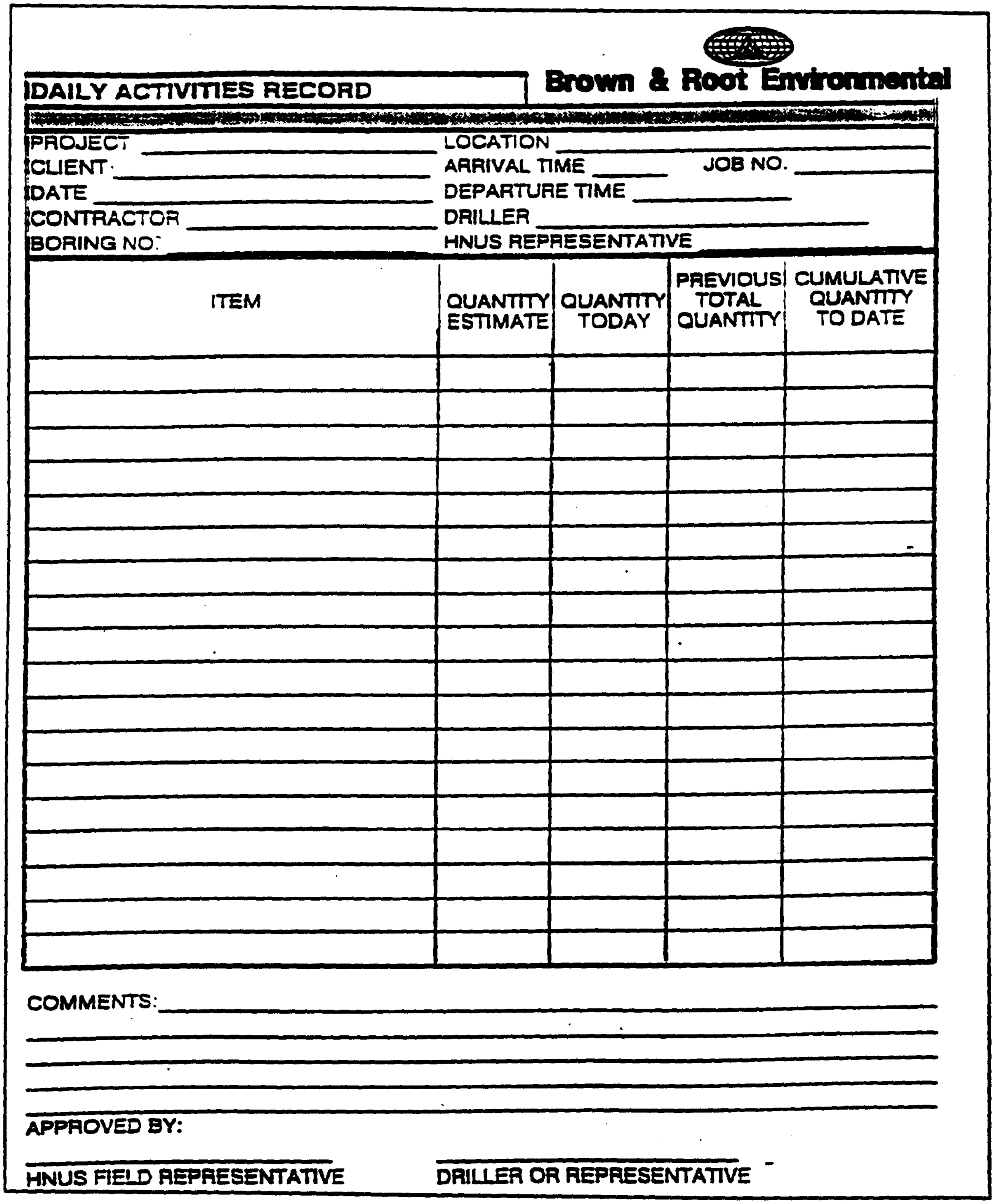
JOB NAME : ________________

MANUFACTURER : ____________________

JOB NUMBER : ________________

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

ATTACHMENT E
EXAMPLE DAILY ACTIVITIES RECORD



DAILY ACTIVITIES RECORD | **Brown & Root Environmental**

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: ____

TETRA TECH NUS	STANDARD OPERATING PROCEDURES	Number SA-7.1	Page 1 of 9
		Effective Date 01/21/97	Revision 1
		Applicability TETRA TECH NUS	
		Prepared Earth Sciences Department	
Subject	DECONTAMINATION OF FIELD EQUIPMENT AND WASTE HANDLING	Approved D. Senovich	

TABLE OF CONTENTS

ATTACHMENTS

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

Acid - For decontamination of equipment when sampling for trace levels of inorganics, a 10% solution of nitric acid in deionized water should be used. Due to the leaching ability of nitric acid, it should not be used on stainless steel.

Alconox/Liquinox - A brand of phosphate-free laboratory-grade detergent.

Deionized Water - Deionized (analyte free) water is tap water that has been treated by passing through a standard deionizing resin column. Deionized water should contain no detectable heavy metals or other inorganic compounds at or above the analytical detection limits for the project.

Potable Water - Tap water used from any municipal water treatment system. Use of an untreated potable water supply is not an acceptable substitute for tap water.

Solvent - The solvent of choice is pesticide-grade Isopropanol. Use of other solvents (methanol, acetone, pesticide-grade hexane, or petroleum ether) may be required for particular projects or for a particular purpose (e.g. for the removal of concentrated waste) and must be justified in the project planning documents. As an example, it may be necessary to use hexane when analyzing for trace levels of pesticides, PCBs, or fuels. In addition, because many of these solvents are not miscible in water, the equipment should be air dried prior to use. Solvents should not be used on PVC equipment or well construction materials.

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 off site.

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
- Pesticide-grade isopropanol (unless otherwise required)
- Pesticide-grade hexane rinse[**]
- Copious distilled/Deionized water rinse
- Air dry

If sampling for volatile organic compounds (VOCs) only, the nitric acid, isopropanol, and hexane rinses may be omitted. Only reagent grade or purer solvents are to be used for decontamination. When solvents are 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.

---

[*] 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.

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

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.

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
- Pesticide-grade isopropanol (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.

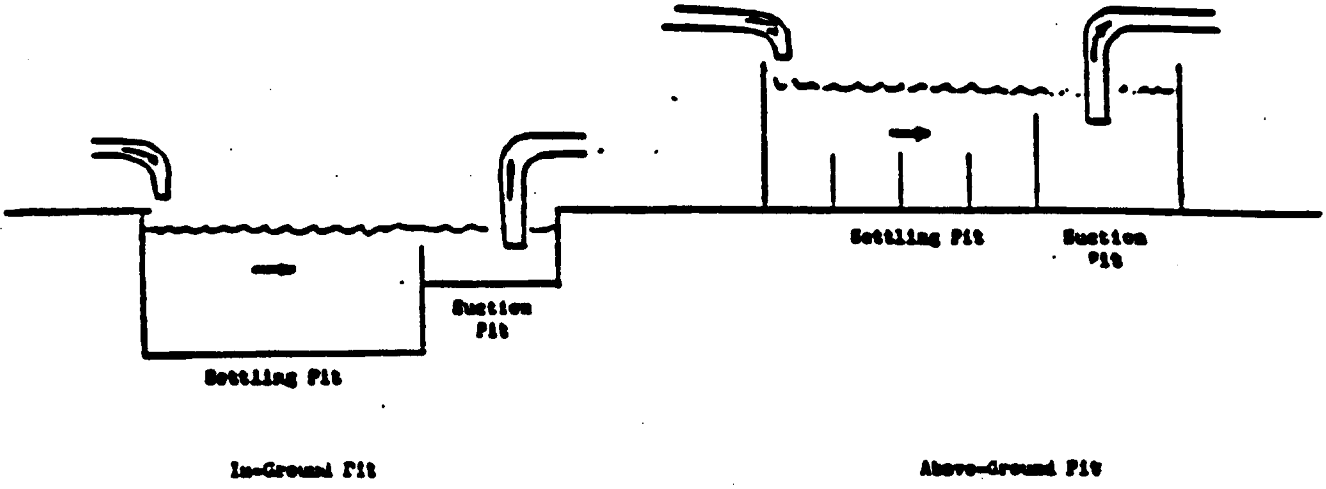
Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation 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



TETRA TECH NUS	STANDARD OPERATING PROCEDURES	Number GH-1.2	Page 1 of 9
		Effective Date 03/01/96	Revision 0
		Applicability TETRA TECH NUS	
		Prepared Earth Sciences Department	
Subject	EVALUATION OF EXISTING MONITORING WELLS AND WATER LEVEL MEASUREMENT	Approved D. Senovich	

TABLE OF CONTENTS

SECTION **PAGE**

ATTACHMENTS

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: ____________________
PROJECT NUMBER: ____________________
PERSONNEL: ____________________
DATE: ____________________
WEATHER CONDITIONS: ____________________

LOCATION: ____________________
MEASURING DEVICE: ____________________
ADJUSTMENT FACTOR: ____________________
REMARKS: ____________________

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): ____________________

TETRA TECH NUS	**STANDARD OPERATING PROCEDURES**	Number SA-1.1	Page 1 of 27
		Effective Date 03/01/96	Revision 3
		Applicability TETRA TECH NUS	
		Prepared Earth Sciences Department	
Subject GROUNDWATER SAMPLE ACQUISITION AND ONSITE WATER QUALITY TESTING		Approved D. Senovich	

TABLE OF CONTENTS

SECTION PAGE

ATTACHMENTS

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.

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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 volume	$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

Subject	Number	Page
GROUNDWATER SAMPLE ACQUISITION AND ONSITE WATER QUALITY TESTING	SA-1.1	27 of 27
	Revision	**Effective Date**
	3	03/01/96

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.

TETRA TECH NUS	**STANDARD OPERATING PROCEDURES**	Number ME-12	Page 1 of 21
		Effective Date 05/01/96	Revision 0
		Applicability TETRA TECH NUS	
		Prepared Health Sciences Department	
Subject	PHOTOVAC 2020 PHOTOIONIZATION AIR MONITOR	Approved D. Senovich	

TABLE OF CONTENTS

TABLE OF CONTENTS

FIGURES

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.

<u>Health and Safety Officer (HSO)</u> - 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).

<u>Site Safety Officer (SSO)</u> - 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 <u>Principle of Operation</u>

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

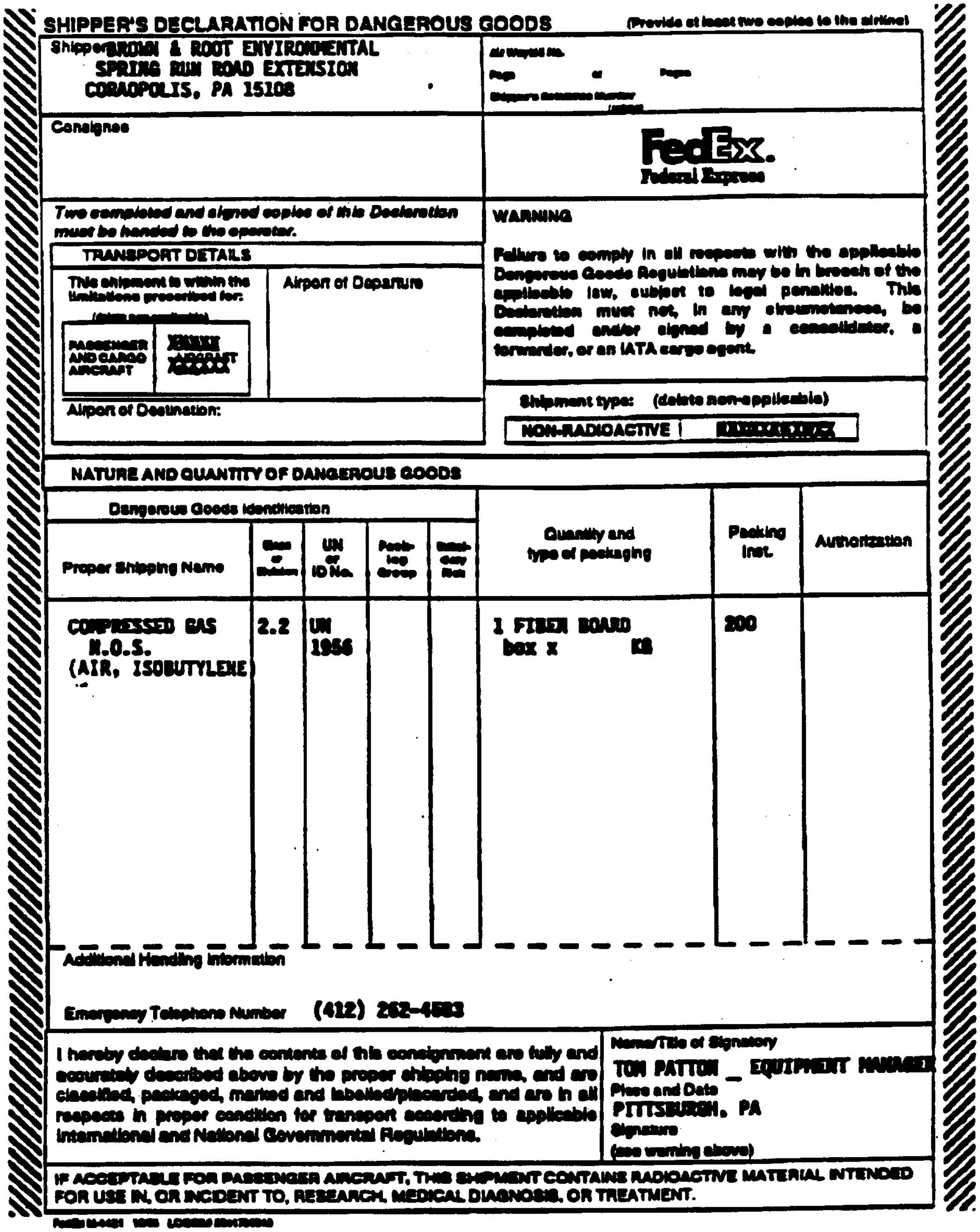
The Photovac may be shipped as cargo or carried on as luggage providing there is no calibration gas cylinder accompanying the kit. When shipping or transporting the calibration gas, a Hazardous Airbill including the information as stipulated in Figure 7-1 will be entered.

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 Reference 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	XXXXX AIRCRAFT XXXXXX

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	XXXXXXXXXXX

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
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.

[illegible]

BROWN & ROOT ENVIRONMENTAL	**STANDARD OPERATING PROCEDURES**	Number GH-1.3	Page 1 of 26
		Effective Date 03/01/96	Revision 0
		Applicability B&R Environmental, NE	
		Prepared Earth Sciences Department	
Subject SOIL AND ROCK DRILLING METHODS		Approved D. Senovich	

TABLE OF CONTENTS

ATTACHMENT

FIGURE

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 constructio 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.

BROWN & ROOT ENVIRONMENTAL	**STANDARD OPERATING PROCEDURES**	**Number** GH-1.5	**Page** 1 of 21
		Effective Date 03/01/96	**Revision** 0
		Applicability B&R Environmental, NE	
		Prepared Earth Sciences Department	
Subject BOREHOLE AND SAMPLE LOGGING		**Approved** D. Senovich	

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

FIGURES

1.0 PURPOSE

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

2.0 SCOPE

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

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

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

5.0 PROCEDURES

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

5.1 Materials Needed

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

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

5.2 Classification of Soils

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

5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure 1 (Continued).

FIGURE 1

BORING LOG (EXAMPLE)

BORING LOG

Page ___ of ___

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			USCS*	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole**	Driller BZ

* 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. #: ______________

FIGURE 1 (CONTINUED)

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 MCL)	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)				GROUP SYMBOL	TYPICAL NAMES
Identification Procedures on Fraction Smaller than No. 40 Sieve Size					
	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 penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
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 BROKENNESS

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-NX (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

This method of classification identifies soil types on the basis of grain size and cohesiveness.

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

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

5.2.2 Color

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

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

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

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

5.2.3 Relative Density and Consistency

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

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

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

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140-pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure 2.

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength), or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are shown in Figure 2.

FIGURE 2

CONSISTENCY FOR COHESIVE SOILS

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

5.2.4 Weight Percentages

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

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
Trace	0 - 10 percent
Some	11 - 30 percent
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

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

5.2.5 Moisture

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

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

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Figure 3.

5.2.7 Texture/Fabric/Bedding

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

FIGURE 3

BEDDING THICKNESS CLASSIFICATION

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

(Weir, 1973 and Ingram, 1954)

5.2.8 Summary of Soil Classification

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

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

5.3 Classification of Rocks

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

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.

- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.

- Claystone - Very fine-grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.

- Shale - A fissile very fine-grained rock. Fractures along bedding planes.

- Limestone - Rock made up predominantly of calcite ($CaCO_3$). Effervesces strongly upon the application of dilute hydrochloric acid.

- Coal - Rock consisting mainly of organic remains.

- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

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

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

5.3.1 Rock Type

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

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

5.3.2 Color

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

Rock color charts shall not be used unless specified by the Project Manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification (see Figure 3) will also be used for rock classification.

5.3.4 Hardness

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

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

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

FIGURE 4

GRAIN SIZE CLASSIFICATION FOR ROCKS

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

After Wentworth, 1922

5.3.5 Fracturing

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

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

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

Method of Calculating RQD
(After Deere, 1964)

$$\text{RQD \%} = r/l \times 100$$

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

l = Total length of the coring run.

5.3.6 Weathering

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

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.

- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.

- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.

- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified).

- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic).
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

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

5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inches or less), probably continuous layer.

- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."

- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."

- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."

- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

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

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.

- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.

- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.

- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.

- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse-grained dark igneous rock.

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

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

5.4 Abbreviations

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

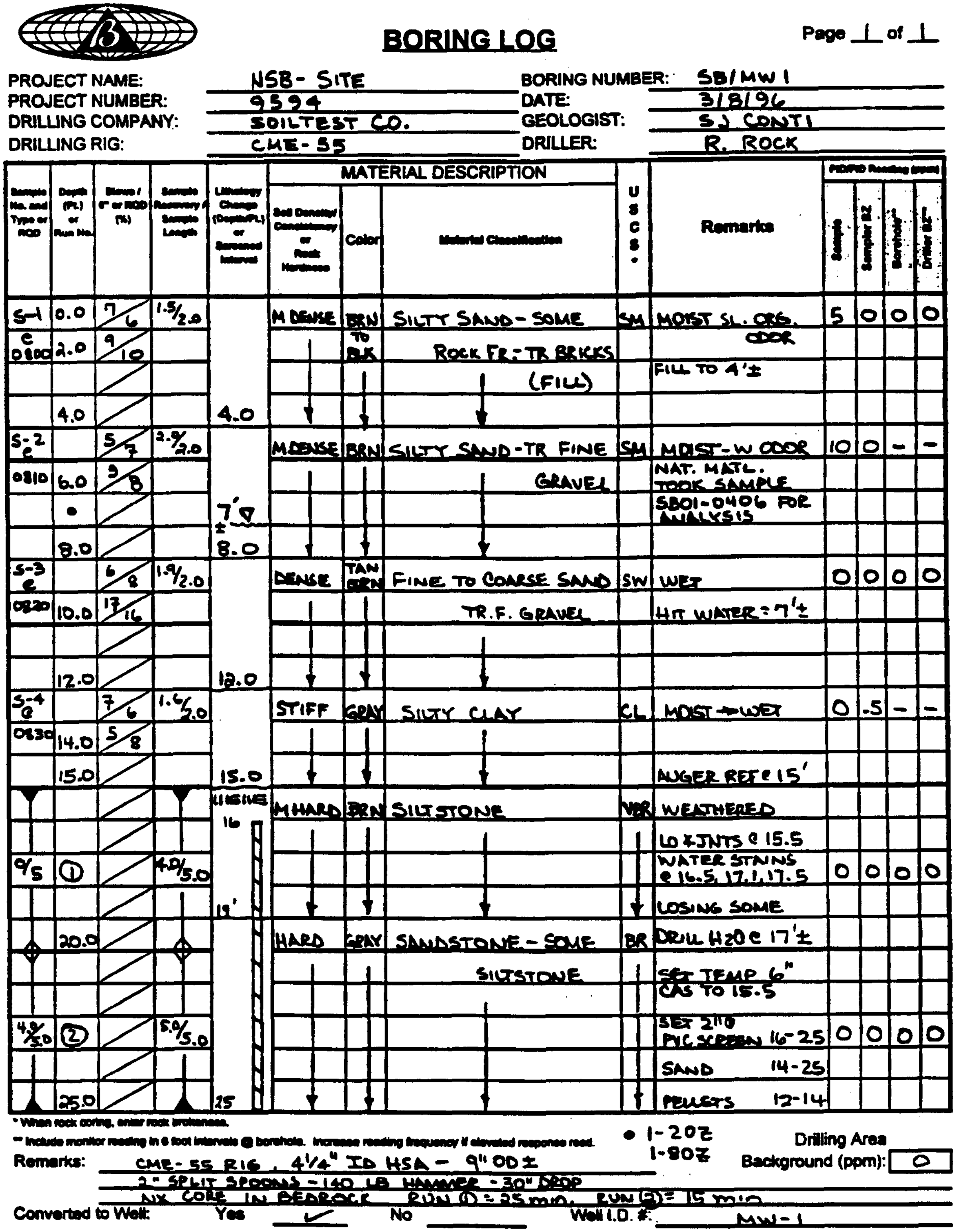
C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine-grained
Tr - Trace		

5.5 Boring Logs and Documentation

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Figure 5.

The field geologist/engineer shall use this example as a guide in completing each boring log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the back of the boring log or on a separate sheet, for field use.

FIGURE 5
COMPLETED BORING LOG (EXAMPLE)



BORING LOG

Page 1 of 1

PROJECT NAME: NSB- SITE
PROJECT NUMBER: 9594
DRILLING COMPANY: SOILTEST CO.
DRILLING RIG: CME-55
BORING NUMBER: SB/MW 1
DATE: 3/8/96
GEOLOGIST: SJ CONTI
DRILLER: R. ROCK

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			USCS *	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole**	Driller BZ
S-1	0.0	7/6	1.5/2.0		M DENSE	BRN	SILTY SAND - SOME	SM	MOIST SL. ORG.	5	0	0	0
@ 0800	2.0	9/10				TO BLK	ROCK FR. - TR BRICKS		ODOR				
							(FILL)		FILL TO 4'±				
	4.0			4.0	↓	↓	↓						
S-2 @		5/7	2.9/2.0		M DENSE	BRN	SILTY SAND - TR FINE	SM	MOIST - W ODOR	10	0	-	-
0810	6.0	9/8					GRAVEL		NAT. MATL. TOOK SAMPLE				
	•			7' ▽ ±					SB01-0406 FOR ANALYSIS				
	8.0			8.0	↓	↓	↓						
S-3 @		6/8	1.9/2.0		DENSE	TAN BRN	FINE TO COARSE SAND	SW	WET	0	0	0	0
0820	10.0	17/16					TR. F. GRAVEL		HIT WATER @ 7'±				
	12.0			12.0	↓	↓	↓						
S-4 @		7/6	1.6/2.0		STIFF	GRAY	SILTY CLAY	CL	MOIST → WET	0	.5	-	-
0830	14.0	5/8											
	15.0			15.0	↓	↓	↓		AUGER REF @ 15'				
					M HARD	BRN	SILTSTONE	VBR	WEATHERED				
				16					LO ∠ JNTS @ 15.5				
9/5	①		4.0/5.0						WATER STAINS @ 16.5, 17.1, 17.5	0	0	0	0
				19'	↓	↓	↓	↓	LOSING SOME				
	20.0				HARD	GRAY	SANDSTONE - SOME	BR	DRILL H2O @ 17'±				
							SILTSTONE		SET TEMP 6" CAS TO 15.5				
4.8/5.0	②		5.0/5.0						SET 2" Ø PVC SCREEN 16-25	0	0	0	0
									SAND 14-25				
	25.0			25	↓	↓	↓	↓	PELLETS 12-14				

* When rock coring, enter rock brokenness.

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

• 1-2OZ
1-8OZ

Drilling Area Background (ppm): 0

Remarks: CME-55 RIG, 4¼" ID HSA - 9" OD ±
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP
NX CORE IN BEDROCK RUN ① = 25 min. RUN ② = 15 min.

Converted to Well: Yes ✓ No ______ Well I.D. #: MW-1

5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.

- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology at 13.7 feet, shall be lined off at the proportional location between the 13- and 14-foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.

- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split-spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.

- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.

- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart on back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.

- Enter color of the material in the appropriate column.

- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:

- Trace:	0 - 10 percent
- Some:	11 - 30 percent
- And/Or:	31 - 50 percent

- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.

- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.

- The following information shall be entered under the "Remarks" column and shall include, but is not limited by, the following:

    - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.

  - Angularity - describe angularity of coarse grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
  - Particle shape - flat, elongated, or flat and elongated.
  - Maximum particle size or dimension.
  - Water level observations.
  - Reaction with HCl - none, weak, or strong.

- Additional comments:
  - Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
  - Indicate odor and Photoionization Detector (PID) or Flame Ionization Detector (FID) reading if applicable.
  - Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.
  - At the bottom of the page indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).
  - Vertical lines shall be drawn (as shown in Figure 5) in columns 6 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
  - Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 Rock Classification

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent, and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.

- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.

- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.

- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:

    - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.

    - Indicate calcareous zones, description of any cavities or vugs.

    - Indicate any loss or gain of drill water.

    - Indicate drop of drill tools or change in color of drill water.

- Remarks at the bottom of Boring Log shall include:

    - Type and size of core obtained.

    - Depth casing was set.

    - Type of rig used.

- As a final check the boring log shall include the following:

    - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.

    - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.3 Classification of Soil and Rock from Drill Cuttings

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

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock" bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.). Cuttings shall be closely examined to determine general lithology.

- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Figure 1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 Review

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

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

6.0 REFERENCES

Unified Soil Classification System (USCS).

ASTM D2488, 1985.

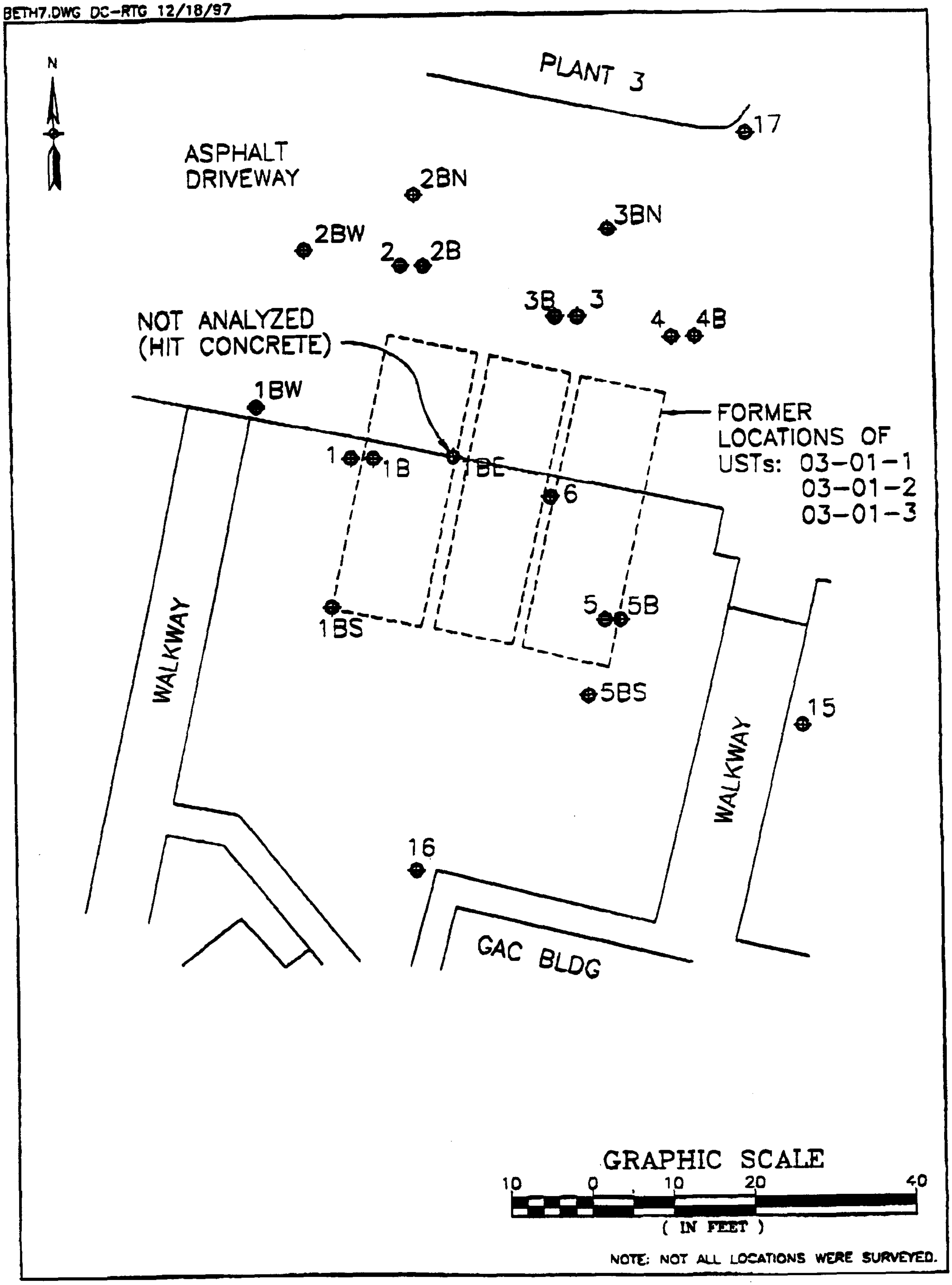
Earth Manual, U.S. Department of the Interior, 1974.

7.0 RECORDS

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

APPENDIX B

PREVIOUS INVESTIGATIVE DATA



NOTE: NOT ALL LOCATIONS WERE SURVEYED.

AOC 22 Samples

BACKGROUND REPORT

AREA OF CONCERN #22, UNDERGROUND STORAGE TANKS

This report includes information on the below ground tanks (numbered UST 03-01-1, UST 03-01-2, UST 03-01-3) that have been used to store various petroleum products at the plant 3 area of concern (AOC) #22. Figure 15 shows the location of the three under ground storage tanks (USTs) previously located at AOC #22.

Information contained within this report was compiled utilizing the first available Grumman Aerospace Corporation (GAC) Spill Prevention, Control and Countermeasures (SPCC) Plan dated 1979, past GAC correspondences, and interviews with site personnel.

The three (3) USTs in question were installed in 1941 and located along the southwest corner of plant 3 (Figure 15). The construction of each tank was of steel with asphaltic coating and each tank retained a maximum volume of 25,000 gallons (Table #1).

Table #1
Northrop Grumman Corporation
Bethpage Complex
Area of Concern #22 Oil Storage Tanks

Tank #	Location	Contents	Gallons	Material of Construction
03-01-1	Plant 3 - AOC # 22	Fuel Oils #6, #4	25,000	Steel - Asphaltic Coating
03-01-2	Plant 3 - AOC # 22	Fuel Oils #6, #4	25,000	Steel - Asphaltic Coating
03-01-3	Plant 3 - AOC # 22	Fuel Oils #6, #4	25,000	Steel - Asphaltic Coating

Prior to construction of the Central Steam Plant, Plant 3, located at the GAC Bethpage Facility, was equipped with several boilers for generating steam. Initially USTs 03-01-1, 03-01-2, 03-01-3 stored #6 fuel oil used to fire these boilers. The above tanks served this role for 25 years until 1966 when the Central Steam Plant was put on-line and connected to plant 3. At that time the conventional heating system and associated boilers were abandoned and heat for Plant 3 was then generated through the Central Steam Plant. Thus, the above tanks were no longer used to store #6 fuel oil.

Subsequently, these oil storage tanks were used to store reserve quantities of #4 fuel oil. The lighter #4 fuel oil was stored in reserve instead of #6 fuel oil because tanks storing #6 fuel oil would have to be heated. In an emergency, lighter #4 oil could be pumped out of the reserve tanks trucked to the desired location and used to fire boilers which normally burned #6 fuel oil.

It is believed tanks 03-01-1, 03-01-2, and 03-01-3 served as reserve #4 fuel oil tanks until approximately1980-1984 when they were removed. Due to the fact that the tanks in question were listed in the 1979 SPCC plan but not referred to in the next consecutive SPCC plan, which was prepared in 1985, it is concluded that the tanks were removed no later than 1984 and no earlier than 1980. Records describing the closure activities for the tanks in question are not available; however, their removal has been verified through statements made by site personnel present during the removal and a negative magnetometer study of AOC #22 performed during Radian Internationals 1997 Phase II Study of Plant 3.

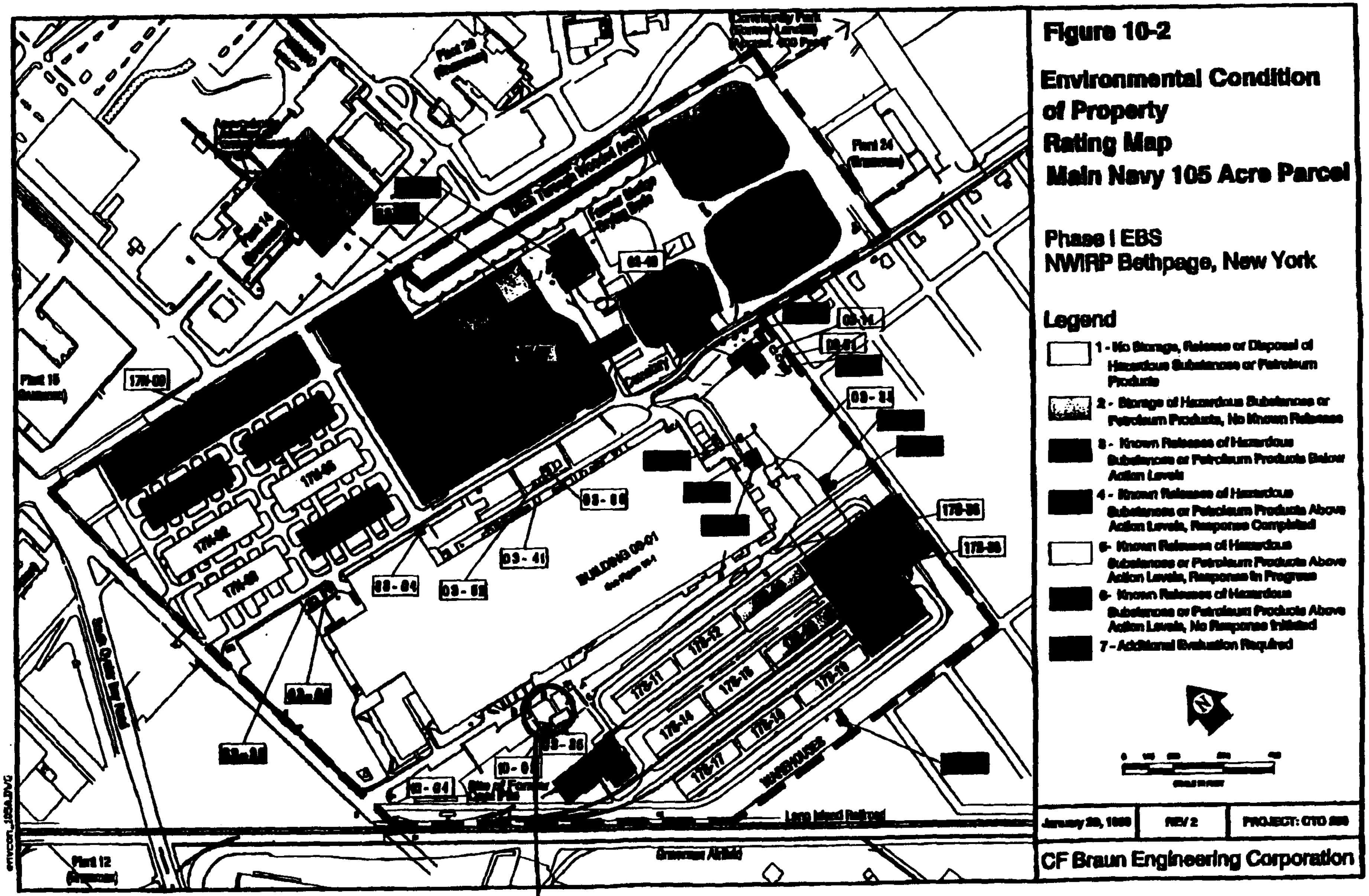


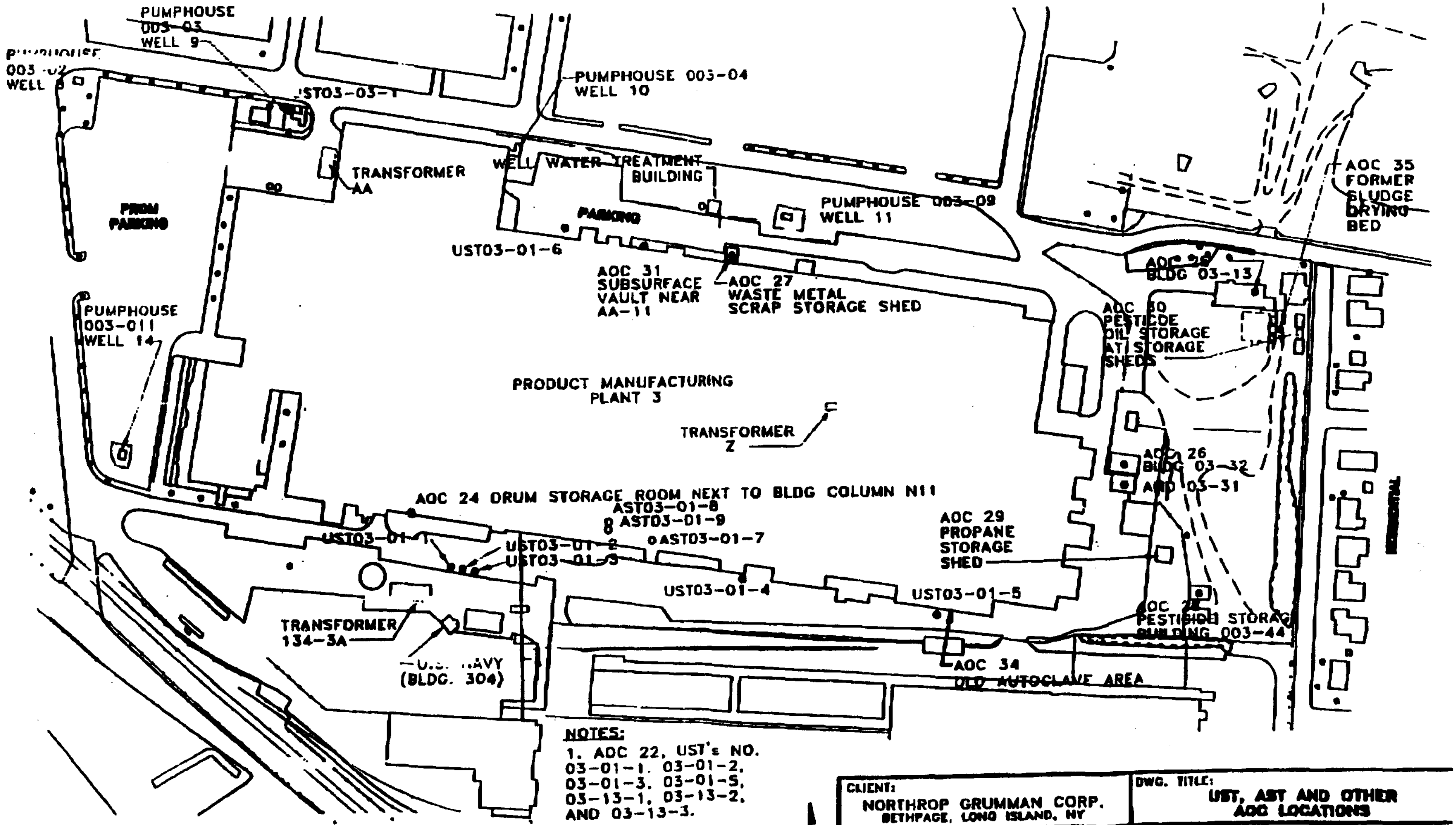
Figure 10-2

Environmental Condition of Property Rating Map Main Navy 105 Acre Parcel

Phase I EBS
NWIRP Bethpage, New York

CF Braun Engineering Corporation

AOC 22



NOTES:

1. AOC 22, UST's NO. 03-01-1, 03-01-2, 03-01-3, 03-01-5, 03-13-1, 03-13-2, AND 03-13-3.
2. SEE FIGURE 18 FOR UST's AND AST's AT ROADS AND GROUNDS BUILDING.

CLIENT: NORTHROP GRUMMAN CORP.
BETHPAGE, LONG ISLAND, NY

RADIAN INTERNATIONAL
FAIRFIELD, NEW JERSEY

DWG. TITLE: UST, AST AND OTHER AOC LOCATIONS

DRAWN BY: DTD
DATE: MAR 1997
FIGURE: 15
PROJECT No.: 002704-3003
SCALE: NONE
FILE NUMBER: 2704

Sample ID		03-22-01-S5		03-22-02-S4		03-22-03-S6		03-22-04-S4		03-22-05-S4		03-22-06-S4		03-22-07-S1		03-22-07-S2		03-22-08-S1		03-22-08-S2		03-22-11-S1		03-22-11-S2		03-22-12-S1		03-22-12-S2	
AOC	NYSDEC	22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Soil Cleanup	18-20		14-16		16-18		14-16		14-16		14-16		8-10		10-12		8-10		10-12		8-10		10-12		8-10		10-12	
Date Collected	Objective (a)	6/5/97		6/5/97		6/5/97		6/5/97		6/5/97		6/5/97		5/12/97		5/12/97		5/12/97		5/12/97		5/13/97		5/13/97		5/30/97		5/30/97	
Volatile Organics (ug/kg)																													
Acetone	200	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	12		10	U	13	U	10	UJ	14	UJ
Benzene	60	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Bromodichloromethane	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Bromoform	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Bromomethane	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
2-Butanone	300	11	U	11	U	51	U	10	U	11	U	11	U	10	UJ	10	UJ	10	UJ	10	UJ	10	U	13	U	10	UJ	14	UJ
Carbon Disulfide	2700	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Carbon tetrachloride	600	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Chlorbenzene	1700	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Chloroethane	1900	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Chloroform	300	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Chloromethane	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Dibromochloromethane	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,1-Dichloroethane	200	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,2-Dichloroethane	100	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,1-Dichloroethene	400	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,2-Dichloroethene (total)	300	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,2-Dichloropropene	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
ciS1,3-Dichloropropene	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
tranS1,3-Dichloropropene	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Ethylbenzene	5500	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
2-Hexanone	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	UJ	10	UJ	10	UJ	10	UJ	10	U	13	U	10	UJ	14	UJ
4-Methyl-2-pentanone	1000	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Methylene chloride	100	2	J	4	J	8	J	2	J	2	J	1	J	4	U	1	U	1	U	2	U	10	U	1		10	U	14	U
Styrene	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,1,2,2-Tetrachloroethane	600	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Tetrachloroethene	1400	4	J	3	J	51	U	6	J	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Toluene	1500	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
1,1,1-Trichloroethane	800	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	UJ	14	UJ
1,1,2-Trichloroethane	NL	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Trichloroethene	700	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Vinyl chloride	200	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Total Xylenes	1200	11	U	11	U	51	U	10	U	11	U	11	U	10	U	10	U	10	U	10	U	10	U	13	U	10	U	14	U
Total VOCs	10000	6		7		8		8		2		1		0		0		0		12		0		1		0		0	
Petroleum Hydrocarbons (mg/kg)																													
TPH (as Gasoline)	NL	6.1		3.6	J	5	U	5	U	5	U			5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TPH (as *Diesel*)	NL	4800		2500		11000		330		73				4	U	4	U	17		66		4	U	17		4	U	4	U

Sample ID	NYSDEC	03-22-01A-S1		03-22-01A-S2		03-22-01A-S3		03-22-01BSS1		03-22-01BSS2		03-22-01BSS3		03-22-01BSS4		03-22-01BSS5		03-22-01BSS6		03-22-01BSS7		03-22-01BSS8		03-22-01BSS9		03-22-01BSS10		03-22-01BSS11		03-22-01BSS12		03-22-01BSS13		03-22-01BSS14	
AOC	STARS	22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	8-10		10-12		12-14		8-10		10-12		12-14		14-16		16-18		18-20		20-22		22-24		24-26		28-30		30-32		32-34		34-36		36-38	
Date Collected	Value (a)	8/4/97		8/4/97		8/4/97		10/23/97		10/23/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97		10/24/97	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	2	U	2	U	2	U	2.2	U	1.8	U	2.2	U	2.2	U	2.2	U	2.2	U	2	U	2	U	2	UJ	2.2	UJ	2.6	UJ	2.2	U	2.4	UJ	2	U
n-Butylbenzene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
sec-Butylbenzene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
tert-Butylbenzene	NL	1	UJ	1	UJ	1	UJ	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
Ethylbenzene	8000000	2	U	2	U	2	U	2.2	U	1.8	U	2.2	UJ	2.2	UJ	2.2	UJ	2.2	UJ	2	UJ	2	UJ	2	UJ	2.2	UJ	2.6	UJ	2.2	UJ	2.4	UJ	2	UJ
Isopropylbenzene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	U	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
p-Isopropyltoluene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
Methy t-butyl ether	NL	1	U	1	U	1	U	2.2	U	1.8	U	2.2	U	2.2	U	2.2	U	2.2	U	2	U	2	U	2	UJ	2.2	UJ	2.6	UJ	2.2	U	2.4	UJ	2	U
Naphthalene	300000	1	U	1	U	1	U	1.9		1.2		1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
n-Propylbenzene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
Toluene	20000000	2	U	2	U	2	U	2.2	U	1.8	U	2.2	U	2.2	U	2.2	U	2.2	U	2	U	2	U	2	UJ	2.2	UJ	2.6	UJ	2.2	U	2.4	UJ	2	U
1,2,4-Trimethylbenzene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
1,3,5-Trimethylbenzene	NL	1	U	1	U	1	U	1.1	U	0.89	U	1.1	UJ	1.1	UJ	1.1	UJ	1.1	UJ	0.98	UJ	1	UJ	1	UJ	1.1	UJ	1.3	UJ	1.1	UJ	1.2	UJ	0.99	UJ
Total Xylenes	200000000	2	U	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
m-Xylene	200000000	2	U	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
o-Xylene	200000000	2	U	2	U	2	U	2.2	U	1.8	U	2.2	U	2.2	U	2.2	U	2.2	U	2	U	2	U	2	U	2.2	U	2.6	U	2.2	U	2.4	U	2	U
m- & p-Xylene	200000000	NA		NA		NA		2.2	U	1.8	U	2.2	U	2.2	U	2.2	U	2.2	U	2	U	2	U	2	U	2.2	U	2.6	U	2.2	U	2.4	U	2	U
p-Xylene	NL	2	U	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	340	UJ	340	UJ	350	UJ	3600	U	1800	U	720	U	360	U	3600	U	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Anthracene	20000000	340	UJ	340	UJ	350	UJ	3600	U	1800	U	720	U	360	U	3600	U	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Benz(a)anthracene	220	340	UJ	340	UJ	350	UJ	3600	U	1800	U	720	U	360	U	3600	U	1100	U	3500	U	240	J	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Benzo(a)pyrene	61	340	UJ	340	UJ	350	UJ	3600	U	680	J	680	J	360	U	1300	J	1100	U	3500	U	450	J	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Benzo(b)fluoroanthene	220	340	UJ	340	UJ	350	UJ	3600	U	1800	U	380	J	360	U	630	J	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Benzo(g,h,i)perylene	NL	340	UJ	340	UJ	350	UJ	3600	U	410	J	1100		360	U	3600	U	1100	U	3500	U	780	J	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Benzo(k)fluoroanthene	220	340	UJ	340	UJ	350	UJ	3600	U	1800	U	380	J	360	U	470	J	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Chrysene	NL	340	UJ	340	UJ	350	UJ	3600	U	1800	U	1300		360	U	1400	J	1100	U	960	J	800	J	1100	U	390	J	1300	J	3600	U	3700	U	3700	U
Dibenz(a,h)anthracene	14	340	UJ	340	UJ	350	UJ	3600	U	1800	U	250	J	360	U	3600	U	1100	U	3500	U	450	J	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Fluoranthene	3000000	620	J	340	UJ	350	UJ	3600	U	1800	U	720	U	360	U	3600	U	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Fluorene	3000000	340	UJ	340	UJ	350	UJ	3600	U	1800	U	720	U	360	U	3600	U	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Indeno (1,2,3-cd)pyrene	NL	340	UJ	340	UJ	350	UJ	3600	U	1800	U	300	J	360	U	3600	U	1100	U	3500	U	360	J	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Phenanthrene	NL	340	UJ	340	UJ	350	UJ	3600	U	1800	U	720	U	360	U	3600	U	1100	U	3500	U	1800	U	1100	U	1100	U	3800	U	3600	U	3700	U	3700	U
Pyrene	2000000	1000	J	340	UJ	350	UJ	3600	U	1800	U	210	J	360	U	3600	U	1100	U	3500	U	1800	U	1100	U	140	J	950	J	3600	U	3700	U	3700	U
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(b)fluoroanthene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(g,h,i)perylene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Chrysene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Flouroanthene	0.05	0.04	U	0.04	U	0.04	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Naphthalene	0.01	NA		NA		NA		0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U
Phenanthrene	0.05	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	NC		NC		NC		5	U	5	U	5	UJ	5	UJ	5	UJ	5	U	5	U	5	U	5	U	0.058	J	0.3	J	0.051	J	0.057	J	0.068	J
TPH (as Diesel)	NL	NC		NC		NC		630		500		2800		49		2300		520	J	1400	J	1300	J	620	J	2900	J	3900	J	1600	J	4100	J	1400	J

Sample ID	NYSDEC	03-22-01BSS15		03-22-01BSS16		03-22-01BSS17		03-22-01BSS18		03-22-01BSS19		03-22-01BSS20		03-22-01BSS21		03-22-01BW-S1		03-22-01BW-S2		03-22-01BW-S3		03-22-01BW-S4		03-22-01BW-S5		03-22-01BW-S6		03-22-01BW-S7		03-22-01BW-S8		03-22-01BW-S9		03-22-02A-S1	
AOC	STARS	22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	38-40		40-42		45-46.5		50-51.5		55-57		60-62		65-67		8-10		10-12		12-14		14-16		16-18		18-20		20-22		22-24		24-26		6-8	
Date Collected	Value (a)	10/24/97		11/4/97		11/4/97		11/4/97		11/4/97		11/4/97		11/4/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		8/4/97	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	3.8	U	2.4	U	2.2	U	2.4	U	9.6	U	150	J	9.8	U	2	U	1.9	U	2	U	5	U	2.2	U	2	U	2.2	U	1.9	U	2	U	2	U
n-Butylbenzene	NL	1.9	UJ	1.2	U	1.1	U	1.2	U	4.8	U	6.1	U	270	J	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
sec-Butylbenzene	NL	1.9	UJ	1.2	U	1.1	U	5.8	J	72	J	6.1	U	88	J	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
tert-Butylbenzene	NL	1.9	UJ	1.2	U	1.1	U	1.2	U	4.8	U	6.1	U	4.9	U	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	UJ
Ethylbenzene	8000000	3.8	UJ	2.4	U	2.2	U	2.4	U	9.6	U	1900	DNR	720	J	2	UJ	1.9	UJ	2	UJ	5	UJ	2.2	UJ	2	UJ	2.2	UJ	1.9	UJ	2	UJ	2	U
Isopropylbenzene	NL	1.9	UJ	1.2	U	1.1	U	1.3	J	54	J	210	J	79	J	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
p-Isopropyltoluene	NL	1.9	UJ	1.2	U	1.1	U	1.2	U	4.8	U	6.1	U	4.9	U	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
Methy t-butyl ether	NL	3.8	U	2.4	U	2.2	U	2.4	U	9.6	U	12	U	9.8	U	2	U	1.9	U	2	U	5	U	2.2	U	2	U	2.2	U	1.9	U	2	U	1	U
Naphthalene	300000	1.9	UJ	1.2	U	1.1	U	1.2	U	69	J	310	J	90	J	1.1	J	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
n-Propylbenzene	NL	1.9	UJ	1.2	U	1.1	U	58	J	240	J	610	J	350	J	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
Toluene	20000000	3.8	U	2.4	U	2.2	U	2.4	U	9.6	U	12	U	9.8	U	2	U	1.9	U	2	U	5	U	2.2	U	2	U	2.2	U	1.9	U	2	U	2	U
1,2,4-Trimethylbenzene	NL	1.9	UJ	1.2	U	1.1	U	1.2	U	4.8	U	6.1	U	4.9	U	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
1,3,5-Trimethylbenzene	NL	1.9	UJ	1.2	U	1.1	U	1.2	U	220	J	500	J	4.9	U	0.99	UJ	0.95	UJ	0.99	UJ	2.5	UJ	1.1	UJ	1	UJ	1.1	UJ	0.97	UJ	1	UJ	1	U
Total Xylenes	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U
m-Xylene	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U
o-Xylene	200000000	3.8	U	2.4	U	2.2	U	2.4	U	9.6	U	63	J	19	J	2	U	1.9	U	2	U	5	U	2.2	U	2	U	2.2	U	1.9	U	2	U	2	U
m- & p-Xylene	200000000	3.8	U	2.4	U	2.2	U	2.4	U	9.6	U	12	U	9.8	U	2	U	1.9	U	2	U	5	U	2.2	U	2	U	2.2	U	1.9	U	2	U	NA	
p-Xylene	NL	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	U	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Anthracene	20000000	3700	U	7300	U	3500	U	3500	U	2200	J	5100	J	480	J	690	U	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Benz(a)anthracene	220	3700	U	7300	U	3500	U	1000	J	2500	J	4300	J	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Benzo(a)pyrene	61	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Benzo(b)fluoroanthene	220	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Benzo(g,h,i)perylene	NL	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Benzo(k)fluoroanthene	220	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Chrysene	NL	3700	U	7300	U	990	J	1400	J	5000	J	6900	J	3900	U	340	J	340	U	420	J	1400	J	420	J	600	J	710	J	120	J	340	U	340	U
Dibenz(a,h)anthracene	14	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Fluoranthene	3000000	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	U	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Fluorene	3000000	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	U	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Indeno (1,2,3-cd)pyrene	NL	3700	U	7300	U	3500	U	3500	U	14000	U	18000	U	3900	U	690	UJ	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Phenanthrene	NL	3700	U	7300	U	3500	U	540	J	11000	J	25000		2600	J	690	U	340	U	1000	U	3500	U	1700	U	1800	U	1700	U	340	U	340	U	340	U
Pyrene	2000000	3700	U	7300	U	1100	J	4200		8200	J	17000	J	1600	J	690	UJ	340	U	190	J	2200	J	260	J	530	J	910	J	39	J	340	U	340	U
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Benzo(a)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Benzo(b)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Benzo(g,h,i)perylene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Benzo(k)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Chrysene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Dibenz(a,h)anthracene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Flouroanthene	0.05	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.04	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Naphthalene	0.01	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.015	J	0.02	J	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	NA	
Phenanthrene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	0.052	J	2.5	J	5	U	14	J	110	J	190	J	29	J	5	U	5	U	5	U	0.1	J	5	U	0.08	J	5	U	5	U	5	U	NC	
TPH (as Diesel)	NL	2500	J	5500	J	1800	J	3600	J	5900	J	18000	J	2800	J	510		4	U	1000		6800		2700		1200		5800		260		27		NC	

Sample ID	NYSDEC	03-22-02A-S2		03-22-02A-S3		03-22-02B-S1		03-22-02B-S2		03-22-02B-S4		03-22-02B-S5		03-22-02B-S6		03-22-02B-S7		03-22-02B-S8		03-22-02B-S9		03-22-02B-S10		03-22-02B-S11		03-22-02B-S12		03-22-02B-S13		03-22-02B-S14		03-22-02B-S15		03-22-02BN-S1	
AOC	STARS	22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	8-10		10-12		8-10		10-12		14-16		16-18		18-20		20-22		22-24		24-26		26-28		28-30		30-32		32-34		34-36		36-38		8-10	
Date Collected	Value (a)	8/4/97		8/4/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/16/97		10/15/97		10/15/97	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	2	U	2	U	2	U	2	U	2.2	U	2.4	U	2.2	U	2	U	2.2	U	2.2	U	10	U	11	U	2	U	9	U	2.2	U	2	U	2.2	U
n-Butylbenzene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
sec-Butylbenzene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
tert-Butylbenzene	NL	1	UJ	1	UJ	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
Ethylbenzene	8000000	2	U	2	U	2	UJ	2	UJ	2.2	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	UJ	2.2	UJ	10	UJ	11	UJ	2	UJ	9	UJ	2.2	UJ	2	UJ	2.2	UJ
Isopropylbenzene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
p-Isopropyltoluene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
Methy t-butyl ether	NL	1	U	1	U	2	U	2	U	2.2	U	2.4	U	2.2	U	2	U	2.2	U	2.2	U	10	U	11	U	2	U	9	U	2.2	U	2	U	2.2	U
Naphthalene	300000	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
n-Propylbenzene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
Toluene	20000000	2	U	1.2	J	2	UJ	2	UJ	2.2	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	UJ	2.2	UJ	10	UJ	11	UJ	2	UJ	9	UJ	2.2	UJ	2	UJ	2.2	U
1,2,4-Trimethylbenzene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
1,3,5-Trimethylbenzene	NL	1	U	1	U	1	UJ	1	UJ	1.1	UJ	1.2	UJ	1.1	UJ	0.99	UJ	1.1	UJ	1.1	UJ	5.2	UJ	5.4	UJ	1	UJ	4.5	UJ	1.1	UJ	1	UJ	1.1	UJ
Total Xylenes	200000000	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
m-Xylene	200000000	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
o-Xylene	200000000	2	U	2	U	2	UJ	2	UJ	2.2	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	UJ	2.2	UJ	10	UJ	11	UJ	2	UJ	9	UJ	2.2	UJ	2	UJ	2.2	UJ
m- & p-Xylene	200000000	NA		NA		2	UJ	2	UJ	2.2	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	UJ	2.2	UJ	10	UJ	11	UJ	2	UJ	9	UJ	2.2	UJ	2	UJ	2.2	UJ
p-Xylene	NL	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Anthracene	20000000	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Benz(a)anthracene	220	340	U	330	U	340	U	350	U	410		350	U	350	U	700	U	700	U	3600	U	1800	J	780	J	740	U	490	J	3600	U	3600	U	400	U
Benzo(a)pyrene	61	340	U	330	U	340	U	330	J	1400		350	U	87	J	130	J	140	J	3600	U	1600	J	880	J	740	U	1400	J	670	J	870	J	400	U
Benzo(b)fluoroanthene	220	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Benzo(g,h,i)perylene	NL	340	U	330	U	340	U	540		360	U	280	J	350	U	270	J	390	J	3600	U	1400	J	1200	J	240	J	1000	J	1100	J	1500	J	400	U
Benzo(k)fluoroanthene	220	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Chrysene	NL	340	U	330	U	340	U	350	U	1000		350	U	350	U	700	U	700	U	1300	J	3800		2200	J	740	U	2100	J	1100	J	1900	J	400	U
Dibenz(a,h)anthracene	14	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Fluoranthene	3000000	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Fluorene	3000000	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Indeno (1,2,3-cd)pyrene	NL	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Phenanthrene	NL	340	U	330	U	340	U	350	U	360	U	350	U	350	U	700	U	700	U	3600	U	3400	U	3600	U	740	U	3600	U	3600	U	3600	U	400	U
Pyrene	2000000	340	U	330	U	340	U	350	U	1700		350	U	350	U	700	U	700	U	1100	J	11000		5000		240	J	4900		1200	J	2700	J	400	U
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	UJ
Benzo(b)fluoroanthene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	UJ
Benzo(g,h,i)perylene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	UJ
Chrysene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	UJ
Flouroanthene	0.05	0.04	U	0.04	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	UJ
Naphthalene	0.01	NA		NA		0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U
Phenanthrene	0.05	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	NC		NC		5	UJ	5	UJ	5	UJ	5	UJ	5	UJ	5	UJ	5	UJ	0.098	J	0.11	J	0.1	J	5	UJ	5	UJ	5	UJ	5	UJ	5	U
TPH (as Diesel)	NL	NC		NC		7.5		490		10000		300		450		220		550		2200		7100		5100		330		6400		2400		3900		4.6	

Sample ID	NYSDEC	03-22-02BN-S2		03-22-02BN-S3		03-22-02BN-S4		03-22-02BN-S5		03-22-02BN-S6		03-22-02BN-S7		03-22-02BW-S1		03-22-02BW-S2		03-22-02BW-S3		03-22-02BW-S4		03-22-02BW-S5		03-22-02BW-S6		03-22-02BW-S7		03-22-03A-S1		03-22-03A-S2		03-22-03A-S3		03-22-04A-S1	
AOC	STARS	22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	10-12		12-14		14-16		16-18		18-20		20-22		8-10		10-12		12-14		14-16		16-18		18-20		20-22		8-10		10-12		12-14		6-8	
Date Collected	Value (a)	10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		10/15/97		8/4/97		8/4/97		8/4/97		8/4/97	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	2	U	2.2	U	2.6	U	2.4	U	2.2	U	2	U	2.2	U	2	U	2.2	U	2.2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U
n-Butylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
sec-Butylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
tert-Butylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	UJ	1	UJ	1	UJ	1	UJ
Ethylbenzene	8000000	2	UJ	2.2	UJ	2.6	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	UJ	2	UJ	2.2	UJ	2.2	UJ	2	UJ	2	UJ	2	UJ	2	U	2	U	2	U	2	U
Isopropylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
p-Isopropyltoluene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
Methy t-butyl ether	NL	2	U	2.2	U	2.6	U	2.4	U	2.2	U	2	U	2.2	U	2	U	2.2	U	2.2	U	2	U	2	U	2	U	1	U	1	U	1	U	1	U
Naphthalene	300000	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.2	J	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	3.1		3.2	
n-Propylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
Toluene	20000000	2	U	2.2	U	2.6	U	2.4	U	2.2	U	2	UJ	2.2	U	2	U	2.2	U	2.2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U
1,2,4-Trimethylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
1,3,5-Trimethylbenzene	NL	0.99	UJ	1.1	UJ	1.3	UJ	1.2	UJ	1.1	UJ	1	UJ	1.1	UJ	0.98	UJ	1.1	UJ	1.1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	U	1	U	1	U
Total Xylenes	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U	2	U	2	U	2	U
m-Xylene	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U	2	U	2	U	2	U
o-Xylene	200000000	2	UJ	2.2	UJ	2.6	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	U	2	U	2.2	U	2.2	UJ	2	UJ	2	UJ	2	UJ	2	U	2	U	2	U	2	U
m- & p-Xylene	200000000	2	UJ	2.2	UJ	2.6	UJ	2.4	UJ	2.2	UJ	2	UJ	2.2	U	2	U	2.2	U	2.2	UJ	2	UJ	2	UJ	2	UJ	NA		NA		NA		NA	
p-Xylene	NL	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U	2	U	2	U	2	U
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	360	U	350	U	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	330	U	330	U	350	U
Anthracene	20000000	360	U	350	U	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	100	J	330	U	350	U
Benz(a)anthracene	220	360	U	350	UJ	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	200	J	1700	U	340	U	340	U	330	U	840		68	J	110	J
Benzo(a)pyrene	61	360	UJ	350	UJ	360	U	730	U	350	U	200	J	340	U	340	U	3500	U	360	J	1700	U	340	U	340	U	330	U	510		330	UJ	350	UJ
Benzo(b)fluoranthene	220	360	UJ	350	UJ	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	840		330	UJ	170	J
Benzo(g,h,i)perylene	NL	360	U	350	UJ	360	U	730	U	350	U	3600	UJ	340	U	340	U	3500	U	950	J	1700	U	150	J	340	U	330	U	180	J	330	UJ	350	U
Benzo(k)fluoranthene	220	360	UJ	350	UJ	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	450		330	UJ	86	J
Chrysene	NL	360	U	350	UJ	360	U	450	J	350	U	170	J	340	U	340	U	3500	U	340	J	500	J	72	J	340	U	330	U	740		330	UJ	97	J
Dibenz(a,h)anthracene	14	360	UJ	350	UJ	360	U	730	U	350	U	3600	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	82	J	330	UJ	350	UJ
Fluoranthene	3000000	360	U	350	U	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	1600		330	U	71	J
Fluorene	3000000	360	U	350	U	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	330	U	330	U	350	U
Indeno (1,2,3-cd)pyrene	NL	360	UJ	350	UJ	360	U	730	U	350	U	3600	UJ	340	U	340	U	3500	U	210	J	1700	U	86	J	340	U	330	U	230	J	330	UJ	350	UJ
Phenanthrene	NL	360	U	350	U	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	1700	U	340	U	340	U	330	U	330		330	U	350	U
Pyrene	2000000	360	U	350	UJ	360	U	730	U	350	U	360	UJ	340	U	340	U	3500	U	1800	U	330	J	340	U	340	U							100	J
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Benzo(a)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Benzo(b)fluoranthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Benzo(g,h,i)perylene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Benzo(k)fluoranthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Chrysene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Dibenz(a,h)anthracene	0.05	0.05	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Flouranthene	0.05	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.04	U	0.04	U	0.04	U	0.04	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	UJ	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Naphthalene	0.01	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0	U	0	U	0	U	0.03	U	0.03	U	0.03	U	0.03	U	NA		NA		NA		NA	
Phenanthrene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.1	U	0.1	U	0.1	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.04	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0	U	0	U	0	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	5	U	5	U	5	U	0.053	J	5	UJ	5	UJ	5	U	5	U	5	U	5	U	5	U	5	U	NC		NC		NC		NC		NC	
TPH (as Diesel)	NL	4	U	630		130		9.2		430		1400		4.6		2200		7		870		550		310		NC		NC		NC		NC		NC	

Sample ID	NYSDEC	03-22-04A-S2		03-22-04A-S3		03-22-04B-S1		03-22-04B-S2		03-22-04B-S3		03-22-04B-S4		03-22-04B-S5		03-22-04B-S6		03-22-04B-S7		03-22-05A-S1		03-22-05A-S2		03-22-05A-S3		03-22-05BSS1		03-22-05BSS2		03-22-05BSS3		03-22-05BSS4		03-22-05BSS5	
AOC	STARS	22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	8-10		10-12		8-10		10-12		12-14		14-16		16-18		18-20		20-22		6-8		8-10		10-12		8-10		10-12		12-14		14-16		16-18	
Date Collected	Value (a)	8/4/97		8/4/97		10/21/97		10/21/97		10/21/97		10/21/97		10/21/97		10/21/97		10/21/97		8/4/97		8/4/97		8/4/97		10/21/97		10/21/97		10/21/97		10/21/97		10/21/97	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	2	U	2	U	2.4	U	2.2	U	1.9	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	UJ	2	UJ	2.2	U	1.8	U	2.2	U	2.2	U	1.8	U
n-Butylbenzene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	1	UJ	1	UJ	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
sec-Butylbenzene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	1	UJ	1	UJ	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
tert-Butylbenzene	NL	1	UJ	1	UJ	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	UJ	1	UJ	1	UJ	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
Ethylbenzene	8000000	2	U	2	U	2.4	U	2.2	U	1.9	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	UJ	2	UJ	2.2	U	1.8	U	2.2	U	2.2	U	1.8	U
Isopropylbenzene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	1	UJ	1	U/R	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
p-Isopropyltoluene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	1	UJ	1.3	J	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
Methy t-butyl ether	NL	1	U	1	U	2.4	U	2.2	U	1.9	U	2.2	U	2.2	U	2	U	2.2	U	1	U	1	UJ	1	UJ	2.2	U	1.8	U	2.2	U	2.2	U	1.8	U
Naphthalene	300000	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	2.8	J	3.2	J	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
n-Propylbenzene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	4.2		4.3	J	1.5	J	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
Toluene	20000000	2	U	2	U	6.3		2.2	U	1.9	U	2.2	U	2.2	U	2	U	2.2	U	2	U	1.2	J/UJ	0.78	J	2.2	U	1.8	U	2.2	U	2.2	U	1.8	U
1,2,4-Trimethylbenzene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	1	UJ	1	UJ	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
1,3,5-Trimethylbenzene	NL	1	U	1	U	1.2	U	1.1	U	0.94	U	1.1	U	1.1	U	0.99	U	1.1	U	1	U	1	UJ	1	UJ	1.1	U	0.89	U	1.1	U	1.1	U	0.92	U
Total Xylenes	200000000	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		2	U	1	J	2	UJ	NA		NA		NA		NA		NA	
m-Xylene	200000000	2	U	2	U	NA		NA		NA		NA		NA		NA		NA		2	U	2	UJ	2	UJ	NA		NA		NA		NA		NA	
o-Xylene	200000000	2	U	2	U	2.4	U	2.2	U	1.9	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	UJ	2	UJ	2.2	U	1.8	U	2.2	U	2.2	U	1.8	U
m- & p-Xylene	200000000	NA		NA		2.4	U	2.2	U	1.9	U	2.2	U	2.2	U	2	U	2.2	U	NA		NA		NA		2.2	U	1.8	U	2.2	U	2.2	U	1.8	U
p-Xylene	NL	2	U	-2	U															2	U	2	U/R	2	UJ	NA		NA		NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	360	U	330	U	350	U	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	17	J	350	U	340	U	360	U	340	U	340	U
Anthracene	20000000	360	U	330	U	350	U	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	39	J	350	U	340	U	52	J	340	U	340	U
Benz(a)anthracene	220	360	U	44	J	140	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	170	J	81	J	340	U	130	J	340	U	340	U
Benzo(a)pyrene	61	360	U	330	U	130	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	170	J	62	J	340	U	110	J	340	U	340	U
Benzo(b)fluoroanthene	220	360	U	330	U	110	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	250	J	48	J	340	U	110	J	340	U	340	U
Benzo(g,h,i)perylene	NL	360	U	330	U	110	J	340	U	350	U	350	U	3500	U	410	J	710	J	340	UJ	340	U	77	J	350	U	340	U	110	J	340	U	340	U
Benzo(k)fluoroanthene	220	360	U	330	U	120	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	150	J	63	J	340	U	130	J	340	U	340	U
Chrysene	NL	360	U	57	J	140	J	340	U	350	U	350	U	440	J	700	U	480	J	340	UJ	340	U	200	J	73	J	340	U	150	J	340	U	340	U
Dibenz(a,h)anthracene	14	360	U	330	U	350	U	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	18	J	350	U	340	U	360	U	340	U	340	U
Fluoranthene	3000000	360	U	51	J	190	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	330	J	130	J	340	U	220	J	340	U	340	U
Fluorene	3000000	360	U	330	U	350	U	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	350	U	350	U	340	U	360	U	340	U	340	U
Indeno (1,2,3-cd)pyrene	NL	360	U	330	U	100	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	99	J	350	U	340	U	90	J	340	U	340	U
Phenanthrene	NL	360	U	40	J	96	J	340	U	350	U	350	U	3500	U	700	U	3400	U	340	UJ	340	U	200	J	82	J	340	U	190	J	340	U	340	U
Pyrene	2000000	360	U	61	J	180	J	340	U	350	U	350	U	690	J	700	U	3400	U	340	UJ	340	U	340	J	130	J	340	U	240	J	340	U	340	U
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U/R	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U/R	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(b)fluoroanthene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(g,h,i)perylene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Chrysene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Flouroanthene	0.05	0.04	U	0.04	U	0.045	U	0.045	U	0.045	U/R	0.045	U	0.045	U	0.045	U	0.045	U	0.04	U	0.04	U	0.04	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U/R	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Naphthalene	0.01	NA		NA		0.03	U	0.03	U	0.03	U/R	0.03	U	0.03	U	0.03	U	0.03	U	NA		NA		NA		0.03	U	0.03	U	0.03	U	0.03	U	0.03	U
Phenanthrene	0.05	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U/R	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U/R	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	NC		NC		0.28	J	5	UJ	0.075	J	5	U	5	U	5	U	5	U	NC		NC		NC		5	U	5	U	5	U	5	U	5	U
TPH (as Diesel)	NL	NC		NC		4	U	4	U	2900		4.5		4100		190		380		NC		NC		NC		86		5.7		18		32		37	

Sample ID	**NYSDEC**	**03-22-05BSS6**		**03-22-05BSS7**		**03-22-05BSS8**		**03-22-05BSS9**		**03-22-05BSS10**		**03-22-05BSS11**		**03-22-05BS12**		**03-22-05BS13**		**03-22-05BS14**		**03-22-05BS15**		**03-22-05BS16**		**03-22-05BSS17**		**03-22-05BSS18**		**03-22-05BSS19**		**03-22-06A-S1**		**03-22-06A-S2**		**03-22-06A-S3**	
AOC	**STARS**	**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**		**22**	
Depth (Feet BGS)	**Guidance**	**18-20**		**20-22**		**22-24**		**24-26**		**26-28**		**28-30**		**30-32**		**34-34**		**34-36**		**36-38**		**38-40**		**40-42**		**42-44**		**44-46**		**6-8**		**8-10**		**10-12**	
Date Collected	**Value (a)**	**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/21/97**		**10/23/97**		**10/23/97**		**10/23/97**		**8/4/97**		**8/4/97**		**8/4/97**	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	1.9	U	2	U	4.2	U	4.8	U	2	U	2.6	U	2	U	2.2	U	6.8	U	2.4	U	2.6	U	2.2	U	2	U	1.9	U	2	U	2	U	2	U
n-Butylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	21		1	U	1	U	1	U
sec-Butylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	7.8		1	U	1	U	1	U
tert-Butylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	0.96	U	1	UJ	1	UJ	1	UJ
Ethylbenzene	6000000	1.9	U	2	U	4.2	U	4.8	U	2	U	2.6	U	2	U	2.2	U	6.8	U	2.4	U	2.6	U	2.2	U	2	U	1.9	U	2	U	2	U	2	U
Isopropylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	1.9		1	U	1	U	1	U
p-Isopropyltoluene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	0.96	U	1	U	1	U	1	U
Methy t-butyl ether	NL	1.9	U	2	U	4.2	U	4.8	U	2	U	2.6	U	2	U	2.2	U	6.8	U	2.4	U	2.6	U	2.2	U	2	U	1.9	U	1	U	1	U	1	U
Naphthalene	300000	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	UJ	1.1	UJ	3.4	UJ	1.2	UJ	1.3	UJ	1.1	U	1	U	350	U/R	1	U	1	U	1	U
n-Propylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	2.8		1	U	6.1		5.2	
Toluene	20000000	1.9	U	2	U	4.2	U	4.8	U	9.3		6.8		2	U	2.2	U	6.8	U	2.4	U	2.6	U	2.2	U	2	U	1.9	U	2	U	2	U	2	U
1,2,4-Trimethylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	0.96	U	1	U	1	U	1	U
1,3,5-Trimethylbenzene	NL	0.94	U	1	U	2.1	U	2.4	U	0.99	U	1.3	U	0.98	U	1.1	U	3.4	U	1.2	U	1.3	U	1.1	U	1	U	0.96	U	1	U	1	U	1	U
Total Xylenes	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U	2	U	2	U
m-Xylene	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U	2	U	2	U
o-Xylene	200000000	1.9	U	2	U	4.2	U	4.8	U	2	U	2.6	U	2	U	2.2	U	6.8	U	2.4	U	2.6	U	2.2	U	2	U	1.9	U	2	U	2	U	2	U
m- & p-Xylene	200000000	1.9	U	2	U	4.2	U	4.8	U	2	U	2.6	U	2	U	2.2	U	6.8	U	2.4	U	2.6	U	2.2	U	2	U	1.9	U	NA		NA		NA	
p-Xylene	NL	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		2	U	2	U	2	U
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Anthracene	20000000	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Benz(a)anthracene	220	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	48	J	360	UJ	350	UJ	360	UJ
Benzo(a)pyrene	61	2200	J	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	630	J	64	J	360	UJ	350	UJ	360	UJ
Benzo(b)fluoroanthene	220	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Benzo(g,h,i)perylene	NL	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	410	J	3600	U	210	J	360	UJ	350	UJ	360	UJ
Benzo(k)fluoroanthene	220	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Chrysene	NL	1400	J	3600	U	1200	J	450	J	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	180	J	3600	U	110	J	360	UJ	350	UJ	360	UJ
Dibenz(a,h)anthracene	14	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Fluoranthene	3000000	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Fluorene	3000000	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Indeno (1,2,3-cd)pyrene	NL	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Phenanthrene	NL	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	350	U/R	360	UJ	350	UJ	360	UJ
Pyrene	2000000	7000	U	3600	U	3400	U	4200	U	1800	U	2200	U	1900	U	3600	U	3700	U	3700	U	3700	U	1800	U	3600	U	320	J	360	UJ	350	UJ	360	UJ
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Benzo(a)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Benzo(b)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Benzo(g,h,i)perylene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Benzo(k)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Chrysene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Dibenz(a,h)anthracene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Flouroanthene	0.05	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.04	U	0.04	U	0.04	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.45	U	0.45	U	0.45	U
Indeno (1,2,3-cd)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Naphthalene	0.01	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	NA		NA		NA	
Phenanthrene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.04	U	0.04	U	0.04	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	5	U	5	U	0.072	J	0.13	J	5	U	5	U	0.058	J	5	U	0.064	J	5	U	5	U	5	U	5	U	2.1	J	NC		NC		NC	
TPH (as Diesel)	NL	4100		3300		5300		2000		580		1700		720		800		2000		4500		620		1600		770		2300		NC		NC		NC	

Sample ID	NYSDEC	03-22-08A-S1		03-22-08A-S2		03-22-08A-S3		03-22-11A-S1		03-22-11A-S2		03-22-11A-S3		03-22-15-S1		03-22-15-S2		03-22-15-S3	
AOC	STARS	22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	2-4		4-6		6-8		2-4		4-6		6-8		10-12		15-17		20-22	
Date Collected	Value (a)	8/4/97		8/4/97		8/4/97		8/4/97		8/4/97		8/4/97		11/4/97		11/5/97		11/5/97	
STARS Volatile Organics - Total (ug/kg)																			
Benzene	24000	2	U	2	U	2	U	2	U	2	U	2	U	1.8	U	2	U	2	U
n-Butylbenzene	NL	1	U	1	U	1	U	1	U	1	U	1	U	0.92	U	1	U	1	U
sec-Butylbenzene	NL	1	U	1	U	1	U	1	U	1	U	1	U	0.92	U	1	U	1	U
tert-Butylbenzene	NL	1	UJ	1	UJ	1	UJ	1	UJ	1	U	1	UJ	0.92	U	1	U	1	U
Ethylbenzene	8000000	2	U	2	U	2	U	2	U	2	U	2	U	1.8	U	2	U	2	U
Isopropylbenzene	NL	1	U	1	U	1	U	1	U	1	U	1	U	0.92	U	1	U	1	U
p-Isopropyltoluene	NL	1	U	1	U	1	U	1	U	1.6		1	U	0.92	U	1	U	1	U
Methy t-butyl ether	NL	1	U	1	U	1	U	1	U	1	U	1	U	1.8	U	2	U	2	U
Naphthalene	300000	1	U	1	U	1	U	1.2		1	UJ	1.1		1.1	U	2.8	U	1.5	U
n-Propylbenzene	NL	1	U	1	U	1	U	1	U	1	U	1	U	0.92	U	1	U	1	U
Toluene	20000000	2	U	2	U	2	U	2	U	2	U	1.1	J	1.8	U	2	U	2	U
1,2,4-Trimethylbenzene	NL	1	U	1	U	1	U	1	U	1	U	1	U	0.92	U	1	U	1	U
1,3,5-Trimethylbenzene	NL	1	U	1	U	1	U	1	U	1	U	1	U	0.92	U	1	U	1	U
Total Xylenes	200000000	2	U	2	U	2	U	2	U	2	U	2	U	NA		NA		NA	
m-Xylene	200000000	2	U	2	U	2	U	2	U	2	U	2	U	NA		NA		NA	
o-Xylene	200000000	2	U	2	U	2	U	2	U	2	U	2	U	1.8	U	2	U	2	U
m- & p-Xylene	200000000	NA		NA		NA		NA		NA		NA		1.8	U	2	U	2	U
p-Xylene	NL	2	U/R	2	U/R	2	U/R	2	U/R	2	U/R	2	U/R	NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)																			
Acenaphthene	5000000	340	U	340	U	340	U	130	J	340	U	350	U	340	U	340	U	340	U
Anthracene	20000000	340	U	340	U	9.8	J	220	J	340	U	350	U	340	U	340	U	340	U
Benz(a)anthracene	220	23	J	340	U	100	J	760		340	U	350	U	340	U	340	U	340	U
Benzo(a)pyrene	61	32	J	340	U	100	J	720		340	U	350	U	340	U	340	U	340	U
Benzo(b)fluoroanthene	220	41	J	12	J	130	J	910		340	U	350	U	340	U	340	U	340	U
Benzo(g,h,i)perylene	NL	31	J	340	U	54	J	300	J	340	U	350	U	340	U	340	U	340	U
Benzo(k)fluoroanthene	220	24	J	6.1	J	72	J	450		340	U	350	U	340	U	340	U	340	U
Chrysene	NL	34	J	340	U	110	J	770		340	U	350	U	340	U	340	U	340	U
Dibenz(a,h)anthracene	14	3.9	J	340	U	12	J	64	J	340	U	350	U	340	U	340	U	340	U
Fluoranthene	3000000	340	U	340	U	150	J	800		340	U	350	U	340	U	340	U	340	U
Fluorene	3000000	340	U	340	U	340	U	380	U	340	U	350	U	340	U	340	U	340	U
Indeno (1,2,3-cd)pyrene	NL	33	J	340	U	69	J	400		340	U	350	U	340	U	340	U	340	U
Phenanthrene	NL	22	J	340	U	53	J	1400		340	U	350	U	340	U	340	U	340	U
Pyrene	2000000	340	U	340	U	160	J	1600		340	U	350	U	340	U	340	U	340	U
STARS Semivolatile Organics - TCLP (mg/L)																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Benzo(b)fluoroanthene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Benzo(g,h,i)perylene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Chrysene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Flouroanthene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.045	U	0.045	U	0.045	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Naphthalene	0.01	NA		NA		NA		NA		NA		NA		0.03	U	0.03	U	0.03	U
Phenanthrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	NC		NC		NC		NC		NC		NC		5	U	3	J	5	U
TPH (as Diesel)	NL	NC		NC		NC		NC		NC		NC		53	J	4	U	4	U

Sample ID	NYSDEC	03-22-16-S1		03-22-16-S2		03-22-16-S3		03-22-16-S4		03-22-16-S5		03-22-16-S6		03-22-16-S7		03-22-16-S8		03-22-16-S9		03-22-16-S10		03-22-16-S11		03-22-16-S12		03-22-17-S1		03-22-17-S2		03-22-17-S3		03-22-17-S4		03-22-17-S5	
AOC	STARS	22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	10-12		15-17		20-22		25-27		30-32		35-37		40-42		45-47		50-52		55-57		60-62		65-67		10-12		15-17		20-22		25-27		30-32	
Date Collected	Value (a)	11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/6/97		11/7/97		11/7/97	
STARS Volatile Organics - Total (ug/kg)																																			
Benzene	24000	2.2	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	U	2	U	2	U	11	U	39	J	9	U	2.2	U	2	U	2.2	U	2	U	2.2	U
n-Butylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	100		8	U	62		1.1	U	1	U	1.1	U	1	U	1.1	U
sec-Butylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	88		8	U	4.5	U	1.1	U	1	U	1.1	U	1	U	1.1	U
tert-Butylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	5.6	U	8	U	4.5	U	1.1	U	1	U	1.1	U	1	U	1.1	U
Ethylbenzene	8000000	2.2	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	U	2	U	2	U	260		1500	J	95		2.2	U	2	U	2.2	U	2	U	2.2	U
Isopropylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	17		110	J	6.2		1.1	U	1	U	1.1	U	1	U	1.1	U
p-Isopropyltoluene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	5.6	U	8	U	4.5	U	1.1	U	1	U	1.1	U	1	U	1.1	U
Methy t-butyl ether	NL	2.2	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	U	2	U	2	U	11	U	16	U	9	U	2.2	U	2	U	2.2	U	2	U	2.2	U
Naphthalene	300000	1.1	U	1.1	U	1.1	U	1.3	J	1.9	J	1.3	J	1.2	J	2.2	J	1	J	59	J	220	J	110	J	3.1	J	1.1	J	1.1	U	1	U	2	
n-Propylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	7.3		8	U	55		1.1	U	1	U	1.1	U	1	U	1.1	U
Toluene	20000000	2.2	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	U	2	U	2	U	11	U	16	U	9	U	2.2	U	2	U	2.2	U	2	U	2.2	U
1,2,4-Trimethylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	5.6	U	8	U	4.5	U	1.1	U	1	U	1.1	U	1	U	1.1	U
1,3,5-Trimethylbenzene	NL	1.1	U	1.1	U	1.1	U	1	U	1.1	U	1	U	1	U	1	U	1	U	110		500	J	4.5	U	1.1	U	1	U	1.1	U	1	U	1.1	U
Total Xylenes	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
m-Xylene	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
o-Xylene	200000000	2.2	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	U	2	U	2	U	11	U	75		9	U	2.2	U	2	U	2.2	U	2	U	2.2	U
m- & p-Xylene	200000000	2.2	U	2.2	U	2.2	U	2	U	2.2	U	2	U	2	U	2	U	2	U	11	U	23		9	U	2.2	U	2	U	2.2	U	2	U	2.2	U
p-Xylene	NL	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)																																			
Acenaphthene	5000000	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	1200	J	4100	J	170	J	360	U	340	U	350	U	340	U	340	U
Anthracene	20000000	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	1200	J	2800	J	150	J	360	U	340	U	350	U	340	U	340	U
Benz(a)anthracene	220	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	1100	J	400	J	220	J	360	U	340	U	350	U	340	U	340	U
Benzo(a)pyrene	61	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	760	J	2700	J	100	J	360	U	340	U	350	U	340	U	340	U
Benzo(b)fluoroanthene	220	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	3500	UJ	2300	UJ	390	UJ	360	U	340	U	350	U	340	U	340	U
Benzo(g,h,i)perylene	NL	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	620	J	2300	UJ	390	UJ	360	U	340	U	350	U	340	U	340	U
Benzo(k)fluoroanthene	220	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	3500	UJ	2300	UJ	390	UJ	360	U	340	U	350	U	340	U	340	U
Chrysene	NL	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	2000	J	7500	J	310	J	360	U	340	U	350	U	340	U	340	U
Dibenz(a,h)anthracene	14	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	3500	UJ	2300	UJ	390	UJ	360	U	340	U	350	U	340	U	340	U
Fluoranthene	3000000	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	3500	UJ	4200	J	180	J	360	U	340	U	350	U	340	UJ	340	U
Fluorene	3000000	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	3500	UJ	8600	J	290	J	360	U	340	U	350	U	340	U	340	U
Indeno (1,2,3-cd)pyrene	NL	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	3500	UJ	2300	UJ	390	UJ	360	U	340	U	350	U	340	U	340	U
Phenanthrene	NL	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	6200	J	27000	J	1200	J	360	U	340	U	350	U	340	U	340	U
Pyrene	2000000	340	U	340	U	350	U	340	U	340	U	340	U	340	U	340	U	350	U	6600	J	32000	J	1100	J	360	U	340	U	350	UJ	340	U	340	U
STARS Semivolatile Organics - TCLP (mg/L)																																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(b)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(g,h,i)perylene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Chrysene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Flouranthene	0.05	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Naphthalene	0.01	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.008	J	0.012	J	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U
Phenanthrene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	1.2	J	1.2	J	1.1	J	5	U	5	U	5	U	5	U	5	U	0.99	J	48	J	94	J	6.7	J	5	U	5	U	3.2	J	0.53	J	5	U
TPH (as Diesel)	NL	17		4	U	4	U	4	U	5.6	U	NA		NA		NA		NA		3500		19000		540		7.5		11		4	U	4	U	4	U

Sample ID	NYSDEC	03-22-17-S6		03-22-17-S7		03-22-17-S8		03-22-17-S9		03-22-17-S10		03-22-17-S11		03-22-17-S12	
AOC	STARS	22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	35-37		40-42		45-47		50-52		55-57		60-62		65-67	
Date Collected	Value (a)	11/7/97		11/7/97		11/7/97		11/7/97		11/7/97		11/7/97		11/7/97	
STARS Volatile Organics - Total (ug/kg)															
Benzene	24000	2	U	2.2	U	2	U	2.2	U	11	U	2.6	U	2.2	U
n-Butylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	130		3		1.1	U
sec-Butylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	55		1.3	U	1.1	U
tert-Butylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	5.3	U	1.3	U	1.1	U
Ethylbenzene	8000000	2	U	2.2	U	2	U	2.2	U	11	U	2.6	U	2.2	U
Isopropylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	13		1.3	U	1.1	U
p-Isopropyltoluene	NL	0.99	U	1.1	U	1	U	1.1	U	5.3	U	1.3	U	1.1	U
Methy t-butyl ether	NL	2	U	2.2	U	2	U	2.2	U	11	U	2.6	U	2.2	U
Naphthalene	300000	1	U	1.1	U	1	U	1.6	U	5.3	U	1.3	U	1.1	U
n-Propylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	21		2.1		1.1	U
Toluene	20000000	2	U	2.2	U	2	U	2.2	U	11	U	2.6	U	2.2	U
1,2,4-Trimethylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	5.3	U	1.3	U	1.1	U
1,3,5-Trimethylbenzene	NL	0.99	U	1.1	U	1	U	1.1	U	5.3	U	1.3	U	1.1	U
Total Xylenes	200000000	NA		NA		NA		NA		NA		NA		NA	
m-Xylene	200000000	NA		NA		NA		NA		NA		NA		NA	
o-Xylene	200000000	2	U	2.2	U	2	U	2.2	U	11	U	2.6	U	2.2	U
m- & p-Xylene	200000000	2	U	2.2	U	2	U	2.2	U	11	U	2.6	U	2.2	U
p-Xylene	NL	NA		NA		NA		NA		NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)															
Acenaphthene	5000000	340	U	340	U	340	U	1700	UJ	800	J	390	U	370	U
Anthracene	20000000	340	U	340	U	340	U	1700	U	2000	J	390	U	370	U
Benz(a)anthracene	220	340	U	340	U	340	U	570	J	1400	J	390	U	370	U
Benzo(a)pyrene	61	340	U	340	U	340	U	520	J	1200	J	390	U	370	U
Benzo(b)fluoroanthene	220	340	U	340	U	340	U	1700	U	3600	U	390	U	370	U
Benzo(g,h,i)perylene	NL	340	U	340	U	340	U	1700	U	3600	U	390	U	370	U
Benzo(k)fluoroanthene	220	340	U	340	U	340	U	1700	U	3600	U	390	U	370	U
Chrysene	NL	340	U	340	U	340	U	230	J	3700	J	390	U	370	U
Dibenz(a,h)anthracene	14	340	U	340	U	340	U	1700	U	3600	U	390	U	370	U
Fluoranthene	3000000	340	U	340	U	340	U	1700	U	1400	J	390	U	370	U
Fluorene	3000000	340	U	340	U	340	U	1700	UJ	3600	U	390	U	370	U
Indeno (1,2,3-cd)pyrene	NL	340	U	340	U	340	U	1700	U	3600	U	390	U	370	U
Phenanthrene	NL	340	U	340	U	340	U	1700	U	5800		390	U	370	U
Pyrene	2000000	340	U	340	U	340	U	1700	U	5200	J	390	U	370	U
STARS Semivolatile Organics - TCLP (mg/L)															
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(b)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(g,h,i)perylene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Chrysene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Flouroanthene	0.05	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	UJ
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Naphthalene	0.01	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U
Phenanthrene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	5	U	5	U	5	U	5	U	34		5	U	5	U
TPH (as Diesel)	NL	4	U	4	U	4	U	980		6400		130		32	

Sample ID	NYSDEC	03-22-15-S4		03-22-15-S5		03-22-15-S6		03-22-15-S7		03-22-15-S8		03-22-15-S9		03-22-15-S10		03-22-15-S11		03-22-15-S12	
AOC	STARS	22		22		22		22		22		22		22		22		22	
Depth (Feet BGS)	Guidance	25-27		30-32		35-37		40-42		45-47		50-52		55-57		60-62		65-67	
Date Collected	Value (a)	11/5/97		11/5/97		11/5/97		11/5/97		11/5/97		11/5/97		11/5/97		11/5/97		11/5/97	
STARS Volatile Organics - Total (ug/kg)																			
Benzene	24000	1.7	U	1.8	U	1.9	U	2.2	U	1.8	U	2.4	U	10	U	7.6	U	9.6	U
n-Butylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	190		3.8	U	95	
sec-Butylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	73		210		88	
tert-Butylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	5.2	U	3.8	U	4.8	U
Ethylbenzene	8000000	1.7	U	1.8	U	1.9	U	2.2	U	1.8	U	2.4	U	10	U	180		49	
Isopropylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	25		54		14	
p-Isopropyltoluene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	5.2	U	120		74	
Methy l-butyl ether	NL	1.7	U	1.8	U	1.9	U	2.2	U	1.8	U	2.4	U	10	U	7.6	U	9.6	U
Naphthalene	300000	1.5	U	1.6	U	5	U	1.5	U	2.1	U	1.2	U/U	11	J	34	J	44	J
n-Propylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	180		58		27	
Toluene	20000000	1.7	U	1.8	U	1.9	U	2.2	U	1.8	U	2.4	U	10	U	7.6	U	9.6	U
1,2,4-Trimethylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	5.2	U	3.8	U	38	
1,3,5-Trimethylbenzene	NL	0.87	U	0.91	U	0.97	U	1.1	U	0.9	U	1.2	U	140		44		4.8	U
Total Xylenes	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA	
m-Xylene	200000000	NA		NA		NA		NA		NA		NA		NA		NA		NA	
o-Xylene	200000000	1.7	U	1.8	U	1.9	U	2.2	U	1.8	U	2.4	U	7.4	J	7.6	U	9.6	U
m- & p-Xylene	200000000	1.7	U	1.8	U	1.9	U	2.2	U	1.8	U	2.4	U	10	U	84		12	
p-Xylene	NL	NA		NA		NA		NA		NA		NA		NA		NA		NA	
STARS Semivolatile Organics - Total (ug/kg)																			
Acenaphthene	5000000	340	U	340	U	340	U	340	U	340	U	690	U	1100	J	2500	J	3800	U
Anthracene	20000000	340	U	340	U	340	U	340	U	340	U	690	U	1200	J	2800	J	400	J
Benz(a)anthracene	220	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	3900	J	3800	U
Benzo(a)pyrene	61	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	14000	U	3800	U
Benzo(b)fluoroanthene	220	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	14000	U	3800	U
Benzo(g,h,i)perylene	NL	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	14000	U	3800	U
Benzo(k)fluoroanthene	220	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	14000	U	3800	U
Chrysene	NL	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	6100	J	3800	U
Dibenz(a,h)anthracene	14	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	14000	U	3800	U
Fluoranthene	3000000	340	U	340	U	340	U	340	U	340	U	690	U	830	J	14000	U	3800	U
Fluorene	3000000	340	U	340	U	340	U	340	U	340	U	690	U	1200	J	5000	J	390	J
Indeno (1,2,3-cd)pyrene	NL	340	U	340	U	340	U	340	U	340	U	690	U	3500	U	14000	U	3800	U
Phenanthrene	NL	340	U	340	U	41	J	340	U	340	U	690	U	4900		14000		1900	J
Pyrene	2000000	340	U	340	U	340	U	340	U	340	U	690	U	7800		13000	J	1700	J
STARS Semivolatile Organics - TCLP (mg/L)																			
Acenaphthene	0.02	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Anthracene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Benz(a)anthracene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(a)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(b)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(g,h,i)perylene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Benzo(k)fluoroanthene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Chrysene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Dibenz(a,h)anthracene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Flouroanthene	0.05	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U	0.045	U
Fluorene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Indeno (1,2,3-cd)pyrene	0.000002	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Naphthalene	0.01	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.03	U	0.01	J	0.006	J
Phenanthrene	0.05	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Pyrene	0.05	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
TPH (as Gasoline)	NL	2.6	J	2.6	J	2.3	J	2.1	J	0.94	J	1.3	J	22		72		6.6	
TPH (as Diesel)	NL	4		3.9	J	12		4	U	22		680		4800		14000		1000	

Sample ID			03-22-16-W-1	
AOC	NYSDEC		22	
Depth (Feet BGS)	Soil Cleanup	Eastern		
Date Collected	Objective (a)	USA (SB)	6/22/97	
Metals (mg/kg)				
Antimony	SB	N/A	11	UJ
Arsenic	7.5 or SB	3-12	6.1	U
Beryllium	0.16 or SB	0.1-1.75	1	U
Cadmium	10 (b)	0.1-1.0	1.2	
Chromium	50(b)	1-40	3.4	U
Copper	25 or SB	1-50	49.8	J
Lead	SB	200-500	11.8	J
Mercury	0.1	0.001-0.2	0.2	U
Nickel	13 or SB	0.5-25	4.5	
Selenium	2 or SB	0.1-3.9	4.9	UJ
Silver	SB	N/A	4.7	J
Thallium	SB	N/A	4.3	U
Zinc	20 or SB	9-50	44.6	J
Volatile Organics (ug/kg)				
Acetone	200	—	10	UJ
Benzene	60	—	10	U
Bromodichloromethane	NL	—	10	U
Bromoform	NL	—	10	U
Bromomethane	NL	—	10	U
2-Butanone	300	—	10	U
Carbon Disulfide	2700	—	10	U
Carbon tetrachloride	600	—	10	U
Chlorbenzene	1700	—	10	U
Chloroethane	1900	—	10	U
Chloroform	300	—	10	U
Chloromethane	NL	—	10	U
Dibromochloromethane	NL	—	10	U
1,1-Dichloroethane	200	—	10	U
1,2-Dichloroethane	100	—	10	U
1,1-Dichloroethene	400	—	10	U
1,2-Dichloroethene (total)	300	—	10	U
1,2-Dichloropropane	NL	—	10	U
ciS1,3-Dichloropropene	NL	—	10	U
tranS1,3-Dichloropropene	NL	—	10	U
Ethylbenzene	5500	—	10	U
2-Hexanone	NL	—	10	UJ
4-Methyl-2-pentanone	1000	—	10	U
Methylene chloride	100	—	10	U
Styrene	NL	—	10	U
1,1,2,2-Tetrachloroethane	600	—	10	U
Tetrachloroethene	1400	—	10	U
Toluene	1500	—	10	U
1,1,1-Trichloroethane	800	—	10	U
1,1,2-Trichloroethane	NL	—	10	U
Trichloroethene	700	—	10	U
Vinyl chloride	200	—	10	U
Total Xylenes	1200	—	10	U
Total VOCs	10000	—	0	
Semivolatile Organics (ug/kg)				
Acenaphthene	50000	—	10	UJ
Acenaphthylene	41000	—	10	U
Anthracene	50000	—	10	U
Benz(a)anthracene	24 or MDL (330	—	10	U
Benzo(a)pyrene	1 or MDL (330	—	10	U
Benzo(b)fluoroanthene	1100	—	10	U
Benzo(g,h,i)perylene	50000	—	10	U
Benzo(k)fluoroanthene	1100	—	10	U
Bis(2-chloroethoxy)methane	NL	—	10	U
Bis(2-chloroethyl)ether	NL	—	10	U
Bis(2-ethylhexyl)phthalate	50000	—	10	U
4-Bromophenyl phenyl ether	NL	—	10	U
Butyl benzyl phthalate	50000	—	10	U
Carbazole	NL	—	10	U
4-Chloro-3-methylphenol	40 or MDL (330	—	10	U
4-Chloroaniline	20 or MDL (330	—	10	U
2-Chloronaphthalene	NL	—	10	U
2-Chlorophenol	800	—	10	U
4-Chlorophenyl phenyl ether	NL	—	10	U
Chrysene	400	—	0.5	J
Di-n-butyl phthalate	8100	—	10	U

)ibenz(a,h)anthracene	4 or MDL (330	---	10	U
)ibenzofuran	6200	---	10	U
,2-Dichlorobenzene	7900	---	10	U
,3-Dichlorobenzene	1600	---	10	U
,4-Dichlorobenzene	8500	---	10	U
3,3'-Dichlorobenzidine	NL	---	10	U
2,4-Dichlorophenol	400	---	10	U
Diethyl phthalate	7100	---	10	U
2,4-Dimethylphenol	NL	---	10	U
Dimethyl phthalate	2000	---	10	U
4,6-Dinitro-2-methylphenol	NL	---	25	U
2,4-Dinitrophenol	00 or MDL (800	---	25	UJ
2,4-Dinitrotoluene	NL	---	10	U
2,6-Dinitrotoluene	1000	---	10	U
Di-n-octyl phthalate	50000	---	10	U
Fluoranthene	50000	---	10	U
Fluorene	50000	---	10	U
Hexachlorobenzene	410	---	10	U
Hexachlorobutadiene	NL	---	10	U
Hexachlorocyclopentadiene	NL	---	10	U
Hexachloroethane	NL	---	10	U
Indeno (1,2,3-cd)pyrene	3200	---	10	U
Isophorone	4400	---	10	U
2-Methylnaphthalene	36400	---	10	U
2-Methylphenol	00 or MDL (330	---	10	U
4-Methylphenol	900	---	10	U
N-Nitroso-di-n-propylamine	NL	---	10	UJ
N-Nitrosodiphenylamine	NL	---	10	U
Naphthalene	13000	---	10	U
2-Nitroaniline	30 or MDL (800	---	25	U
3-Nitroaniline	00 or MDL (800	---	25	U
4-Nitroaniline	NL	---	25	U
Nitrobenzene	00 or MDL (330	---	10	U
2-Nitrophenol	330	---	10	U
4-Nitrophenol	00 or MDL (800	---	25	U
Pentachlorophenol	1000	---	25	U
Phenanthrene	50000	---	0.6	J
Phenol	0 or MDL (330)	---	10	U
Pyrene	50000	---	10	U
1,2,4-Trichlorobenzene	3400	---	10	UJ
2,4,5-Trichlorophenol	100	---	25	U
2,4,6-Trichlorophenol	NL	---	10	U
Total Carcinogenic PAHs	500000	---	0	
tal Non-carcinogenic PAHs	100000	---	1	
Total SVOCs	10000	---	1	
TPH (as Gasoline)	NL	---	0.1	U
TPH (as Diesel)	NL	---	0.1	J

APPENDIX C

SITE HEALTH AND SAFETY PLAN

This Appendix will be provided at a later date.