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Operable Unit 3 Pre-Design Investigation Quality Assurance Project Plan

for

Portsmouth Naval Shipyard
Kittery, Maine

Engineering Field Activity Northeast
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0166

August 2001

TETRA TECH NUS, INC.

050114/P

OPERABLE UNIT 3 PRE-DESIGN INVESTIGATION
QUALITY ASSURANCE PROJECT PLAN

FOR

PORTSMOUTH NAVAL SHIPYARD
KITTERY, MAINE

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Engineering Field Activity Northeast
Environmental Branch Code 18
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
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CONTRACT TASK ORDER 0166

AUGUST 2001

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I certify that the attached "Operable Unit 3 he-Design Investigation Quality Assurance Project Plan" has been prepared with input from engineers of the United States Army Corps of Engineers (USACE, Omaha District), the Engineering Field Activity North East, Navy and TtNUS, Pittsburgh. This document is intended to provide the basis and direction for the field work to collect the information required by the USACE, Omaha District for the design of the selected remedy for Operable Unit 3.

STATE OF MAINE
J.P. PRADEEP KUMAR
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REGISTERED PROFESSIONAL ENGINEER

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ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACSM	American Congress on Surveying and Mapping
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
CPT	Cone Penetration Testing
CTO	Contract Task Order
DPT	Direct Push Technology
DQCR	Daily Quality Control Report
DQO	Data Quality Objective
DTM	Digital Terrain Model
EFANE	Engineering Field Activity Northeast
FOL	Field Operations Leader
FS	Feasibility Study
GAI	Geosynthetic Accreditation Institute
GIS	Geographical Information System
GPS	Geographic Positioning System
HAS	Hollow-Stem Auger
HASP	Health and Safety Plan
IDW	Investigation Derived Waste
IRM	internal reference materials
IRP	Installation Restoration Program
JILF	Jamaica Island Landfill (Site 8)
LGS	Landfill Gas Survey
MB	Mercury Burial Sites (MBI and MBII) (Site 9)
MEDEP	Maine Department of Environmental Protection
MSL	mean sea level
MTADS	Multi-sensor Towed Array Detection System
Navy	U.S. Department of Navy
NIST	National Institutes for Standards and Technology
OSHA	Occupational Safety and Health Administration
OU3	Operable Unit 3
PARCC	Precision Accuracy, Completeness and Comparability
PE	Professional Engineer
PID	Photoionization Detector

PM	Project Manager
PNS	Portsmouth Naval Shipyard
PPE	Personnel Protective Equipment
PRAP	Proposed Remedial Action Plan
PVC	Poly Vinyl Chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAB	Restoration Advisory Board
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
RQD	Rock Quality Determination
SMC	Sample Management Coordinator
SOP	Standard Operating Procedure
SPT	Standard Penetration Test
TBM	temporary benchmark
TIN	triangulated irregular network
TtNUS	Tetra Tech NUS, Inc.
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency
USEPA-NE	U.S. Environmental Protection Agency Region 1 New England
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

This Quality Assurance Project Plan (QAPP) for the Operable Unit 3 (OU3) Pre-design Investigation at Portsmouth Naval Shipyard (PNS) in Kittery, Maine was prepared for the U.S. Department of the Navy (Navy), Engineering Field Activity Northeast (EFANE) by Tetra Tech NUS, Inc. (TtNUS) under the Comprehensive Long-term Environmental Action Navy (CLEAN) program, Contract Number N62472-90-D-1298, Contract Task Order (CTO) 166. This investigation is being conducted as part of the PNS Installation Restoration Program (IRP) and under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly referred to as Superfund) process.

OU3 is an approximate 25-acre area located on the eastern portion of the Shipyard. The boundary of OU3 is defined by the approximate boundary of the Jamaica Island Landfill (Site 8). Site 9 (mercury burial vaults) and Site 11 (former waste oil tanks) are located within the boundary of the landfill. The Jamaica Island Landfill was tidal mudflats that the Navy used as a disposal area from 1945 to 1978 for general refuse, trash, construction rubble, and various industrial wastes. The mercury burial vaults at Site 9 were placed in the landfill in the 1970s and were removed (intact) in the 1990s/early 2000. The underground tanks at Site 11 were used from 1943 to 1989 and were removed (intact) in 1989. However, spills appeared to have occurred during filling of the tanks in years past. No residual contamination associated with Site 9 remains, whereas, contamination associated with Site 11 (in soil and groundwater) remains.

The Navy is currently in the process of preparing the Record of Decision (ROD) for OU3 (the draft final ROD is dated July 2001), which documents the selection of an environmental remedy for OU3 as part of the Superfund process. The Navy's selected remedy for OU3 is a hazardous waste landfill cover, shoreline erosion controls, monitoring, and institutional controls.

To support the design of the components of the remedy for OU3, the Navy determined that an investigation was necessary before the conducting the design (i.e., a pre-design investigation is necessary). This document (referred to as the OU3 Pre-design Investigation QAPP) provides the Navy's planned activities to collect the necessary information to support the remedy design for OU3. This document was prepared in accordance with the U.S. Environmental Protection Agency (USEPA) Region 1 New England Quality Assurance Project Plan (USEPA-NE QAPP) guidance (USEPA, October 1999) as appropriate for the pre-design investigation. The QAPP contains the following:

- A discussion of the people and organizations involved in the investigation
- Background on OU3
- The objectives of the investigation

- The planned field activities and testing
- The way the activities will be conducted
- The procedures and activities to make sure the data are collected appropriately and meet the quality requirements for the project, and
- The reporting of the data collected (i.e., in a data package).

Comments on the draft QAPP were received from the regulators and RAB and revisions to the DQOs and QAPP were made accordingly (Comments and responses are included in Appendix D).

TtNUS will be the lead organization conducting the field work (including work by subcontractors to TtNUS) and preparation of the data package resulting from the investigation. U.S. Army Corps of Engineers (USACE, Omaha District) personnel will provide field oversight and assistance during the field investigation. USACE will be using the information collected as part of the pre-design investigation to support the design for the landfill cover.

Project planning/scoping was conducted between the Navy, TtNUS, and USACE to develop the objectives and scope of the pre-design investigation for OU3. The USEPA Data Quality Objective (DQO) process was used as a guideline to develop the project objectives and scope for preparation of the draft QAPP. During the scoping it was determined that the following information was needed:

- Data on the physical properties (geotechnical properties) of site soils/landfill material and underlying materials (such as mudflats and bedrock). Activities include collection of samples from deep borings and surface soil for geotechnical analysis in the field and by a laboratory as well as obtaining data on physical properties in-place (without collecting a sample) using a method referred to as Cone Penetration Testing (CPT).

- Topography of the land at and around the site and of the off shore floor of Clark Cove and Jamaica Cove areas of the Piscataqua River (through topographic and hydrographic surveys).

- Visual determination of the areal extent of waste materials at OU3 (through test pitting).

- Data from CPT, test pitting, and deep borings will provide a better estimation of the volume and extent of waste in the areas under consideration for consolidation. Consolidation of waste from two areas of the landfill (south western portion by the former mercury burial vault II area and northern portion by Jamaica Cove) into the remaining portion of the landfill is being evaluated as part of the landfill cover design.

- Determination of the presence of landfill gas (methane) through a landfill gas survey. If methane is detected, then the emission rate of the methane gas will be estimated.

- More specific understanding of the groundwater flow patterns at the site (through development of groundwater table elevation contours). Installation of temporary groundwater wells (piezometers) and collection of groundwater level readings correlated with tidal water level measurements will be conducted to obtain the necessary information.

- Evaluation of the current status of the shoreline along OU3 to provide a visual understanding of the condition of any existing shoreline erosion controls (controls to prevent soil/landfill materials along the shoreline from washing into the surface water) and wetlands along the shore. In particular, the shoreline of Clark Cove currently has rocks that were placed to provide erosion controls and the shoreline of Jamaica Cove has a wetland area (mudflats). The evaluation of the wetlands will be to provide information on its functions and values to help the Navy evaluate potential impacts of the cover and shoreline erosion controls.

Standard sampling and testing methods for geotechnical characteristics provided by American Society for Testing and Materials (ASTM) standards or Geo Testing Express, Inc. Standard Operating Procedures (SOPs) will be conducted to provide the necessary data quality for the project. Field activities are currently schedule to begin in August 2001.

1.0 INTRODUCTION AND PROJECT MANAGEMENT

This section provides an introduction for the document, explanation of the document format, and a discussion of the project organization.

1.1 INTRODUCTION

This Quality Assurance Project Plan (QAPP) for the Operable Unit 3 (OU3) Pre-design Investigation at Portsmouth Naval Shipyard (PNS) in Kittery, Maine was prepared for the U.S. Department of Navy (Navy), Engineering Field Activity Northeast (EFANE) by Tetra Tech NUS, Inc. (TtNUS) under the Comprehensive Long-Term Environmental Action Navy (CLEAN), Contract Number N62472-90-D-1298, Contract Task Order (CTO) 166. The investigation is being conducted as part of the PNS Installation Restoration Program (IRP) and under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

This document provides a discussion of the project management, project background and objectives, sampling and testing requirements and methods, data acquisition and verification requirements and methods, and assessment and oversight activities for the collection of information to support the design for the selected remedy for OU3 (i.e., hazardous waste landfill cover, shoreline erosion controls, monitoring, and institutional controls).

1.2 DOCUMENT FORMAT

The OU3 Pre-design Investigation QAPP was prepared in accordance with the requirements of the U.S. Environmental Protection Agency (USEPA) Region 1 New England Quality Assurance Project Plan (USEPA-NE QAPP) guidance (USEPA, October 1999) as appropriate for the pre-design investigation. The following provides the discussion of the document format to meet the USEPA-NE QAPP guidance and indicates where required QAPP elements are provided in this document (in USEPA-NE QAPP Worksheet #2 in Section 1.2.3).

1.2.1 Document Control Format

The document control procedures are used to identify the most current version of the QAPP and to help ensure that only the most current version of the QAPP is used by all project participants. To meet this goal, text, tables, and figures in the OU3 Pre-design Investigation QAPP include a header indicating the document name and revision number and date. The footer indicates the page number within the section. The Table of Contents indicates the total number of pages within each section.

The draft version will be marked Revision 0 until final approval. Revision numbers and dates will be updated as the QAPP is modified.

1.2.2 Document Control Numbering System

A document control numbering system will not be used for the OU3 Pre-design Investigation QAPP because this is a small project with a distinct document distribution list. The QAPP and any revisions, addenda, or amendments will be provided in accordance with the PNS distribution list. The PNS distribution list includes the USEPA, Maine Department of Environmental Protection (MEDEP), Navy, Natural Resources Trustees, and Restoration Advisory Board (RAB) members. The mailing address and number of copies of the document are provided for each name on the mailing list. In addition, the cover letter accompanying the document indicates the distribution list and number of copies (in the case of multiple copies only). For this project the U.S. Army Corp of Engineers (USACE) as a contractor to the Navy is also included on the distribution list because USACE will be using the data as part of the OU3 design (as well as providing field support and oversight for the data collection activities).

1.2.3 USEPA-NE QAPP Worksheet #2

The USEPA-NE QAPP guidance (USEPA, October 1999) requires inclusion of Worksheet #2 to provide prefacing information in the QAPP to identify key project players, previous site work, and the USEPA program for which the current project is being performed. USEPA-NE QAPP Worksheet #2 for the OU3 Pre-design Investigation is provided on Pages 1-3 through 1-7.

1.3 DISTRIBUTION LIST AND PROJECT PERSONNEL SIGN-OFF SHEET

The distribution list for the OU3 Pre-design Investigation QAPP is summarized in Table 1-1. Each person listed in Table 1-1 will receive a copy of this Revision 0 QAPP and any subsequent revisions.

Table 1-2 provides an example of the project personnel sign-off sheet, which will be signed by all personnel working on the project. A signature on this form indicates the person has read this QAPP and is familiar with the tasks to be performed. The completed sign-off sheet will be maintained in the TtNUS project file.

1.4 PROJECT ORGANIZATION

This section discusses the project organization and personnel responsibilities.

USEPA-NE QAPP Worksheet #2 - Rev. 0

Site Name/Project Name: OU3 Pre-design Investigation
Site Location: Portsmouth Naval Shipyard, Kittery, Maine
Site Number/Code: Sites 8, 9, and 11
Operable Unit: Operable Unit 3

Contractor Name: Tetra Tech NUS, Inc. (TtNUS)
Contract Task Order Number: 166
Contract Title: Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program

1. **Identify Guidance used to prepare QAPP:**

   Region I, USEPA-NE Compendium QAPP Guidance, Attachment and/or other*:*

   Region 1 USEPA-*New England Compendium of Quality Assurance Project Plan Guidance, October 1999, Final.*

2. **Identify USEPA Program:** *Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)*

3. **Identify approval entity: USEPA-NE or State:** *USEPA-NE*

   or other entity:

4. **Indicate whether the QAPP is a generic program QAPP or a project specific QAPP:**
   Project Specific

5. **List dates scoping meetings were held:** *Navy team scoping and planning activities were conducted through electronic mail, teleconference, and meetings as discussed in Section 2.0.*

6. **List dates and titles of QAPP documents written for previous site work, if applicable:**

   Various investigative activities have been conducted at the sites within OU3. Section 5.0 provides a list of sources of previously collected data that were reviewed for the development of this QAPP.

7. **List organizational partners (stakeholders) and connection with USEPA and/or State:**
   MEDEP
   Natural Resources Trustees
   PNS RAB

8. **List data users:** *The Navy will use the data to prepare the landfill cover design for OU3. The USEPA, MEDEP, and PNS RAB will review the QAPP. A data package will be provided after the field activities are completed. Use of the data as part of the OU3 landfill design will be documented in the design report.*

9. **If any required QAPP Elements (1-20), Worksheets and/or Required Information are not applicable to the project, then circle the omitted QAPP Elements, Worksheets, and Required Information on the attached Table. Provide an explanation for their exclusion below:**

   All of the elements related to sample collection, analysis, and analytical data for chemical analytical related activities have been excluded as shown in the worksheet.. The scope of this investigation is predominantly geotechnical in nature. The information needed for the worksheets were directly filled into the tables of relevant sections; therefore, except for this work sheet (Worksheet #2), worksheets are not included in the QAPP. Information not required for this investigation is indicated by "strikethrough" font.

REQUIRED USEPA QA/R-5 ELEMENTS	QAPP CORRESPONDING SECTION	REQUIRED USEPA-NE QAPP ELEMENT(S) and CORRESPONDING USEPA-NE QAPP SECTION(S)	USEPA-NE QAPP Worksheet #	REQUIRED INFORMATION
		Project Management and Objectives		
A1	Begin. of Document	1.0 Title and Approval Page	1	- Title and Approval Page
A2	1.2 Begin. of Document 1.2.1 1.2.2 1.2.3	2.0 Table of Contents and Document Format 2.1 Table of Contents 2.2 Document Control Format 2.3 Document Control Numbering System 2.4 USEPA-NE QAPP Worksheet #2	2	- Table of Contents - USEPA-NE QAPP Worksheet
A3	1.3	3.0 Distribution List and Project Personnel Sign-off Sheet	3 4	- Distribution List - Project Personnel Sign-off Sheet
A4, A8	1.4 1.4.1 1.4.2 1.4.2.1 1.4.3 1.4.4	4.0 Project Organization 4.1 Project Organizational Chart 4.2 Communication Pathways 4.2.1 Modifications to Approved QAPP 4.3 Personnel Responsibilities and Qualifications 4.4 Special Training Requirements/ Certification	5a 5b 6 7	- Organizational Chart - Communication Pathways - Personnel Responsibilities and Qualifications Table - Special Personnel Training Requirements Table
A5	2.1 2.1.1 2.1.2, 2.1.3, 2.1.4	5.0 Project Planning/Project Definition 5.1 Project Planning Meetings 5.2 Problem Definition/Site History and Background	8a 8b	- Project Planning Meeting Documentation - Project Scoping Meeting Attendance Sheet with Agenda - Problem Definition/Site History and Background - USEPA-NE DQO Summary Form - Site Maps (historical and present)

Note: Text with strikeout notation is not required for this investigation – See note on first page of Worksheet #2.

REQUIRED USEPA QA/R-5 ELEMENTS	QAPP CORRESPONDING SECTION	REQUIRED USEPA-NE QAPP ELEMENT(S) and CORRESPONDING USEPA-NE QAPP SECTION(S)	USEPA-NE QAPP Worksheet #	REQUIRED INFORMATION
Project Management and Objectives (Continued)				
A6	2.2 2.2.1 through 2.2.9 2.2.10	6.0 Project Description and Schedule 6.1 Project Overview 6.2 Project Schedule	9a 9b 9c 9d 10	- Project Description - ~~Contaminants of Concern and Other Target Analytes Table~~ - ~~Field and Quality Control Sample Summary Table~~ - ~~Analytical Services Table~~ - ~~System Designs~~ - Project Schedule Timeline Table
A7	2.3 2.3.1 2.3.2	7.0 Project Quality Objectives and Measurement Performance Criteria 7.1 Project Quality Objectives 7.2 Measurement Performance Criteria	11a 11b	- Measurement Performance Criteria
Measurement/Data Acquisition				
B1	3.1 3.1.1 through 3.1.6	8.0 ~~Sampling~~ (Field) Process Design 8.1 Sampling Design Rationale	12a 12b	- ~~Sampling~~ (Field Investigation) Rationale - Sampling Locations, Sampling and ~~Analytical~~ (Testing) Method/SOP Requirements Table - Sample Location Map
B2, B6, B7, B8	3.2 3.2.1 through 3.2.6 3.2.7 4.1.3 4.1.4 4.1.5	9.0 ~~Sampling~~ (Field) Procedures and Requirements 9.1 Sampling Procedures 9.2 Sampling SOP Modifications 9.3 Cleaning and Decontamination of Equipment/Sample Containers 9.4 Field Equipment Calibration 9.5 Field Equipment Maintenance, Testing and Inspection Requirements 9.6 Inspection and Acceptance Requirements for Supplies/Sample	13 12b 14 15	- Sampling SOPs - Project Sampling SOP Reference Table - ~~Sampling Container, Volumes and Preservation Table~~ - Field ~~Sampling~~ (Testing) Equipment Calibration Table - Cleaning and Decontamination SOPs - Field Equipment Maintenance, Testing and Inspection Table

Note: Text with strikeout notation is not required for this investigation – See note on first page of Worksheet #2.

REQUIRED USEPA QA/R-5 ELEMENTS	QAPP CORRESPONDING SECTION	REQUIRED USEPA-NE QAPP ELEMENT(S) and CORRESPONDING USEPA-NE QAPP SECTION(S)	USEPA-NE QAPP Worksheet #	REQUIRED INFORMATION
		Containers		
		Measurement/Data Acquisition (Continued)		
B3	3.3 3.3.1 3.3.2 3.3.3	10.0 Sample Handling, Tracking, and Custody Requirements 10.1 Sample Collection Documentation 10.1.1 Field Notes 10.1.2 Field Documentation Management System 10.2 Sample Handling and Tracking System 10.3 Sample Custody	16	- Sample Handling, Tracking and Custody SOPs - ~~Sample Handling Flow Diagram~~ - Sample Container Label (Sample Tag) - Chain-of-Custody Form and Seal
B4, B6, B7, B8	4.1 4.1.1 4.1.2 4.1.3 4.1.4 4.1.5	11.0 Field ~~Analytical~~ (Testing) Method Requirements 11.1 Field ~~Analytical~~ (Testing) Methods and SOPs 11.2 Field ~~Analytical~~ (Testing) Method/ SOP Modifications 11.3 Field ~~Analytical~~ (Testing) Instrument Calibration 11.4 Field ~~Analytical~~ (Testing) Instrument/ Equipment Maintenance, Testing and Inspection Requirements 11.5 Field ~~Analytical~~ (Testing) Inspection and Acceptance Requirements for Supplies	17 18 19	- Field ~~Analytical~~ (Testing) Methods/SOPs - ~~Field Analytical Method/SOP Reference Table~~ - ~~Field Analytical Instrument Calibration Table~~ - ~~Field Analytical Instrument/ Equipment Maintenance, Testing and Inspection Table~~

Note: Text with strikeout notation is not required for this investigation – See note on first page of Worksheet #2.

REQUIRED USEPA QA/R-5 ELEMENTS	QAPP CORRESPONDING SECTION	REQUIRED USEPA-NE QAPP ELEMENT(S) and CORRESPONDING USEPA-NE QAPP SECTION(S)	USEPA-NE QAPP Worksheet #	REQUIRED INFORMATION
Measurement/Data Acquisition (Continued)				
B4, B6, B7, B8	4.2 4.2.1 4.2.2 4.2.3 4.2.4 4.2.5	12.0 Fixed Laboratory ~~Analytical~~ (Testing) Method Requirements 12.1 Fixed Laboratory ~~Analytical~~ (Testing) Methods and SOPs 12.2 Fixed Laboratory ~~Analytical~~(Testing) Method/SOP Modifications 12.3 Fixed Laboratory Instrument Calibration 12.4 Fixed Laboratory Instrument/ Equipment Maintenance, Testing and Inspection Requirements 12.5 Fixed Laboratory Inspection and Acceptance Requirements for Supplies	20 21	- Fixed Laboratory ~~Analytical~~ (Testing) Methods/SOPs - Fixed Laboratory ~~Analytical~~ (Testing) Method/SOP Reference Table - Fixed Laboratory Instrument Maintenance and Calibration Table
B5	4.3 4.3.1 4.3.2	13.0 Quality Control Requirements 13.1 ~~Sampling~~ (Field) Quality Control 13.2 ~~Analytical~~ Fixed Laboratory Quality Control ~~13.2.1Field Analytical QC~~ ~~13.2.2Fixed Laboratory QC~~	22a 22b 23a 23b 24a 24b	**Sampling** - ~~Field Sampling QC Table~~ - ~~Field Sampling QC Table cont.~~ ~~**Analytical**~~ - ~~Field Analytical QC Sample Table~~ - ~~Field Analytical QC Sample Table cont.~~ - ~~Field Screening/Confirmatory Analysis Decision Tree~~ - ~~Fixed Laboratory Analytical QC Sample Table~~ - ~~Fixed Laboratory Analytical QC Sample Table cont.~~
B9	5.1	14.0 Data Acquisition Requirements	25	- Non-Direct Measurements Criteria and Limitations Table

Note: Text with strikeout notation is not required for this investigation – See note on first page of Worksheet #2.

REQUIRED USEPA QA/R-5 ELEMENTS	QAPP CORRESPONDING SECTION	REQUIRED USEPA-NE QAPP ELEMENT(S) and CORRESPONDING USEPA-NE QAPP SECTION(S)	USEPA-NE QAPP Worksheet #	REQUIRED INFORMATION
Measurement/Data Acquisition (Continued)				
A9, B10	5.2 5.2.1 5.2.2 5.2.3 5.2.4 5.2.5 5.2.6	15.0 Documentation, Records, and Data Management 15.1 Project Documentation and Records 15.2 Field ~~Analysis~~ (Testing) Data Package Deliverables 15.3 Fixed Laboratory Data Package Deliverables 15.4 Data Reporting Formats 15.5 Data Handling and Management 15.6 Data Tracking and Control	26	- Project Documentation and Records Table - Data Management SOPs
Assessment/Oversight				
C1	7.1 7.1.1 7.1.2	16.0 Assessments and Response Actions 16.1 Planned Assessments 16.2 Assessment Findings and Corrective Action Responses ~~16.3 Additional QAPP Non-Conformances~~	27a 27b 27c	- Assessment and Response Actions - Project Assessment Table - Project Assessment Plan - Audit Checklists
C2	7.2	17.0 QA Management Reports	28	- QA Management Reports Table
Data Validation and Usability				
D1	6.1	18.0 Verification and Validation Requirements		- ~~Validation Criteria Documents~~
D2	6.2	19.0 Verification and Validation Procedures	29a 29b 29c	- Data Evaluation Process - ~~Data Validation Summary Table~~ - ~~Data Validation Modifications~~
D3	6.3	20.0 Data Usability/Reconciliation with Project Quality Objectives	30	- Data Usability Assessment

Note: Text with strikeout notation is not required for this investigation – See note on first page of Worksheet #2.

1.4.1 Project Organizational Chart

A Project Organizational Chart depicting the agencies and contracting personnel involved with the OU3 Pre-design Investigation is included as Figure 1-1. The Navy is the lead agency in addressing this site, with TtNUS (Navy contractor) implementing the investigation. USACE (Navy contractor for the landfill cover design) will provide field support to TtNUS and oversight. Names and telephone numbers are provided in the Organizational Chart.

1.4.2 Communication Pathways

The following is a summary of the pathways to be used to transfer information and to make alterations to project methods that may be required because of unforeseen circumstances. It will be the responsibility of the TtNUS Project Manager (PM) to keep both the TtNUS project team and the Navy informed of the following:

- Schedule, deliverables, meetings, and milestones
- Recent data collected from the site
- Technical changes made to the plans and specifications
- Developments that will cause changes in the schedule

The TtNUS PM will be in frequent communication with the Navy Remedial Project Manager (RPM). Any changes in the plans and specifications, field methodology, sampling protocol, or data objectives will be communicated to the Navy RPM and TtNUS Maine Professional Engineer (PE), in a timely manner. As appropriate, a field modification record will be used to identify the need for a change and a recommended course of action. The Navy will consult with USEPA and MEDEP on any major scope changes that may occur while the field work is proceeding.

The TtNUS PM will communicate directly with the field team and indirectly with the geotechnical laboratory and subcontractors through the Lead Engineer. The Lead Engineer will provide technical guidance and assess data as they become available. The laboratories will notify TtNUS immediately of any issues that develop with the data or quality assurance/quality control (QA/QC) requirements. The Navy will be notified if significant issues arise with the laboratories regarding data, data quality objectives, or schedule.

The TtNUS Field Operations Leader (FOL) will notify the TtNUS PM of the daily sample shipping information and will be in daily contact with the TtNUS PM. The PM will provide sample shipping information to the sample shipping coordinator. The FOL and the required subcontractors will

communicate directly onsite. During site activities, project sample logsheets, logbook notations, and appropriate field forms will be completed in the field and maintained at the TtNUS office.

1.4.2.1 Modifications to the Approved QAPP

This section documents the procedures that will be followed when any project activity originally described in the approved QAPP requires real-time modification to achieve the project goals.

Proposed changes will be presented to the Navy by TtNUS and followed up with a field modification record for significant changes. The documentation will describe why the change is necessary, the nature of the proposed change, and its impacts on the project. The change will be implemented after Navy concurrence. Minor changes will be documented in the field logbook.

When changes require immediate action, the proposed change will be briefly discussed internally by TtNUS and approved, as appropriate, by the TtNUS PM or Lead Engineer. The Navy RPM will be notified as soon as possible. Concurrence from the USEPA and MEDEP will be sought for any major scope changes, as determined by the Navy. In the event of conditions requiring a major scope change, the investigation will be put on hold until concurrence is obtained.

1.4.3 Personnel Responsibilities and Qualifications

Mr. John Trepanowski, the Program Manager, is responsible for the overall management and implementation of the Navy CLEAN contract. Ms. Deborah Cohen will serve as the TtNUS PM for the work assignment and has the primary responsibility for the implementation and execution of the work assignment, including technical quality, oversight/review, control of costs and schedule, and implementation of appropriate QA procedures during all phases. Mr. J.P. Kumar will be the TtNUS Maine PE providing oversight for the entire project. Mr. John Wright will be the Lead Engineer assisting on all aspects of the project, as required.

The TtNUS FOL is the primary person who implements the field work activities outlined in this QAPP. The FOL will report directly to the TtNUS PM and the Lead Engineer. Responsibilities of the FOL include: supervising TtNUS field staff and field operations; interfacing with onsite USACE personnel; coordinating with the various subcontractors onsite; ensuring the procedures specified in the QAPP are properly implemented; identifying and documenting necessary field changes; maintaining daily schedules; and reporting to the PM on a regular basis regarding the status and progress of the field activities. The FOL will also be responsible for ensuring that the field staff adhere to the primary duties of the Health and Safety Plan (HASP); reporting any health and safety issues to the TtNUS Health and Safety Officer; and reporting any hazards, injuries, or decisions to stop work to the TtNUS PM.

The QA Officer will provide input on all aspects of adherence to the QAPP to the PM as needed. The sample management coordinator will be responsible for ensuring that the laboratory supplies the appropriate sample containers to the field; verifying receipt of samples and their integrity at the laboratory; ensuring that the data supplied by the laboratory is complete; and providing liaison with the laboratory contact to obtain data of the content and format that is suitable for the data quality objectives of this project.

The Maine PE will provide review of the QAPP, oversight of the field activities, and certification of the QAPP and project report for the field activities.

The PNS RAB are not listed in the organizational chart, although the Navy will obtain their review and input on this QAPP and ensuing reports.

Table 1-3 lists the TtNUS OU3 Pre-design Investigation personnel and includes their respective roles, names, and titles. Resumes of the TtNUS personnel are available on request.

1.4.4 Special Training Requirements and Certifications

Tasks to be performed while implementing the field activities that require special training are summarized in Table 1-4.

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TABLE 1-1

DISTRIBUTION LIST
OU3 PRE-DESIGN INVESTIGATION QAPP
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

QAPP Recipients	Title	Organization	Telephone Number
Ms. Meghan Cassidy	USEPA RPM	USEPA Region 1	617-918-1387
Mr. Iver McLeod	MEDEP RPM	MEDEP	207-287-8010
Mr. Fred Evans	Navy RPM	EFANE, Navy	610-595-0567 ext. 159
Ms. Marty Raymond	PNS IRP Manager	PNS, Kittery, Maine	207-438-2536
Ms. Deborah Cohen	TtNUS PM	TtNUS, Pittsburgh, PA	Contact Mr. Fred Evans
Mr. Paul Frank	TtNUS QA Officer	TtNUS, Pittsburgh, PA	Contact Mr. Fred Evans
Mr. J.P. Kumar	TtNUS Maine PE	TtNUS, Pittsburgh, PA	Contact Mr. Fred Evans
Mr. John Wright	TtNUS Lead Engineer	TtNUS, Pittsburgh, PA	Contact Mr. Fred Evans
Mr. Stan Conti	TtNUS FOL	TtNUS, Pittsburgh, PA	Contact Mr. Fred Evans
Mr. Jim Conroy	USACE Project Engineer	USACE, Omaha, NE	Contact Mr. Fred Evans

Note: All members on the PNS distribution list (including RAB members) will receive copies of the QAPP and all updates to the QAPP. A complete distribution list is available from the Navy and can be readily provided on request. TtNUS PM will be responsible for distribution of copies of the QAPP and all updates to the QAPP to TtNUS project personnel including the TtNUS FOL.

TABLE 1-2

EXAMPLE PROJECT PERSONNEL SIGN-OFF SHEET
OU3 PRE-DESIGN INVESTIGATION QAPP
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Project Personnel	Title	Signature	Date QAPP Read	QAPP Acceptable As Written
Deborah Cohen	TtNUS PM			
Paul Frank	TtNUS QA Officer			
J.P. Kumar	TtNUS Maine PE			
John Wright	TtNUS Lead Engineer			
Stan Conti	TtNUS FOL			
Fred Evans	Navy RPM			
Jim Conroy	USACE Project Engineer			

TABLE 1-3

**PERSONNEL RESPONSIBILITIES AND QUALIFICATIONS
OU3 PRE-DESIGN INVESTIGATION QAPP
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**

Name	Organizational Affiliation	Responsibilities	Location of Personnel Resumes, if not included	Education and Experience Qualifications
John Trepanowski/ Garth Glenn	TtNUS	Program Manager/Deputy	TtNUS, King of Prussia, PA	Available on request
Deborah Cohen	TtNUS	PM	TtNUS, Pittsburgh, PA	Available on request
Paul Frank	TtNUS	QA Officer	TtNUS, Pittsburgh, PA	Available on request
Matt Soltis	TtNUS	Health & Safety Officer	TtNUS, Pittsburgh, PA	Available on request
J.P. Kumar	TtNUS	Maine PE	TtNUS, Pittsburgh, PA	Available on request
John Wright	TtNUS	Lead Engineer	TtNUS, Pittsburgh, PA	Available on request
Tom Johnston	TtNUS	Data Quality Objectives (DQO) Advisor	TtNUS, Pittsburgh, PA	Available on request
Stan Conti	TtNUS	FOL	TtNUS	Available on request
Jim Conroy	USACE	Field Oversight/Support	USACE, Omaha, NE	Available on request

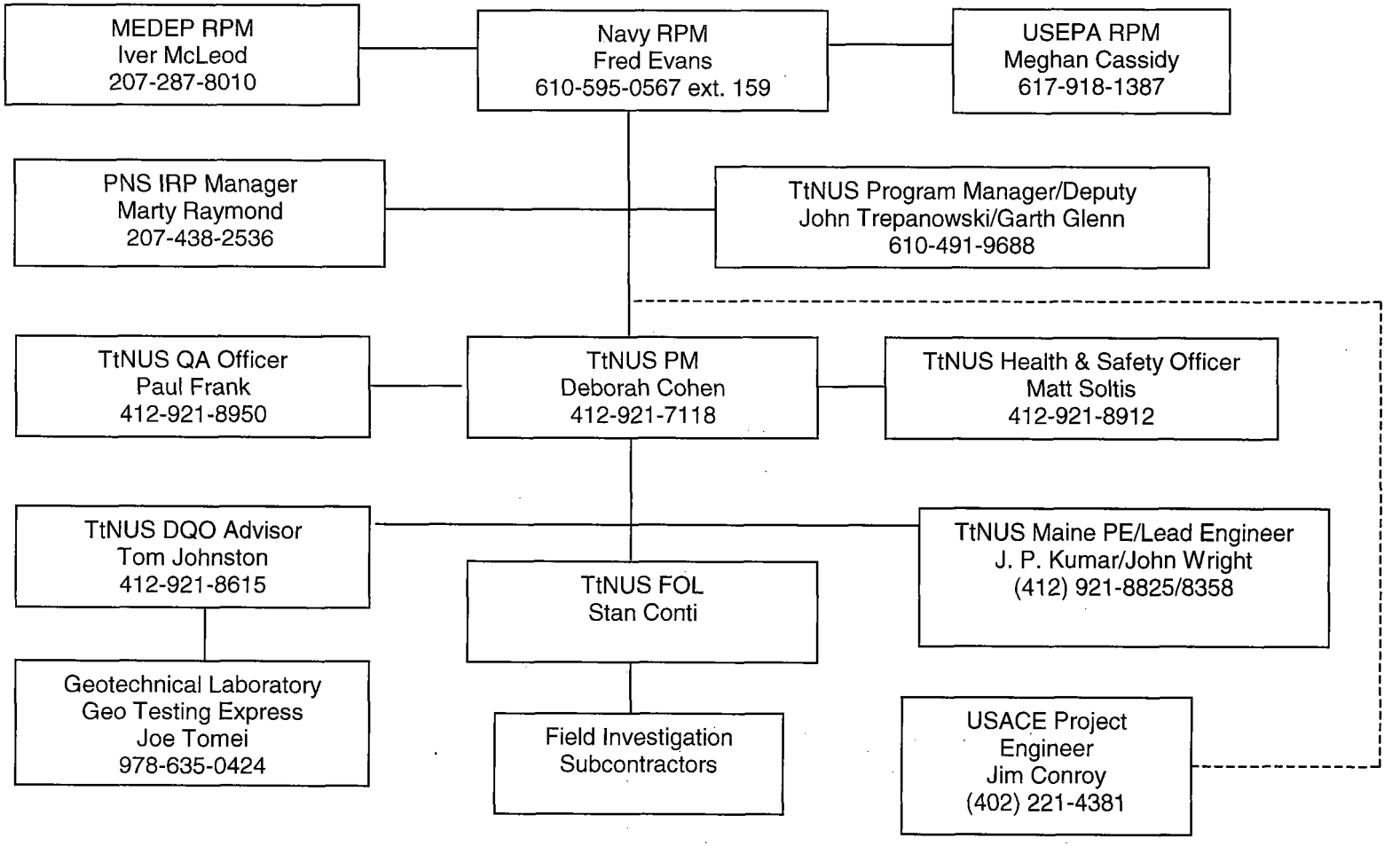
TABLE 1-4

SPECIAL PERSONNEL TRAINING REQUIREMENTS
OU3 PRE-DESIGN INVESTIGATION QAPP
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Project Function	Specialized Training Title of Course or Description	Training Provided By	Training Date	Personnel/Groups Receiving Training	Personnel Titles/ Organizational Affiliation	Location of Training Records/Certificates
Field Sampling	• 40-hour Occupational Safety and Health Administrative training, 8 hour annual refresher training • Supervisory training	Health & safety training specialists	various	• All field (onsite) personnel • FOL	FOL and field sampling team members	Training records for TtNUS employees are maintained by TtNUS. Training records for USACE employees are maintained by USACE. Training records will be obtained from all subcontractor personnel.

FIGURE 1-1

**PROJECT ORGANIZATIONAL CHART
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**



* All contact with TtNUS personnel and subcontractors by nonfield personnel should be made through Mr. Fred Evans.

2.0 PROJECT OBJECTIVES

This section discusses the project objectives. To maintain consistency with the USEPA-NE QAPP guidance (USEPA, October 1999), the outputs of the first Data Quality Objective (DQO) step (problem definition) are summarized in QAPP Section 2.1 and the outputs of remaining steps are summarized in Section 2.2. As necessary, more detailed information is provided in Section 2.3.

2.1 PROJECT PLANNING / PROJECT DEFINITION

This section documents project planning, provides the site background, and identifies the basis for the investigation.

2.1.1 Project Planning

Project planning/scoping was conducted during February through May 2001 between the Navy, Philadelphia, Pennsylvania; TtNUS Pittsburgh, Pennsylvania; and USACE, Omaha, Nebraska. The planning and scoping was conducted via electronic mail to develop and document the DQOs for this project and were supplemented by input via telephone conversation between the three parties. In addition, a meeting was held on May 8 and 9, 2001 at the TtNUS, Pittsburgh office to refine the DQOs and the sampling program.

Participants of electronic mail exchange and participants who were copied on summaries of telephone conversations are listed in the electronic mail list. The Case Team members (i.e., the team of people assisting in development of the QAPP) are listed in Table 2-1. The Case Team is responsible for establishing project requirements, planning the project activities, and sequencing the activities to attain project objectives. Regulatory and RAB participation in the project planning for this project is through review and comment on the draft QAPP. Comments received on the draft QAPP with the Navy's responses are provided in Appendix D of this QAPP.

This project is being undertaken in the context of CERCLA. The project DQOs were developed in accordance with the USEPA Guidance for the DQO Process, commonly known as QA/G-4 (USEPA, August 2000). The emphasis is on the non-statistical aspects of DQO planning (DQO Steps 1 through 5), with a discussion of the rationale for numbers and locations of samples.

The USEPA Region I QAPP Manual (USEPA, October 1999) provides worksheets to be completed during DQO planning meetings. The QAPP tables corresponding to the applicable worksheets were developed directly for insertion into the QAPP to minimize the time necessary for completing the QAPP.

2.1.2 Site Location and Description

OU3 is located close to the eastern end of PNS and is designated as the soil and groundwater within the approximate Jamaica Island Landfill (JILF, i.e., Site 8) boundary. Sites 8, 9, and 11 are included in OU3. PNS is an island located in the Piscataqua River separating Kittery, Maine and Portsmouth, New Hampshire, as shown on Figure 2-1. The site location at PNS is shown on Figure 2-2. The layout of OU3 is shown on Figure 2-3. As shown on Figure 2-3, OU3 borders the Piscataqua River at Jamaica Cove and Clark Cove.

The area within the landfill boundary is estimated to be approximately 25 acres and the surface is covered with topsoil/vegetation, pavement, and gravel. The site is currently used for limited recreational activities, vehicle parking, and equipment storage. Crane testing activities are also conducted at the crane test pad, located in the central portion of the JILF, south of Parker Avenue. Adjacent areas of the landfill are used for equipment storage, hazardous waste storage facility, residential use, temporary lodging facility, office facilities, and ambulatory services (health clinic).

2.1.3 Site History and Background

Within OU3 are Sites 8, 9, and 11. The following is a summary of the histories of these three sites.

Site 8 is mainly the JILF, which was a tidal mudflat area that the Navy used as a disposal area for various industrial wastes from 1945 to 1978. Approximately 100,000 cubic yards of dredged sediment from the Shipyard's Berths 6, 11, and 13 were deposited at the JILF (covering approximately 9 acres corresponding with the area within the running track) per a permit issued by the Army Corps of Engineers in 1978. A new dike was designed and constructed to contain these dredge spoils and prevent post-construction seepage and run-off into the adjacent Piscataqua River. A 2-foot thick clay cover was placed on the dredge spoils to minimize infiltration of rainfall.

Site 9, Former Mercury Burial Sites I and II (MBI and MBII), is located within the boundary of the JILF. The burial sites consisted of poured concrete blocks and a precast concrete pipe (also referred to as concrete vaults) containing mercury-contaminated wastes that were reportedly buried between 1973 and 1975 at two locations. The concrete vaults at MBI and MBII have been removed (portions of MBI in 1994 and the rest in 1997 and MBII in 2000). All the contents of MBI and MBII were disposed of properly at a licensed offsite disposal facility and no exceedances of regulatory criteria for mercury were found in the excavated soil. The area was backfilled and seeded (Halliburton NUS, 1995; FWENC, 1997; FWENC, 2001).

Site 11, Former Waste Oil Tanks Nos. 6 and 7, was used from 1943 to 1989 to store waste oils from facility shops before offsite disposal. The types of waste oils included cooling and cutting oils, motor oils, transmission oils, and hydraulic oils. Some of the waste oils may have contained metals. It is possible that degreaser solvents labeled as waste oils and Freon may also have been stored in the tanks. Twice before removal from service (in 1979 and 1986), the tanks were evaluated and determined to be sound. When the tanks were removed from service in 1989, the tanks were excavated and again found to be sound. PNS and the MEDEP collected soil samples and found elevated levels of lead and other contaminants. The contamination was believed to occur from spills during filling of the tanks. The tanks were removed and disposed of offsite. At that time, 332 tons of surrounding contaminated soil were also excavated and disposed of offsite, however, residual contamination associated with Site 11 remains.

During 1989 to 1992, as part of the RFI, surface and subsurface soil, groundwater (bailer sampling method), and seep samples were collected from the sites within OU3. During the RFI Data Gap investigation conducted in 1994, hydrogeology and tidal influences were further investigated. In 1996 and 1997, four rounds of groundwater monitoring (using low-flow sampling method) were conducted for the OU3 monitoring wells.

Test pitting within portions of the JILF was conducted in February and March 2000 at 25 locations, selected based on a survey for buried metallic objects, to investigate the possibility of the presence of a large number (nearly 10,000) of 55-gallon (or similar capacity) drums reportedly buried above the water table in the landfill between 1945 and 1965. Test pits were not included in the MBII area or within the clay covered area of the landfill (within the running track). Forty-one drums of non-hazardous material were located and 40 of these drums were removed from one location and disposed of offsite and one of these drums, containing a Portland cement type material, from another location was replaced in the landfill. Subsurface soil samples were collected as part of the investigation (TtNUS, October 2000).

Section 1.0 of the Feasibility Study Report for Operable Unit 3 (TtNUS, November 2000) provides additional details on the site history and enforcement activities for OU3. In addition, the Feasibility Study Report for Operable Unit 3 provides the identification and evaluation of alternatives to address soil and groundwater within the boundary of the JILF (i.e., source control) and the management of migration of groundwater offshore of the JILF. The Navy, USEPA, and MEDEP decided to finalize the OU3 FS without addressing the separation of source control (OU3) and management of migration (OU6) for the JILF. The Navy prepared an OU3 FS Clarification Memorandum (Navy, November 2000) that discusses the decision to separate the operable units and the impact on the OU3 FS. The Proposed Remedial Action Plan (PRAP) for OU3 (Navy, January 2001) was prepared for public comment to indicate the Navy's preliminary proposed remedy for source control for the JILF. A draft final Record of Decision (ROD) was issued to document the selected remedy for OU3 (Navy, July 2001), which requires a

hazardous waste landfill cover, shoreline erosion controls, monitoring, and institutional controls. This QAPP addresses the collection of data required for the design of the selected remedy.

2.1.4 Problem Definition

As part of the problem definition, the available environmental assessment data from the earlier investigations at OU3 were evaluated to determine what data were available to support the design for the selected remedy and to determine whether the data were of sufficient level of detail or quality to be used in the design. Because the available data are not sufficient for the design, it was determined that the basis for this investigation is the need to collect site-specific information to support the design of the selected remedy. The data will be used as input for various design parameters and engineering decision making related to the design.

The current investigation is focused on obtaining the appropriate information based on the DQOs that are defined in subsequent sections.

2.2 PROJECT DESCRIPTION AND SCHEDULE

This section of the QAPP provides a general overview of the activities that will be performed under the OU3 Pre-design Investigation and how and when they will be performed to address the problems defined in Section 2.1. Specific details for individual project activities are discussed in later sections of the QAPP, as indicated herein.

2.2.1 Project Overview

The project planning phase determines the project quality objectives, i.e., the type, quantity, and quality of data needed to ensure project data can be used for their intended purpose. The project planning considerations are discussed in Section 2.1. The project quality objectives are discussed in Section 2.3.

During project planning the site contaminants, sampling tasks, systems design, analytical tasks, data verification and validation tasks, quality assurance assessment, data usability assessments, and records and reports are considered to determine how and when investigation activities will be conducted. The following discusses how the project planning items were considered for the OU3 pre-design investigation. A discussion of the site contaminants and quantitation limits is not applicable to the pre-design investigation because the objective of the investigation is to provide data required for the design of the selected remedy for OU3 and not for additional investigation for environmental decision-making purposes. Instead, the field investigation activities for the pre-design are discussed.

2.2.2 Field Investigation Activities

The following field investigation activities will be conducted as part of the OU3 Pre-design Investigation to provide the information necessary to support the design of the remedial option for OU3.

- Landfill surface topography and intertidal/subtidal offshore substrate topography to obtain the current topography and accurate investigative locations.

- Cone penetration testing (CPT) to determine the thickness of the landfill/waste material as well as to obtain in-situ geotechnical characteristics of the existing surface soil, waste/fill material, and underlying mudflats material/sediment.

- Deep boring sampling and analysis of the existing surface soil, waste/fill material, and underlying mudflats material/sediment as well as the underlying rock to determine the geotechnical characteristics of the materials.

- Surface soil sampling and analysis (including shelby tube sampling) to determine the current surface soil geotechnical characteristics. Disturbed samples will be used to determine the suitability of the existing clay cover material within the running track of the OU3 area for use in the proposed cap. If suitable the material would be removed from its existing location and placed within the cap as determined by the design. Undisturbed samples, either Shelby tube or sand-cone density, are to determine the density of the soil so volume of suitable material can be determined.

- Test pitting to determine the horizontal extent of the landfill.

- Landfill gas survey and field testing to investigate and determine the emission rate of methane, if any, from the landfill.

- Installation of piezometers and the collection of groundwater level readings and tidal surface water level measurements to obtain groundwater potentiometric contours, and correlation to surface water levels in the cove.

- Completion of a wetland functions and values assessment to support the evaluation of the impacts to wetlands.

- A visual inspection of the Clark Cove rip-rap and earthen shoring material to support the design of the shoreline erosions controls in Clark Cove.

- Sand-cone density testing for surface soil samples if a shelby tube sample cannot be collected for laboratory testing.

Data from CPT, test pitting, and deep borings will provide a better estimation of the volume and extent of waste in the areas under consideration for consolidation. The evaluation of consolidation will be conducted as part of the landfill cover design.

Details of the rationale and sample location selections for each of these investigations are discussed in Section 3.1. Details of the investigation procedures are discussed in Sections 3.2 and 3.3. The sections following Section 3.0 contain details of how the field data or fixed-base laboratory data will be verified, checked for quality, processed, and presented in the data package.

2.2.3 Sampling Tasks

Samples will be collected during the following field activities:

- Deep borings to gather sediment samples for geotechnical laboratory testing and rock cores for field testing
- Sampling of the existing clay cover surface soil for geotechnical laboratory testing
- Gas samples for field testing
- Subsurface waste and soil sampling for visual classification during the installation of piezometers

Details regarding the sampling methodologies and procedures are presented in Section 3.2.

2.2.4 Systems Designs

This section relates to remediation and/or monitoring engineering design systems. Such systems are not applicable to the pre-design investigation or design for the OU3 landfill cover and shoreline erosion controls. A separate QAPP for the monitoring program for the OU3 remedy will be developed after the ROD for OU3 is signed.

2.2.5 Analytical Tasks

Various geotechnical analyses will be performed during the Pre-Design Field Investigation. Geo Testing Express, Inc. of Boxboro, Massachusetts will perform the goetechnical tests in the laboratory. Field tests will also be performed by TtNUS or designee.

Sediment and surface soil samples for geotechnical testing will be transported from the site to the laboratory by Geo Testing Express, Inc. and the samples will be tested for the following parameters:

- Soil classification
- Moisture content
- Undisturbed material density
- Disturbed material density
- Liquid and plastic limits
- Grain size distribution
- Specific gravity
- Moisture-density relationship
- Permeability
- Consolidation
- Triaxial Compression

American Society for Testing and Materials (ASTM) test methods will be used for these tests. The selected laboratory, Geo Testing Express, Inc., is certified according to USACE-New England District. Field or laboratory QC samples are not required for geotechnical testing. Any QC associated with field testing is addressed under calibration in Section 4.0.

In addition to the laboratory geotechnical testing listed above, various field testing methods will be performed to support the OU3 design. These ASTM field tests include the following:

- Visual soil classification
- In-situ material density (only if sand cone method is performed)
- Rock Quality Designation (RQD)

2.2.6 Data Verification and Validation Tasks

Geotechnical data will be verified and checked as part of this project. The requirements and procedures for verification and checking of geotechnical laboratory results are discussed in Section 6.0 of this QAPP. Chemical data will not be collected; therefore, validation is not required for this project.

2.2.7 Data Usability Assessments

Data usability assessments will be based on the results of data verification and checking and a reconciliation of the investigation outcome with project quality objectives. Descriptions of these activities are provided in Section 6.3. Data usability will also be evaluated as part of the preliminary design phase.

2.2.8 Quality Assurance Assessments

Quality assurance assessment for this project is discussed in Section 7.0 of this QAPP.

2.2.9 Records and Reports

This QAPP will be submitted for review to the USEPA, MEDEP, and RAB as draft and final versions. A final version will be prepared in response to the comments received on the draft version and documented in the final report. The final version will be distributed per the PNS distribution list (see Table 1-1).

The data collected during the implementation of the QAPP will be prepared as a data package. Data collected as part of the pre-design investigation will be used as part of the OU3 remedial design, which will be documented in a design report. The data package will include the following field investigation documents:

- Cone penetration testing results and interpretation (prepared by Applied Research Associates, Inc.)
- Boring logs and subsurface soil sample collection logs and records (prepared by TtNUS).
- Surface soil sample collection logs and records (prepared by TtNUS).
- OU3 topographic mapping of the entire landfill and surrounding areas (prepared by Owen-Haskell). This will include the incorporation of hydrographic survey data (prepared by Ocean Surveys).
- Test pitting logs (by TtNUS).
- Landfill gas survey readings and results (prepared by Beacon Environmental Services, Inc.).
- Piezometer construction logs, direct push classification logs, and subsequent water level measurements. This will include the reporting of groundwater and surface water level data for the corresponding period of time (prepared by TtNUS).

- Wetland functions and values assessment (prepared by Woodlot Alternatives, Inc.).

- Results of the visual inspection of the Clark Cove rip-rap and earthen shoring material (prepared by USACE).

- Sand-cone density testing results (if performed) (prepared by USACE).

The data package will also incorporate the following data obtained from the field investigation:

- Chain-of-custody forms (prepared by TtNUS)
- Daily Quality Control Report (DQCR) forms (prepared by TtNUS)
- Surveyed investigative locations map (prepared by TtNUS)
- Geotechnical laboratory test results (from Geo Testing Express)
- Water level data (groundwater compiled with tidal survey data) (prepared TtNUS)
- Groundwater contour maps (prepared by TtNUS)
- Landfill gas survey contours (prepared by Beacon Environmental Services, Inc.)
- Wetland functions and values field data (prepared by Woodlot Alternatives, Inc.)
- Discussion of Clark Cove shoreline rip-rap and earthen shoring material (prepared by USACE)

Deviations from the final QAPP will also be discussed in the data package.

2.2.10 Project Schedule

The schedule for the main phases of the project and deliverables are presented in Table 2-2.

2.3 PROJECT QUALITY OBJECTIVES AND MEASUREMENT PERFORMANCE CRITERIA

The following section details the project quality objectives that have been developed for the OU3 Pre-design Investigation activities currently scoped. According to the USEPA-NE QAPP guidance (USEPA, October 1999), project quality objectives are descriptions of the type, quality, and quantity of data needed to answer a specific environmental question. However, project quality objectives as applied to the current pre-design investigation are to define the type, quality and quantity of data required for design purposes. Measurement performance criteria are objective measures that can be used to determine whether a project quality objective has been met.

2.3.1 Project Quality Objectives

Project quality objectives were developed using the USEPA DQO process as a guide. This section summarizes the seven DQO steps, listed below, as applied to the OU3 Pre-design Investigation.

1. State Objectives
2. State the Decisions to be made
3. Identify Information needed to make Decisions
4. Establish Spatial and Temporal Boundaries of Investigation
5. State the Decision Rules
6. Establish Error Tolerances
7. Optimize Sampling Plan Design

Details on the sampling process design and sampling procedures/requirements are provided in Section 3.0.

Step 1 - State the Objective

The objective of the pre-design investigation is to collect physical/geotechnical data to support the design of the remedy for OU3. Previous investigations were focused on obtaining data to address environmental questions for this site.

Step 2 - State the Decisions to be made

Decisions will be made during the design of the OU3 landfill cover system and shoreline erosion protection based on the results from the pre-design investigation. The design documents will be primary documents in accordance with the Federal Facility Agreement for PNS; and will be submitted for review and comment by USEPA, MEDEP, and the RAB. As lead agency under CERCLA, the Navy will make the decisions after considering comments raised during the review and comment process. The decisions during the design will be made on the following broad topics:

i) Landfill slopes and geometry
ii) Landfill cover components
iii) Factor of safety to protect against slope failure
iv) Suitability of the existing clay layer over the dredge spoils area for use in the barrier layer of the landfill cover
v) Landfill boundary and extent of cover system
vi) Landfill gas management requirements

vii) The need for wetlands mitigation when shoreline erosion controls are implemented.

Step 3 - Identify Information needed to make decision.

The decisions for the OU3 design identified in Step 2 will be based on the following characteristics:

i) Geotechnical information will be used to determine future cover system settlement characteristics. Soil borings will be used at a selected number of limited locations to collect samples to determine these properties. Cone Penetration Testing (CPT) will also be used to obtain indirect data at additional locations to estimate these same properties over a larger portion of the landfill. Undisturbed samples of tidal mudflats underlying the landfill are required for testing their consolidation and strength characteristics. CPT and deep borings will provide information on the thickness of the waste layer which that will be used in the settlement analysis and to in the estimation of the waste volume to consider for consolidation. The slope of the surface of the cover and the drainage layer will be determined based on the extent of settlement that can be expected.

ii) Cover system components will be determined based on the characteristics of the landfill material, cover geometry and slopes (above), rainfall data, and other design parameters. The cover components, such as the geomembrane material and thickness, will also be determined based on the results of the settlement and consolidation analysis. Drainage layer features will be incorporated in the cover system and grading plan to provide acceptable conveyance after consolidation has occurred.

iii) The geotechnical information will also be used to determine the slope stability of the landfill material. Hydrographic contour data will also be used to determine possible slope failure planes. Groundwater potentiometric data will be used in the slope stability analysis and determination of a factor of safety to protect against slope failure. Piezometers at several locations will be used to monitor groundwater levels over several tidal fluctuation cycles to obtain this information. Slope stability analysis will be conducted using information on groundwater levels change with the tidal cycle. Seepage forces can be calculated from the drawdown gradient. The areal extent the forces are applied to will be determined by the inland extent of drawdown. The design will be adjusted to achieve acceptable slope stability based on site-specific information (which will be determined as part of the design and documented in the design report).

iv) Permeability and moisture-density relationship information will be used for evaluating the use of the existing clay cover material over the dredge spoils that covers the southern portion of the

landfill (within the running track) as a possible source for the OU3 cover system. For this task, surface soil samples within the known boundary of the clay layer will be collected.

v) Visual identification and classification of the subsurface material along the expected edges of the landfill will be used to determine the extent of landfill. Test pits will be excavated at several locations perpendicular to the expected edge of landfill. Test pitting will also provide information to conduct a better estimation of the volume and extent of wastes in the areas under consideration for consolidation (as part of the landfill cover design). A survey of the topography and extent of the landfill will be used for the design of the landfill cover system dimensions.

vi) Landfill gas emissions, if any, will be detected and an emission rate will be estimated.

vii) The functions and values of the wetlands as defined in The Highway Methodology Workbook Supplement by the U.S. Army Corps of Engineers, New England District. Functions are defined as the self-sustaining properties of a wetland ecosystem that exist in the absence of society. Functions result from both the living and non-living components of a wetland. These include all processes necessary for the self-maintenance of the wetland ecosystem such as primary production and nutrient cycling. Therefore, functions relate to the ecological significance of wetland properties without regard to subjective human values. Values are benefits derived from either one or more functions and the physical characteristics associated with the wetland. The value of a particular wetland function, or combination thereof, is based on human judgement of the worth, merit, quality, or importance attributed to those functions.

Step 4 - Establish Spatial and Temporal Boundaries

The spatial and temporal considerations for the decisions identified in Step 2 are identified in Step 4. These considerations for this project are as follows:

i) Soil borings are planned at locations representing approximately equal areas of the landfill, with additional density near the Clark Cove shoreline for visual characterization and to obtain samples from the underlying tidal mudflat. The additional density of samples in Clark Cove area is required for targeting the thicker layer of tidal mudflats expected. CPT will be conducted at a higher frequency of two per acre of landfill area to obtain more information. No temporal effects are expected to be present.

ii) The spatial and temporal boundaries as described under paragraph (i) above will be adequate for decision to be made regarding cover system components.

iii) The spatial and temporal boundaries as described under paragraph (i) above will be adequate for decision to be made regarding cover system components. Additionally, the piezometers are located along transects through the landfill mass. The spacing of these piezometers should be sufficient for the development of groundwater contours and the analysis of tidal influence on the groundwater under the OU3 area. Temporal considerations are related to the changes in tide/tidal influence.

iv) Surface soil samples for barrier soil characterization will be taken from locations spaced to approximately represent equal areas of the existing dredge spoils cap. No temporal effects are expected.

v) Test pits are located at points where information is not available with respect to the horizontal extent of landfill material. No temporal effects are expected.

vi) Landfill gas survey points will be located at the frequency of one per acre. Sample collection will be targeted towards maximum soil gas emission times corresponding to the earth-tide phenomenon, as discussed in Section 3.1.6.

vii) The spatial boundaries for the wetlands functions and values assessment are limited to the intertidal areas of the shorelines in Jamaica Cove and Clark Cove, excluding the rip-rap covered areas in the southern shoreline of Clark Cove. The temporal boundary is determined by the tide and season. The time of day for the assessment will be during low tide to allow observation and access. The season will be summer/fall to ensure the highest level of ecological activity.

Step 5 - State the Decision Rules

The specific decision rules will be based on engineering principles and professional judgment during the design. The design report will document the decisions that were made based on the data in the development of the design. For the shoreline erosion controls, scientific judgement and regulatory information will be used to determine whether mitigation of wetlands would be required.

Step 6 - Establish Error Tolerances

Error tolerances are not applicable to the collection of geotechnical data for design purposes. Error tolerances are not applicable to wetlands functions and values assessments.

Step 7 - Optimize Field Investigation Plan

Engineering judgement and available data on the site have been used to determine the number and location of investigation activities and samples. The types of investigative activities and the number of samples has been planned with the OU3 Navy case team (consisting of Navy, TtNUS, and USACE personnel as listed in Table 2-1). Regulatory and RAB participation in the optimization of the field investigation plan for this project is through review and comment on the draft QAPP. Revisions to the investigation activities and numbers/locations of samples based on comments on the draft QAPP have been made as required. Comments received on the draft QAPP with the Navy's responses are provided in Appendix D of this QAPP. The responses indicate the revisions made based on the comments received. The field activities are discussed in detail in Section 3.0. Based on the planned field investigation activities, the data from this single mobilization for the pre-design investigation effort should be sufficient for design purposes.

2.3.2 Measurement Performance Criteria

The quality assurance objectives typically used for all chemical measurement data include considerations for precision, accuracy, completeness, and comparability (PARCC). However, for geotechnical testing these parameters are not measured with the same level of rigor. Therefore, the PARCC parameters will be used as a guide for quality assurance. To meet any applicable PARCC requirements, quality control procedures are implemented in the field during sample collection and in the laboratories during sample analysis.

2.3.2.1 Precision

Precision is a measure of the mutual agreement among individual measurements of the same property under the same or similar conditions. Precision for chemical data is typically measured using field and laboratory duplicates. However, field duplicates are not required for geotechnical testing purposes. Furthermore, ASTM standards typically do not specify precision requirements and indicate that precision can vary between operators and laboratories. Therefore, it is expected that the use of a reputable laboratory meeting certification requirements and performing periodic precision checks should ensure that the results are within acceptable precision limits if any.

2.3.2.2 Accuracy

Accuracy/bias is the degree of agreement of an observed value (sample result) with an accepted reference or true value (standard). The agreement is usually expressed as a percentage for accuracy and as a difference of (100% - Accuracy) for bias. Accuracy is a measure of the bias of a system but

without the algebraic sign. ASTM standards do not provide accuracy or bias requirements. Calibration checks and corrective measures will be used to ensure that the bias of test results is controlled.

2.3.2.3 Representativeness

Representativeness typically expresses the degree to which a sampling design accurately and precisely reflects the conditions of the site. The consistent collection, preservation, and analysis of samples according to standardized procedures will control representativeness.

Representativeness can be assessed, in part, through the measures of precision and accuracy. Ultimately, the true representativeness of a sampling design cannot be assessed because the true condition of the site cannot be measured. However, a systematic and well-designed sampling plan that considers all pertinent site information and data uses should have the greatest chance of representative site conditions. For geotechnical testing, the rationale for the sampling design, as discussed in Section 3.0 takes into account the need for representativeness of the expected variability in physical properties of the site material.

2.3.2.4 Comparability

Comparability is a measure of the degree of confidence with which one set of data can be compared to a related set of data. Comparability is typically used to address consistency in sampling and consistency within the analytical method applied for chemical analyses. The QA objective for comparability is to ensure that the results of analyses for this project can be compared with potential future sampling events and potentially with analyses by other laboratories. However, for geotechnical testing under the scope of this project, seasonal changes do not significantly affect the soil/fill material properties; therefore only one round of sampling is required. The geotechnical test methods are standardized to the extent practicable by ASTM and therefore comparability should be acceptable.

The landfill gas survey will be completed in the summer months to account for potential variations and lower readings that may be recorded if the survey was performed during cooler periods.

2.3.2.5 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system relative to the amount that would be expected to be obtained under correct, normal conditions. However, adequacy of data (including completeness) for design purposes depends on the specific geotechnical properties of the soil and the variability of the properties at the site. The adequacy of the data will be determined as part of the design and will be documented in the design report.

2.3.3 Decision Rules

The outputs from DQO Steps 1 through 4 are assimilated into descriptions of how data will be used for decision making. Specific decision rules are not applicable to the OU3 Pre-design Investigation. The cover system design decisions based on the pre-design investigation will be incorporated into the design for the remedy for OU3. Rationale for the selection of pre-design investigation locations, quantity of samples, and other field decisions is presented in Section 3.0.

TABLE 2-1

CASE TEAM LIST
OU3 PRE-DESIGN INVESTIGATION QAPP
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Name	Title	Affiliation	Project role
Deborah Cohen	Project Manager	TtNUS	TtNUS PM
J.P. Kumar	Maine PE	TtNUS	TtNUS technical oversight
John Wright	Lead Engineer	TtNUS	TtNUS technical lead and geotechnical support
Tom Johnston (available on a consulting basis)	DQO Facilitator	TtNUS	DQO advisor
Paul Frank (available on a consulting basis)	QA Officer	TtNUS	QA advice
Matt Soltis (available on a consulting basis)	Health and Safety Specialist	TtNUS	Health and safety support
Fred Evans (available by telephone, e-mail, and meeting)	Remedial Project Manager	Navy	Lead organization (Navy) project management
Jim Briggs (available by telephone, e-mail, and meeting)	Design Manager	Navy	Lead organization (Navy) design management
Marty Raymond (available by telephone and e-mail)	PNS IRP Manager	Navy (PNS)	PNS management
David Ray (available by telephone, e-mail, and meeting)	USACE Design Manager	USACE	Design contractor (for Navy) project management
Jim Conroy (available by telephone, e-mail, and meeting)	USACE Project Engineer	USACE	Design contractor (for Navy) technical lead
Meghan Cassidy (available to Navy by telephone and e-mail)	USEPA Remedial Project Manager	USEPA Region 1	USEPA Region I project oversight (See Note)
Iver McLeod (available to Navy by telephone and e-mail)	MEDEP Remedial Project Manager	MEDEP	MEDEP RPM (See Note)

Note: USEPA and MEDEP input to the DQOs are through review of the draft QAPP. USEPA and MEDEP comments on the draft QAPP are addressed in writing by the Navy and included as part of the final OU3 Pre-design QAPP. PNS RAB members (not included in this table) also provided comments on the draft QAPP and their comments are addressed in writing by the Navy and included as part of the final QAPP. The responses to the comments on the draft QAPP are provided in Appendix D.

TABLE 2-2

PROJECT SCHEDULE TIMELINE
OU3 PRE-DESIGN INVESTIGATION QAPP
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Activities(1)	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverables	Deliverable Due Dates
Prepare Draft QAPP	May 2001	June 2001	Report	June 2, 2001
Prepare Final QAPP	July 2001	August 2001	Report	August 3, 2001
Hydrographic Survey	May 2001	May 2001	Map (2)	See data package (3)
Landfill Topographic Survey-Phase I	June 2001	July 2001	Map (2)	See data package (3)
Landfill Topographic Survey-Phase II	July 2001	August 2001	Map (2)	See data package (3)
Landfill Topographic Survey-Phase III	September 2001	September 2001	Map(2)	See data package (3)
Piezometer Installation	August 2001	September 2001	Data download (2)	See data package (3)
Geotechnical Sampling	August 2001	September 2001	Laboratory report (2)	See data package (3)
Cone Penetration Testing	August 2001	September 2001	Field test report with interpretation (2)	See data package (3)
Test Pitting	August 2001	September 2001	Test pit logs (2)	See data package (3)
Landfill Gas Survey	August 2001	September 2001	Field test report with interpretation (2)	See data package (3)
Wetlands Functions and Values Assessment	August 2001	September 2001	Field test report with interpretation (2)	See data package (3)
Prepare Data Package	September 2001	November 2001	Data package	November 12, 2001

(1) Rationale for the phasing and schedule of field activities provided in Section 3.1.
(2) The deliverable will not consist of a formal submittal. The information will be included in the data package. Where applicable, electronic data will also be provided to the Navy design team.
(3) Formal submittal date corresponds to the data package submittal.

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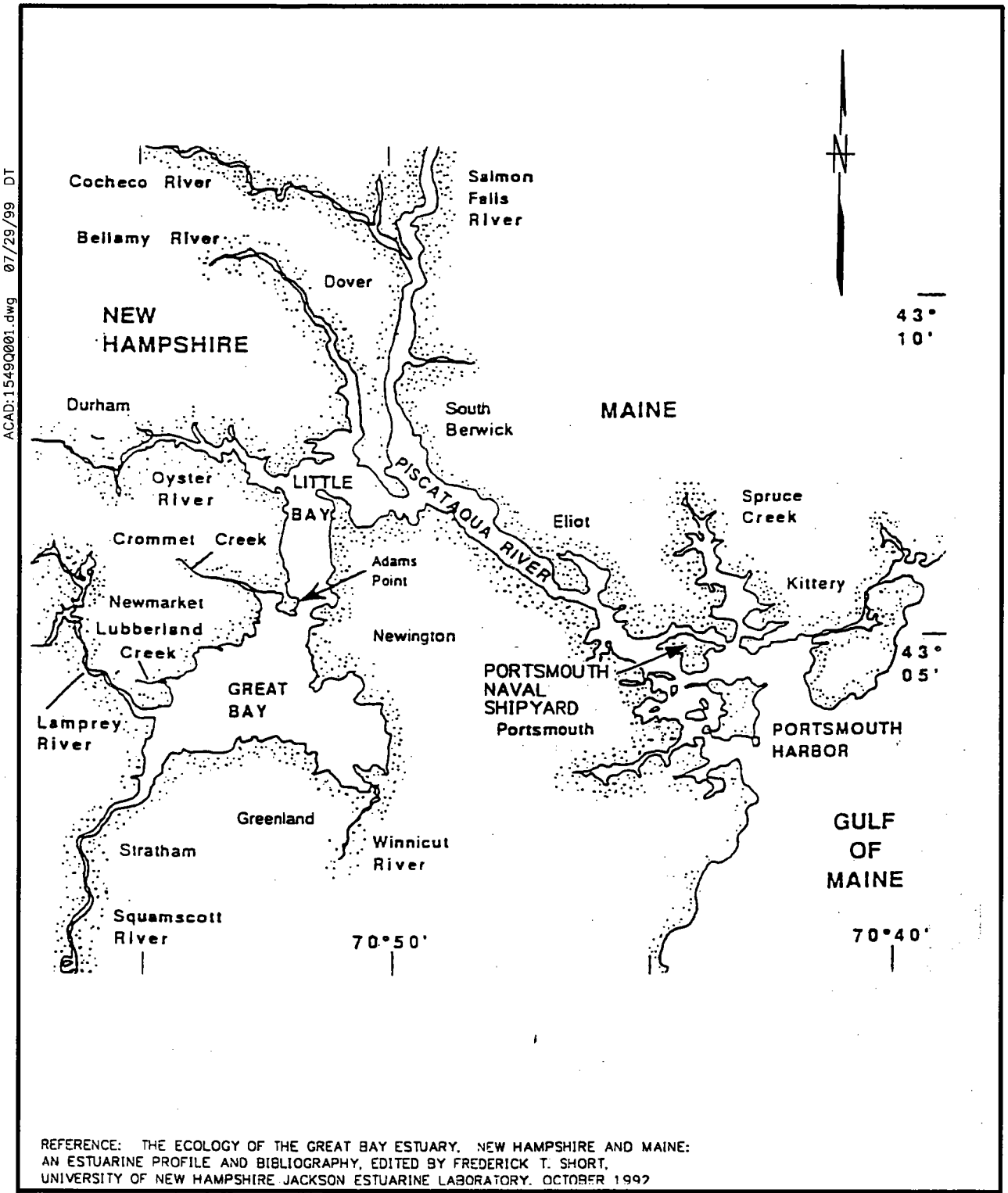

REFERENCE: THE ECOLOGY OF THE GREAT BAY ESTUARY, NEW HAMPSHIRE AND MAINE: AN ESTUARINE PROFILE AND BIBLIOGRAPHY, EDITED BY FREDERICK T. SHORT, UNIVERSITY OF NEW HAMPSHIRE JACKSON ESTUARINE LABORATORY, OCTOBER 1992

DRAWN BY DLT DATE 7/29/99	Tetra Tech NUS, Inc.	CONTRACT NO. 1549	OWNER NO. 0166
CHECKED BY DJC DATE 9/8/99	VICINITY MAP PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE NOT TO SCALE		DRAWING NO. FIGURE 2-1	REV. 0

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

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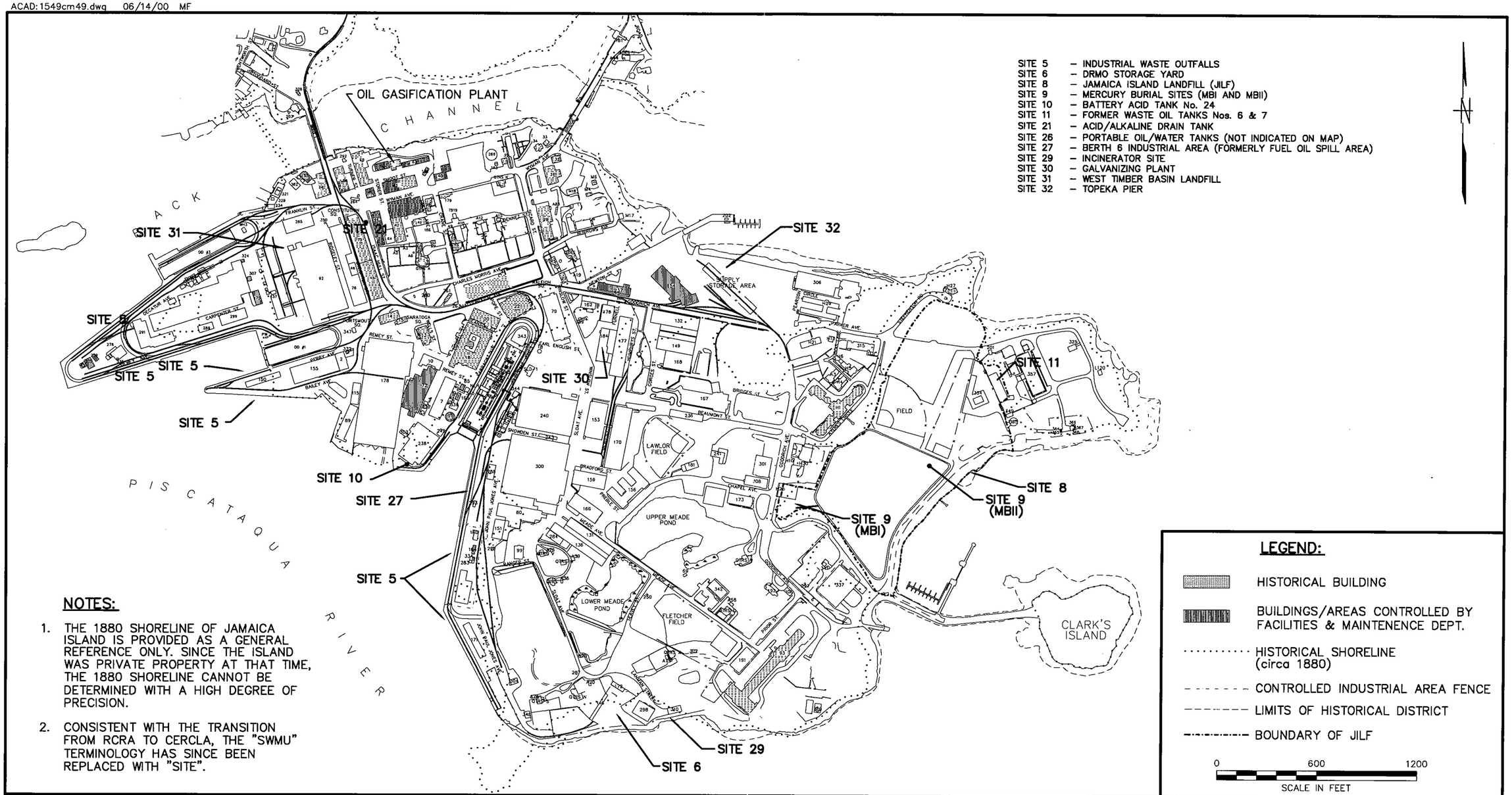

NOTES:

1. THE 1880 SHORELINE OF JAMAICA ISLAND IS PROVIDED AS A GENERAL REFERENCE ONLY. SINCE THE ISLAND WAS PRIVATE PROPERTY AT THAT TIME, THE 1880 SHORELINE CANNOT BE DETERMINED WITH A HIGH DEGREE OF PRECISION.
2. CONSISTENT WITH THE TRANSITION FROM RCRA TO CERCLA, THE "SWMU" TERMINOLOGY HAS SINCE BEEN REPLACED WITH "SITE".

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY DLT DATE 7/29/99
CHECKED BY DJC DATE 7/20/00
COST/SCHED-AREA
SCALE AS NOTED

Tetra Tech NUS, Inc.

FACILITY SITE MAP
PORTSMOUTH NAVAL SHIPYARD
KITTERY, MAINE

CONTRACT NO. 1549
OWNER NO. 0166
APPROVED BY DATE
APPROVED BY DATE
DRAWING NO. FIGURE 2-2
REV. 0

FORM CADD NO. T+NUS_BH.DGN - REV 0 - 1/20/98

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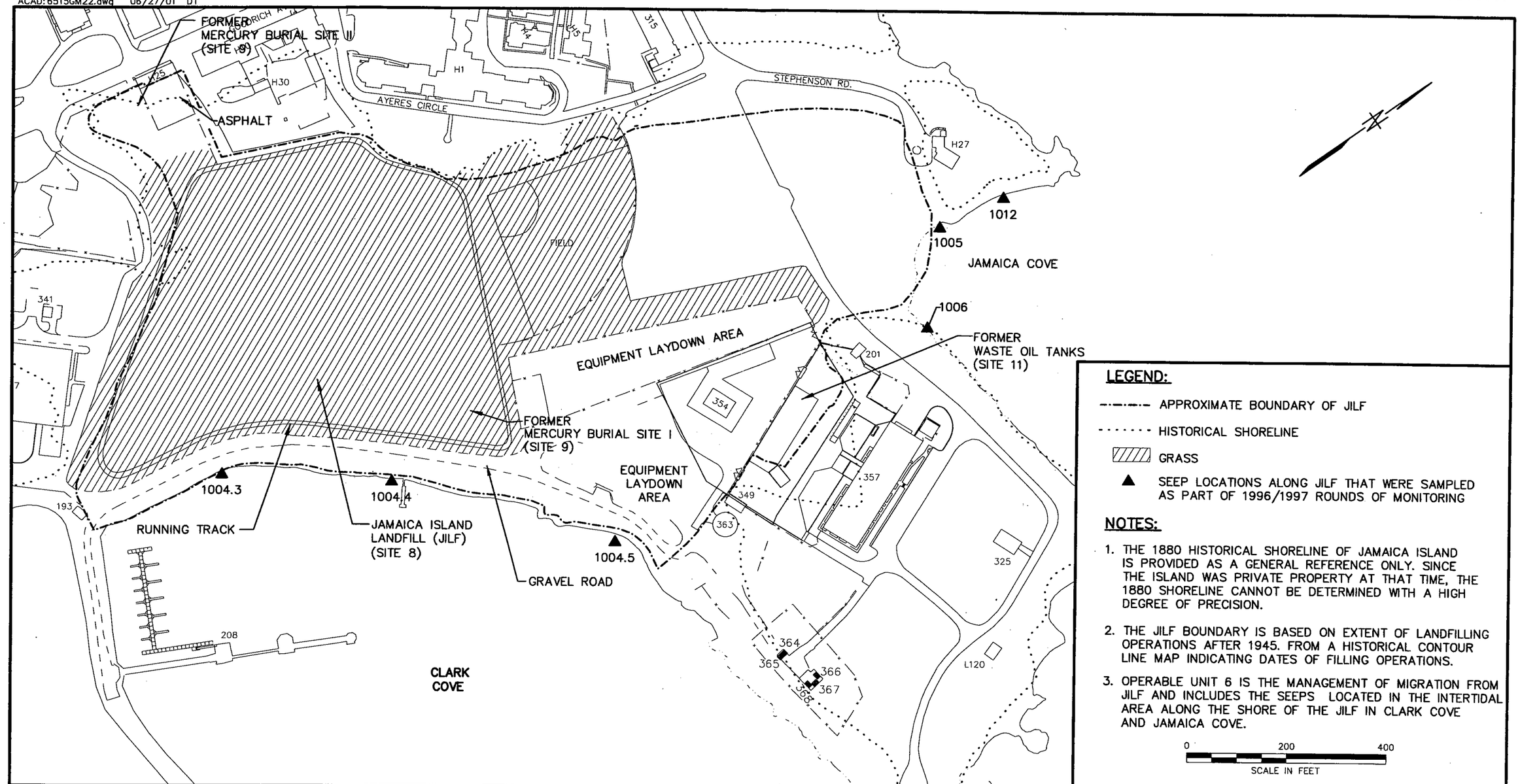


NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJP DATE 3/28/01
CHECKED BY DJC DATE 7/10/01
COST/SCHED-AREA
SCALE AS NOTED

Tetra Tech NUS, Inc.

OPERABLE UNIT 3 LAYOUT MAP
PORTSMOUTH NAVAL SHIPYARD
KITTERY, MAINE

CONTRACT NO. 6515 | 0232 0232
APPROVED BY DATE
APPROVED BY DATE
DRAWING NO. FIGURE 2-3 | REV. 0

FORM CADD NO. TtNUS_BH.DGN - REV 0 - 1/20/98

3.0 FIELD INVESTIGATION RATIONALE, PROCEDURES, AND REQUIREMENTS

This section provides the detailed discussions related to the field investigation rationale, procedures, and requirements for the planned field investigation activities.

3.1 FIELD INVESTIGATION RATIONALE

This section provides the specific objectives and details of the rationale for each field investigation task. As outlined in Section 2.0, the following is the overall scope of the investigation:

- Surveying for landfill surface topography and intertidal/subtidal offshore substrate topography
- Geotechnical testing, Standard Penetration Tests, and CPT for landfill/waste thickness and geotechnical characteristics
- Geotechnical sampling and CPT for underlying soil and rock geotechnical characteristics
- Geotechnical sampling for current surface soil geotechnical characteristics
- Test pitting for landfill extent determination
- Estimation of landfill gas emission rate
- Piezometer installation for groundwater level readings and tidal water level measurements
- Wetland functions and values assessment
- Visual inspection of Clark Cove shoreline
- Sand-cone density testing if a shelby tube sample cannot be collected for laboratory testing

The information obtained during the Multi-sensor Towed Array Detection Survey (MTADS), previous test pitting activities, and other investigation activity was considered in the placement of the investigation locations.

CPT, test pitting, and deep boring locations within the areas being considered for consolidation (former MBII area and northern portion of landfill near Jamaica Cove) will be used to support the estimation of the volume and extent of waste in these two areas.

The area planned for surveying activities is depicted in Figure 3-1. Figure 3-2 provides the planned locations for the geotechnical sampling, test pitting, and piezometer installation. Figure 3-3 provides the planned locations for the CPT and landfill gas survey (LGS) tests.

The piezometers will be installed as the first investigation activity. The piezometors will be installed early in the investigation in order to facilitate the collection of the month-long groundwater data.

The deep boring and surface soil geotechnical sampling is planned to be the second activity of work. Information from deep borings will be used for the correlation of the subsequent CPT activities. The test pits will be performed concurrently with the CPT activities and will use all completed investigation information for the field adjustment of test pit locations as needed. The LGS, wetlands functions and values assessment, and visual inspection of Clark Cove shoreline will be performed throughout the field investigation.

Table 3-1 provides a summary of the required sample collection data. A master investigation plan and tables of all field investigation survey locations and descriptions are presented in Appendix A.

3.1.1 Rationale for Surveying Activities

The surveying activities are based on the total area required to be mapped for use in the OU3 design. Landfill surface topographic and adjacent cove hydrographic activities are planned to gather and develop the data for use in the OU3 design. The surveying data will be used to design the physical layout of the landfill cover system and reuse facilities. The survey will also provide permanent horizontal and vertical control for design and construction of the landfill closure.

Aerial photography and land-based surveying will be used to develop detailed (1-foot contour) topographic maps of the OU3 surface and surrounding area surface features. Accurate and current topography is needed to perform the OU3 design calculations and development of the grading plan. The landfill topographical survey area is assumed to encompass an area of approximately 44 acres, with the landfill area comprising approximately 25 acres. The larger area helps to determine cover termination and surface drainage requirements from the adjacent land. The boundary of the larger area includes the 1940 shoreline as a minimum. The landfill topographic survey and hydrographic survey will include overlaps at the shoreline to aid in the development of a single topographic contour map of the entire OU3 project area, including the adjacent surface water area.

The hydrographic survey data is needed to determine the current contours and elevations of the surface water areas adjacent to OU3 (Clark Cove and Jamaica Cove). The information from the hydrographic survey will be incorporated into the OU3 topographic survey and used for the evaluation and design of the landfill cap, analysis of slope stability, and design and selection of shoreline protection.

The hydrographic survey was performed along the Clark Cove and Jamaica Cove shorelines on May 21 and 22, 2001. The survey was based on obtaining bathymetry on approximate 10-foot intervals along planned transects. The transect lines, shown on Figure 3-1, were generally followed and were extended from the shore at high tide to a distance of approximately 400 feet from the shoreline. The 400-foot distance was based on the assumption that the deepest point of Clark Cove occurs at that distance from

shore. Transects were followed until the operator detected and confirmed a rise in the cove floor after defining the deepest locations and channels. An approximate spacing of 50 feet between transect lines was assumed to provide adequate resolution for developing contours. Additional data was collected as needed to develop 1-foot contour mapping of the floor of the cove areas.

Additional surveying activities include the pre- and post-field investigation location of all activities. Sampling/investigative locations will be pre-located with surveyed and marked stakes to accurately identify these locations for the field team and subcontractors. Surveying of completed investigative locations as part of a post-work survey will be conducted to accurately record and depict the final location of all field investigation locations.

3.1.2 Rationale for Geotechnical Sampling Locations

Consistent with the DQOs generated during Steps 1 through 6, a biased sampling scheme is planned for the geotechnical sampling (deep borings and surface soil sampling). Eight deep soil and rock borings and four surface soil sample locations are planned to collect soil samples for subsequent field and laboratory geotechnical testing. An additional deep boring may be advanced in the future planned location of the crane test pad. This location will be determined prior to the start of the deep borings and will be located by PNS personnel in the field.

The eight borings for the OU3 pre-design investigation are identified as DB-1 through DB-8. The rationale for the locations of the soil borings is to obtain a wide cross section of representative samples of landfill material for visual classification in the field and of tidal mudflats samples for geotechnical testing in the laboratory. DB-1 is located within the dredge spoils disposal area. DB-2, DB-6, and DB-7 are located within general fill areas. Emphasis is placed on collecting buried tidal mudflat samples from soil borings DB-3, DB-4, and DB-5 along the Clark Cove shoreline because of the expected presence of a greater thickness of this natural deposit in this area. DB-8 is located in the northern-most fill area to provide geotechnical data on all strata including bedrock in that area.

An additional deep boring (which if performed will be designated as DB-9) will be located in the center of the Shipyard's proposed new crane test pad location. The geotechnical data from this boring will also assist in determining cover design requirements to support the crane test pad.

Four surface soil samples (locations SS-1 through SS-4) will be collected to determine the geotechnical characteristics of the existing clay cover material within the running track of the OU3 area. The disturbed samples will be designated as SS-1D through SS-4D and the undisturbed samples will be designated as SS-1U through SS-4U.

The geotechnical characteristics obtained from the surface samples will be used in the design evaluation of the clay cover material as a possible source of cover material for the construction of the planned cap system. The sample locations are based on the division of the existing cover area into four approximately equal areas, and then by locating a sample within each quarter area. These sample locations include field measurement of in-situ density measurement using the sand-cone method if Shelby tube samples cannot be collected for laboratory testing.

3.1.3 Rationale for Test Pit Locations

Test pits will be used to fill in the gaps between points of known landfill boundary and the historical shoreline. The test pits will be in the general configuration of trenches, with the length of each trench greater than the width. These investigation features are classified as pits in this report due to the same designation used for similar activities during previous investigations. Test pit (T-1 through T-17) locations were identified using historical photographs showing landfilling within the area of tidal mudflats between the Seavey Island and Jamaica Island. Test pits are planned at locations that were selected based on available information on the historical shoreline (circa 1880), the 1940 shoreline, and the estimated landfilling contour dates. All test pits are planned to define the interface between the original shoreline and undisturbed soil/rock and the waste/fill material. The test pits will be advanced from the assumed clean area to the waste/fill material.

The following is the rationale for each test pit location:

- Test pits T-1 and T-2 are planned to verify the western extent of the dredge spoils and waste along historic Clark Cove shoreline. Test pit locations are not planned in the region between the shoreline to T-1 due to the well defined limit of fill as shown on aerial photographs and the physical boundary created by the headwall in this location.

- Test pits T-3, T-4, and T-5 are planned to verify that the JILF boundary does not extend further west toward the historical shoreline and 1940 shoreline.

- Test pits T-6, T-7, T-8, T-9, T-10 are planned to determine the extent of fill material in the northern portion of the site. These test pit locations are planned to provide information about the nature and extent of the fill material adjacent to Jamaica Cove.

- Test pit T-11 is planned to determine the extent of waste fill material and clean general fill used to construct the former ammunition storage facility.

- Test pits T-12 and T-13 are planned to verify the eastern extent of landfill materials in the eastern portions of the site.

- Test pits T-14, T-15, and T-16 are planned to determine the nature and extent of the fill material on the southern side of the former causeway (Parker Avenue) that was constructed to connect Seavey Island with Jamaica Island. These test pits are also planned to verify that the JILF boundary does not extend to and under the roadway. The roadway was constructed prior to landfilling operations. No waste material was found when utility trenching was conducted within the roadway during construction of the hazardous waste facility. T-15 and T-16 may be continued on the northern side of Parker Avenue to develop a cross-section for the clean fill that was used to construct the causeway.

- Test Pit T-17 is planned to investigate the extent of the fill material between Building 315 and Ayeres Circle.

No test pits are planned in the area between T-2 and T-3 due to the well-defined boundary created by the original headwall and roadway.

No test pits are planned for the limits of the landfill between T-5 and T-17 due to the well-defined boundary where the landfill material meets the steep hillside. It is assumed that landfill material is present up to this boundary.

Test pits are not planned along the Clark Cove shoreline. It is assumed that fill materials extends to the dike structure. Along the shoreline, the extent of the cap will be determined by slope stability considerations.

Additional test pits may be added in the field to confirm field observations.

The depth of excavation for the test pits will be limited to the water table because of the physical limitation caused by sloughing of sidewalls under water. The test pits located along the Clark Cove shoreline (T-12 and T-13) and the Jamaica Cove shoreline (T-8, T-9, and T-10) are expected to be within a tidally-influenced groundwater zone and therefore, the timing of the test pitting will take into account the groundwater fluctuation (i.e. performed or observed at low tide).

Visual identification and classification will be used to make the determination of the extent of landfill/waste as discussed further in Section 3.2.

3.1.4 Rationale for Piezometer Locations

Consistent with the DQOs generated during Steps 1 through 6, a biased sampling scheme is planned for 22 piezometer locations. Existing groundwater contour maps [in Section 2.0 of the OU3 Feasibility Study (FS), TtNUS, November 2000] indicate approximate flow lines toward Clark Cove and Jamaica Cove. The piezometers will be installed to further define these flow lines and to monitor the water level within the landfill and to determine how groundwater levels change with the tidal cycle. Information obtained from these water levels will be used in the slope stability analysis.

Eighteen piezometers (P-1 through P-14 and P-19 through P-22) will be installed along 3 arrays as shown on Figure 3-3 to monitor groundwater levels within the landfill materials. In addition, 4 piezometers (P-15, P-16, P-17, and P-18) will be installed within the original buried tidal mudflat layer to monitor pore-water pressure fluctuations related to Clark Cove. These 4 piezometers will be located adjacent to P-6, P-7, P-13, and P-14 along the Clark Cove shoreline which are screened within the overburden.

Piezometers will be located on a straight line away from the shoreline to determine the inland extent of groundwater fluctuation. Two rows of piezometers will be installed along lines approximately perpendicular to Clark Cove shoreline and one row of piezometers will be installed along a line perpendicular to Jamaica Cove. It is expected that the steepest and therefore critical gradient will occur along the south line of piezometers leading towards Clark Cove (the steepest gradient is in the general area of monitoring wells JW-12 and JW-13), whereas the groundwater gradient toward Jamaica Cove (the steepest gradient toward is in approximately toward JW-15) is relatively shallow. Furthermore, the distributions and spacing of the lines is based on the relative length of shoreline for the two coves. Therefore a greater number and concentration of piezometers is needed towards Clark Cove. A spacing of 100 feet between piezometers within each line is adequate for the purposes of groundwater contour development to support the design. A total of 18 piezometers (14 along two lines towards Clark Cove and 4 along a line toward Jamaica Cove) will be screened within the surficial aquifer, with the screens extending to a length of 10 feet below the estimated low-tide depth of groundwater. Additionally, four piezometers will be installed close to the Clark Cove shoreline. These four piezometers will be screened within the original buried tidal mudflats that are underlying the landfill material.

Surface water tide data will be collected during the measurement and collection of piezometer data. This data will be used to evaluate the effect that tidal fluctuations has on the groundwater levels. Groundwater and surface water tide level data will be collected at fifteen-minute intervals for a month, and it will include monthly high and low tide levels.

3.1.5 Rationale for CPT Locations

The CPT locations (CPT-1 through CPT-54) are based on whole 1-acre grids covering the estimated landfill boundary. As shown on Figure 3-3, the 1-acre grids are designated by letter-number nomenclature (i.e., grid B-5) to provide a reference for field descriptions during activities. Based on the landfill area of 25 acres and using the rate of approximately 2 CPT locations per acre, a total of 54 CPT locations are planned. The total number of CPT locations includes additional investigation areas that exceed the two-per-acre criteria, at biased sampling locations as discussed below. Within each grid, the locations of the CPT samples have been based on targeting different landfilling date contours to the extent possible. If no landfilling date contour was noted in a grid, then the two CPT locations were selected at least 50 feet apart with consideration of spacing (at least 50 feet) from adjacent grid's CPT locations. However, some CPT locations are based on biased criteria, such as adjacent to deep borings for correlation. Outside of the whole grids, CPT locations have been distributed to represent locations within approximately 1-acre areas, with consideration of landfilling date contours, as necessary.

3.1.6 Rationale for LGS Locations

The objective of the LGS is to collect data to determine whether methane is present in the landfill. Although gas generation at OU3 is not expected, if methane is present, the emission rate will be estimated. This data will be used to evaluate the necessity for a gas collection layer in the landfill cover design. If gas collection and venting is determined to be necessary, the emission rate will be used to size the collection layer and determine the spacing of vents. Emission rates will be compared to ensure adequate flow rate capacity of the collection layer and vents. There is no distinct threshold for selecting between active and passive systems, however, given the age of the landfill there is no expectation that an active system would be necessary.

Prior EMFLUX landfill gas investigations have shown that it is not necessary to sample within the waste of a landfill to detect methane that is present. The subcontractor routinely performs soil-gas investigations where soil vapors from heavier and less volatile compounds are detected at the near surface when the compounds (present in a dissolved phase) are at depths in excess of 25 feet. Methane and carbon dioxide are extremely volatile and readily will migrate to the near surface. Typically in EMFLUX Landfill Gas Surveys gas measurements are taken at an 18-inch depth; however, because the clean surface layer overlying the waste/fill material at the Jamaica Landfill can range from 6 to 30 inches, gas measurements will be taken at a 30 inch depth at all locations in the subject investigation. Also, the time of the sampling is critical. The subcontractor will schedule fieldwork to occur during a period of maximum soil-gas movement as determined by the EMFLUX Timing Model. EMFLUX Methane surveys are performed during these periods of maximum soil-gas emissions that occur during strong gravitational influences on the earth's surface. This phenomenon, known as earth tides, has been monitored by USGS

and NASA since the 1920s and EMFLUX - which is a patented technology - is the only soil-gas system that is able to take advantage of the relationship between earth tides and vertical gas movement in the vadose zone. EMFLUX Methane Surveys are scheduled during an accelerated soil-gas emission period to maximize the detection of Methane, resulting in increased sensitivity and virtually eliminating the possibility of false negatives. Prior experience has consistently demonstrated that it is critical to sample soil gas during a maximum emission period.

Similar to the CPT locations, the LGS locations are based on whole 1-acre grids covering the estimated landfill boundary. Based on the landfill area of 25 acres and using the rate of 1 location per acre for the LGS, a total of 25 LGS locations within the landfill area have been planned. Additionally, 6 LGS locations have been selected at the perimeter of the landfill to investigate possible migration of any potential landfill gases. The locations of the LGS (LGS-1 through LGS-31) are not as critical to the OU3 design system as the CPT, and therefore the LGS may be located anywhere within a grid, but with consideration of spacing with the adjacent grid's LGS location. Outside of the whole grids, LGS locations have been distributed to represent locations within the boundaries of the landfill area.

3.1.7 Rationale for Wetlands Functions and Values Assessment Locations

Jamaica Cove mudflats and portions of the northern Clark Cove shoreline not covered by rip rap will be evaluated. The rationale for these locations is that currently no shoreline erosion controls have been placed at these locations. The southern portions of Clark Cove shoreline have already been provided with rip rap and the evaluation of the adequacy of the rip rap in this area as a shoreline erosion control has been conducted by the USACE under a separate investigation.

3.2 FIELD INVESTIGATION PROCEDURES AND REQUIREMENTS

This section of the QAPP describes how representative samples will be collected in an appropriate and consistent manner to meet the project objectives. Drilling and test pit logs will be generated, and subsurface samples and groundwater information will be obtained from borings, piezometers, and trenches. Additionally, laboratory geotechnical analyses of undisturbed, disturbed, and surface soil samples will also be performed. Standard Operating Procedures (SOPs) for conducting the field investigation are summarized in this section. Table 3-2 lists these SOPs and the SOPs are provided in Appendix B. A complete listing of sample collection requirements is provided in Table 3-1.

This section also includes subsections for activities that will be performed for site utility clearance and digging permits, surveying of sample locations, and management of investigation derived waste (IDW).

3.2.1 Surveying

Land surveying will be conducted in three phases. Hydrographic survey data has been collected as a separate task and will be incorporated with the land survey data in the final site topographic mapping.

All land surveying activities and all survey data reduction/mapping work will be conducted under the direction and oversight of and, checked and approved by a Maine-licensed surveyor.

3.2.1.1 Permanent Benchmarks

This task, identified as Phase IA, was completed on July 20, 2001 and consisted of the establishment of permanent horizontal and vertical control points/benchmarks around OU3 area at locations that were determined by TtNUS in the field. Four monuments (PNS-1 through PNS-4) have been installed to establish horizontal and vertical controls at the site. These benchmarks will be used for future activities at OU3. In general, two benchmarks have been located on the north side, and two benchmarks have been located on the south side (locations were determined by PNS personnel on July 17, 2001 with the surveying subcontractor). The locations were planned so that future disturbance with the landfill cap and related activities will not affect the new benchmarks.

These permanent benchmarks were established using the available existing horizontal and vertical control available in the OU3 area. The locations are shown on Figure 3-1.

This task is also needed to provide the required horizontal and vertical control for the purposes of performing the topographic survey described in Phase IB and the location of all field investigation locations.

Ground control was established with the accuracy to support the mapping and database requirements. The control was developed using the State Plane Coordinate System-Maine-West-Zone. The mapping will be projected at zero elevation in true State Plane, unmodified. The standards for control are stated in NOAA-S/T 80-98. The control survey was established with third order type survey specifications as a guideline with the final map accuracy as the controlling specification. State Plane Coordinates and mean sea level (MSL) elevations were assigned to each monument set. Monuments were set so they are intervisible and usable during construction.

The project control survey will meet or exceed the horizontal and vertical accuracy criteria as defined by the Standards of Accuracy and General Specifications of Geodetic Control Surveys established by the U.S. Department of Commerce.

Hubs used to establish temporary horizontal control and control traverse turning points will be nominal 2-inch by 2-inch by 8-inch oak hubs containing tacks to mark the specific point. The stakes used to locate points in connection with the survey will consist of wood with a minimum nominal 1-inch by 1-inch cross section. The stakes will be at least 30-inches long. A piece of colored ribbon (no yellow or magenta to be used at PNS) will be attached to the top of each stake to facilitate identification in the field. Indelible ink will be used to mark each stake with adequate identification for use by field personnel (TtNUS, USACE, or TtNUS subcontractors).

3.2.1.2 Topographic Survey Data Collection

Phase IB consists of an aerial and land-based topographic survey and production of deliverable of OU3 and contiguous areas including incorporation of hydrographic survey benchmarks and data provided by others. Figure 3-1 depicts the area for the survey. Existing information will be used in these locations and will combined with limited point survey information to be collected.

3.2.1.2.1 Accuracy and Precision

The topographic survey will be performed with horizontal precision to ± 0.1 foot and vertical precision to ± 0.10 feet for natural ground surfaces and ± 0.01 feet for manmade surfaces.

3.2.1.2.2 Utilities

Within the limits of the topographic survey, the locations of all utilities will be from the most accurate information available or from field survey activities. Power lines and communication lines, street light poles, guy wires, vaults (including handholes and manholes), transformers, and substations will be located. Water, gas, and other above-ground pressure pipes, as well as fire hydrants, hose bibs, valve meter, regulators, etc., within the limits of the area to be surveyed will be located. Storm sewer manholes and storm drainage structures, such as culverts, head-walls, inlets, cleanouts, and manholes will be located. The elevation at the flow line at the bottom of all the pipes connected to a manhole, culverts, and inlets (invert elevations) will be determined. The size, direction of flow, and type of each pipe will be determined. The pipe invert elevation upstream and downstream of all manholes and inlets even if beyond the limits of the required topography will be obtained. Underground utility information that will be collected includes but is not limited to: storm sewers, electrical, communications (including fiber optic), cathodic protection, water, and underground storage tanks. Utility lines extending outside the indicated mapping area will be shown to logical conclusions (adjacent manhole or potential connecting point) even if that end point is outside the mapping area. It is necessary to show where utilities go to/from the project site. This will be done by collecting the coordinates on the next above-ground indication and invert(s).

3.2.1.2.3 Digital Terrain Model – Ground Survey Points

Ground points will be collected such that the developed contour mapping, with break lines and form lines, constructed from the Digital Terrain Model (DTM) will accurately represent the three dimensional surface of the area to be mapped.

Measurements will be made of sufficient density and precision to support preparation of a topographic map utilizing the contour interval specified, as well as pertinent spot elevations where necessary to show features that would otherwise be "lost" within the contour interval. The DTM coordinates (X, Y, Z) of all topographically significant data points will be recorded.

Break lines, such as non-visible break lines, natural breaks or changes in grade of the terrain such as shelves, depressions, ditches, embankment, road centerlines and other slope break lines will be collected as three-dimensional line strings. This information will be turned off in the final map. Additional features such as visible grade-change lines of planimetric features such as drainage centerlines, shorelines, curb lines, pavement edges and other features affecting the surface definition will be collected. These lines are required elements in the processing of data for contour generation and DTM models for digital surface generation.

All spot elevations supporting visual interpretation of terrain elevation will be provided and shown on final maps. The elevation value will be displayed as text adjacent to an X placed on the spot elevation position or as text with the decimal point centered over the elevation position. Ground elevations on existing breaks or changes in grades will be indicated, such as tops of hills, bottoms of ditches, saddles and embankment elevations, and any high or low elevations necessary for interpretation.

Data will be required to the low tide line to overlap data from the hydrographic survey. All efforts will be made to collect data at the farthest reaches into the coves at low tide – including any mud flats and areas exposed during low tide; as well as areas of land covered by shallow depths of water. The extent of submerged areas to be covered by the land survey will be directed by the TtNUS FOL (or designee) based on the actual limits of the hydrographic survey.

The features along Clark Cove, including the shore stabilization, rip rap, berm, steep slopes, etc., will be accurately collected and represented on the topography. The location and elevation of approximately four temporary benchmarks (TBMs) will be collected. These TBMs will be established during the hydrographic survey activities.

3.2.1.3 Topographic Mapping

The final mapping of the topographic survey will also incorporate the hydrographic data. The data will be used to develop continuous and seamless contouring and feature presentation from the land topography to the hydrographic survey. Existing information, such as building locations, ponds, base topography utilities, etc. outside of the topographic survey will be made available for incorporation into the final mapping.

The mapping procedures will be such as to provide a final contour map with a map scale of 1 inch equals 30 feet with a 1 foot contour interval.

General annotation will include street names, building numbers, feature descriptions, and type of surface. The map features will be shown by the appropriate symbology. All surface features within the area to be mapped will be shown and identified on the mapping. Locations of all utilities, above and below ground, will be shown on the final mapping. In addition, all sewer and drainage structure information gathered will be shown on final mapping.

Any storage tanks, radio antennas, or other surface structures visible and located within the area to be mapped will be shown. Fences, walls, and other similar obstructions will be shown. Existing monitoring wells (i.e. top of casing) within the survey boundary will be located and mapped to provide a reference for previous survey elevations.

3.2.1.4 Pre-Work Survey

Phase II consists of the pre-work point survey (horizontal locations) and staking of the planned investigative locations. Pre-work locations of all soil borings, piezometers, test pits, surface soil sample locations, LGS, and CPT locations will be staked before the commencement of field activities. Approximately 54 single stake points to establish the planned CPT locations, approximately 31 points to establish the planned location for a soil gas survey (single stake locations), approximately 17 test pit locations (two end points to establish orientation for each pit location), 22 piezometer locations, 8 soil boring locations, and 4 surface soil hand auger borings will be installed. The locations will be based on the information presented on Figures 3-2 and 3-3. The survey coordinates for the planned investigation locations are listed in Appendix A.

The locations will be marked with either wooden or metal stakes, pavement nails, or similar established markers such as stakes described under Phase I. All points will be identified using the designation in this QAPP (i.e., CPT-12 or DB-7, etc.) and will be visibly flagged (no yellow or magenta on PNS). Pavement

nails will have ribbon under the nail and will have high visibility spray paint surrounding the location and the TtNUS designation clearly marked.

Accuracy, field notes, stakes, and other specifications will be as discussed for Phase I activities.

3.2.1.5 Post-Work Survey

Phase III consists of the post-work surveying activities. The point survey (horizontal locations) of actual field investigation locations that were field located, adjusted, or in any way varied from the original horizontal location located in Phase II of the plan will be collected at the completion of all field activities. Additionally, an as-built point survey (horizontal and vertical) for all 22 piezometers and the tidal gauge will be completed to establish the installed riser elevation for water level measurements. The top of the installed riser will be used to determine the water levels at each location. The actual number will be based on the field investigation items that are moved or relocated during the investigation activities.

The location of the completed field investigation point will be identified using a temporary stake placed during the field activities by the TtNUS FOL (or designee). The stake will have sufficient permanent identification and visible ribbon to be located by the surveyor. The horizontal location and vertical elevation of each point will be measured and recorded. At this time, the vertical elevations of the top of risers of piezometers and the tidal gauges will also be established. The elevations of the piezometers from the top of the riser pipe will be determined by the surveyor.

Accuracy, field notes, stakes, and other specifications will be as discussed for Phase I activities.

3.2.1.6 Hydrographic Survey

Hydrographic data was collected using electronic horizontal positioning and sonic depth sounding for underwater elevations. The hydrographic survey information was gathered with horizontal and vertical precision to $\pm$ 0.1 foot. The survey for locations close to the shoreline was conducted near high tide time.

As depicted on Figure 3-1, 16 range lines, each of a length of 400 feet extending from the high water line on the shore to a point perpendicular to the shore at that location were performed. X, Y, Z positions were collected continuously along the range azimuth. The X, Y, Z positions were collected and compiled into representative elevations at approximate spacings of 10 along each transect.

Temporary control points were established, with all temporary control points meeting the requirements for accuracy as outlined in Section 3.2.1.

The field effort was directed by a hydrographer certified by the American Congress on Surveying and Mapping (ACSM). The hydrographer was required to comply with quality standards described in the USACE hydrographic surveying manual (USACE, 1994).

All hydrographic data will be incorporated into the final topographic map described in Section 3.2.1

3.2.2 Geotechnical Sampling

Geotechnical sampling at the OU3 will take place while performing the following activities:

- Deep soil borings (disturbed and undisturbed samples)
- Rock sampling
- Surface soils (disturbed and undisturbed samples).

3.2.2.1 Soil Borings

A total of 8 soil borings as shown on Figure 3-2 (DB-1 through DB-8) will be drilled at locations shown on Figure 3-2 using hollow-stem auger (HSA) method at the site. The results of the geotechnical testing will be used in settlement and slope stability analyses. Secondary data collection from the borings include the depth of waste and thickness of the original buried tidal mudflat material. A ninth soil boring may be advanced in the location of the planned crane test pad (to be determined during field activities). Table 3-1 provides information regarding field and laboratory analyses.

3.2.2.1.1 Disturbed Samples

All soil borings will be drilled to the top of bedrock using 4 1/4-inch inside diameter hollow stem augers. The drill rig and all drilling tools will be decontaminated before arriving on site and prior to demobilizing from the site. Chemical analysis of the soils is not required; therefore, it is not necessary to decontaminate between borings. Continuous soil sampling will be performed during drilling (except where undisturbed samples are required) to allow for accurate logging of the soil/landfill lithology. Sampling will be performed by using a 2-foot long, 2-inch diameter split-spoon sampler (ASTM D1586 “Penetration Test and Split-Barrel Sampling of Soils”). All samples will be visually classified in the field using the Unified Soil Classification System (ASTM D2488). Head-space screening will be performed as discussed in Section 3.2.2.1.3. All pertinent data will be entered on the Boring Log Form as provided in Appendix C.

Once bedrock is encountered, the hollow-stem augers will be seated into the top of rock and a 3-inch steel flush-joint casing with cutting shoe attached will be inserted through the augers and spun into the

top of rock. Drilling will proceed inside the casing (using potable water as the drilling fluid) 5 feet into bedrock using NX Coring tools and Rock Quality Designation (RQD) will be performed on the core of rock. The coring and RQD is required to provide information regarding the competence of the bedrock. The cores will be placed in core boxes provided by the drilling contractor, labeled and turned over to the USACE field representative. Refer to SOP GH-1.3 for details regarding soil and rock drilling methods.

3.2.2.1.2 Undisturbed Samples (Shelby Tubes)

Undisturbed samples will be collected from all the borings. Initially one sample will be collected near the top of the underlying tidal mudflat as soon as it is encountered. A second tube will be taken provided that the original buried tidal mudflat material is of sufficient thickness. It is planned to obtain an undisturbed sample at approximate intervals of 10-feet due to the unknown thickness of the tidal mudflats material that will be sampled. The TtNUS FOL and USACE representative will make a determination as to which Shelby tubes will be sent to the laboratory for geotechnical testing. These samples will be taken by pushing a 3-inch OD (outside diameter) thin-walled Shelby Tube sampler a distance of two feet. Undisturbed samples are to be taken in accordance with ASTM D1587, “Thin Walled Tube Sampling of Soils”. The pressure exerted (psi) and time duration (seconds) required to push the Shelby Tube sampler a distance of two feet will be noted and recorded on the Boring Log. The minimum recovery length is required for the necessary laboratory analyses is listed in Table 3-1. If a sample is not recovered at the specified interval or noncohesive soil is encountered in the specified interval, the boring will be advanced through the unsuccessful interval and another attempt for an undisturbed sample at the bottom of the unsuccessful interval will be made.

Upon retrieval of the Shelby Tube samples, the material exposed at both ends of the tube will be examined and recorded on the Boring Log. Sufficient material will be carefully removed from the ends to allow insertion of expandable packers (J-Plugs) into each end of the tube. The wing nut of each packer seal will be tightened until the rubber gasket presses firmly against the entire circumference of the inside wall of the Shelby Tube. Immediately after securing the packers, the outside of the tube will be wiped clean and labeled with an indelible marker to include project name, location, boring number, sample number, sample interval, date and recovery. An end cap will be placed over both ends of the tube and secured with at least three wraps of electrical tape. If temperatures of 35 degrees Fahrenheit or below are anticipated during field activities, sample storage, or sample transport, the TtNUS FOL will be responsible for ensuring undisturbed samples do not freeze at any time prior to receipt at the laboratory.

The laboratory will be instructed to use only the portion of the Shelby tube sample required for testing. The remainder will be wax sealed (according to ASTMD 4220) and shipped to USACE, Omaha district for archiving.

3.2.2.1.3 Headspace Screening

All disturbed samples (split-spoon samples from the borings and macrocore samples from the piezometers) will be screened for volatile organic compounds (VOCs) in the field at the time of sample collection. A Photoionization Detector (PID) will be used to screen the samples as described in SOP ME-12. All screening results will be entered in the appropriate column on the Boring Log. Headspace screening will be performed as follows:

Immediately upon opening the split-spoon (and/or the macrocore sampling device for the installation of the piezometers), a representative portion of the sample will be placed and sealed in a new, clean, plastic zip-lock bag. The sample will be agitated for at least 15 seconds and then allowed to volatilize for a minimum of 10 minutes. During cold weather (which is unlikely during the planned sampling time), the sample will be warmed to near room temperature prior to taking the headspace reading. Then the sample will be reshaken and the PID probe will be quickly inserted into the bag and the maximum reading will be recorded on the Boring Log at the appropriate depth. After readings have been taken, the samples will be handled as IDW.

3.2.2.1.4 Groundwater Information

Groundwater information will be recorded during drilling of the soil borings. The depth at which water is first encountered will be noted and recorded on the Boring Log.

3.2.2.1.5 Recording

A complete and accurate field log for each boring will be prepared by the TtNUS FOL (or designee). The field log will be prepared on a boring log form as presented in Appendix C. Each log will include, at a minimum the following information:

- Date
- Project Name
- Project Location
- Offset dimensions from planned location (if necessary)
- Type or model of drill rig
- Method of drilling/size of boring etc.
- Type and number of samples collected
- Standard penetration test blow count number
- Headspace measurements
- Groundwater observations

- Total depth of boring
- Description of materials encountered including Unified Soil Classification System (USCS) symbol

Soil materials will be classified using the USCS. Soil descriptions will follow ASTM D2488. Rock descriptions will follow the nomenclature as in ASTM C294 and TtNUS GH-1.5.

Samples will be properly labeled and will clearly indicate if the sample is potentially contaminated. The information on the labels will consist of the project name, base location, hole number sample number, depth sample type, date and the samplers initials.

3.2.2.1.6 Backfilling

Upon completion of drilling, the soil borings will be backfilled with a cement-bentonite grout mixture. The cement grout will consist of a mixture of Portland Cement (ASTM C150) and water in the proportion of not more than 7 gallons of approved water per bag (94 pounds) of cement. Additionally, 3 percent by weight of sodium bentonite powder will be added. The grout mixture will be placed by pumping through a tremie pipe or hose with the lower end located within 3 feet of the bottom of the hole. Pumping will continue until undiluted grout flows from the boring at the ground surface.

3.2.2.1.7 Site Restoration

Drill cuttings will be containerized in drums (or other suitable container) supplied by the PNS hazardous materials facility, and moved to a storage/holding area, as directed by the site contact. Other IDW, such as used personnel protective equipment (PPE) will be segregated from the cuttings and disposed of in an appropriate manner (double garbage bagged and disposed in PNS dumpster) and as described in Section 3.2.8.4.

3.2.2.1.8 Testing

The laboratory to be used for any chemical or geotechnical samples will be equipped and trained to analyze the appropriate soils and will be certified by USACE. Analytical methods are discussed in Section 4.0.

3.2.2.2 Surface Soils

Disturbed and undisturbed surface soil samples (SS-1 through SS-4) will be collected as discussed below. The locations shown on Figure 3-2.

3.2.2.2.1 Disturbed Sampling

A total of 4 surface soils samples (SS-1 through SS-4) will be collected using a hand auger, shovel, or mechanical methods (using the excavator bucket or drill rig) at locations shown on Figure 3-2. These samples will be analyzed for the geotechnical parameters as shown on Table 3-1. The samples will be collected from a depth of approximately 6 to 24 inches. The soil samples will be placed into clean sample jars supplied by the laboratory. The disturbed samples will be identified as SS-1D through SS-4D.

The auger equipment and all sample collection tools will be decontaminated before arriving on site and prior to demobilizing from the site. Since no chemical analysis of the soils is required, it is not necessary to decontaminate between samples. Surface soil sampling is described in ASTM D1452 for obtaining shallow soil samples by auger borings. All samples will be visually classified in the field using the USCS (ASTM D2488). All pertinent data will be entered on the appropriate forms provided in Appendix C.

3.2.2.2.2 Undisturbed Sampling

A Shelby Tube will be driven (using the excavator bucket or drill rig) in close proximity to the surface of the four locations (SS-1 through SS-4) for the purpose of laboratory testing for determination of the in-place density of the existing soil cover material. The undisturbed samples will be identified as SS-1U through SS-4U. The sample collection procedure will be in accordance with ASTM D1587, which has been discussed for a different purpose (subsurface soil sampling) in Section 3.2.2.1.2. In the event that the physical characteristics of the surface soils are such that Shelby Tube samples cannot be collected, then the USACE will conduct a Sand Cone test according to the Standard Test Method for Density and Unit Weight of Soil in Place (ASTM D1556). The purpose of these soil samples is to determine the in situ density of the surface soil samples for potential reuse of the material as cover material.

3.2.3 Test Pits

The objective of excavating the test pits is to establish the horizontal extent of the waste material. A total of 17 test pits (T-1 through T-17) will be excavated to delineate the boundaries of the landfill as shown on Figure 3-2. Additional test pits may be added and located as needed in the field. They will be field located by the TtNUS FOL (or designee) and the USACE field representative. The test pits will be a minimum of 2 feet wide and will continue vertically starting in the clean area and working towards the landfill until it is determined that the waste and native soil interface is reached or as decided by TtNUS and the Navy. The existing topsoil and the top one to two feet of each test pit will be separated from the rest of the material (i.e. one side of the test pit) so that this clean material can be replaced during backfilling. A barrier (i.e., plastic sheeting) will be placed on the existing ground surface opposite of the side designated for the clean upper soil as the test pitting operation proceeds. All excavated material

below the upper clean soil described above will be contained on and within the barrier. The test pits will be oriented approximately perpendicular to the estimated landfill boundary.

The TtNUS FOL (or designee) will observe the test pitting work and will be responsible for completing a test pit log for each test pit. The test pit log will document the visual classification of soils in accordance with the USCS (SOP GH-1.3/ASTM D2488); changes in strata; depth and description of metallic and non metallic objects; and the depth of groundwater and other liquids encountered during test pit excavation.

The backhoe operator will excavate the test pit in several increments of depth. After each increment, the operator will wait while the TtNUS FOL inspects the test pit to observe subsurface conditions. The backhoe operator, who will have the best view of the test pit, will temporarily suspend operation if any of the following conditions are encountered:

- Groundwater or non-aqueous phase liquid
- Drums or other potential waste containers
- Utility lines not previously anticipated.

These actions are necessary to permit proper visual logging of the test pit, and to minimize or avoid transferring potential non-aqueous phase liquid to greater depths in the test pit. The operator will start in known clean areas continue excavation in increments until waste materials/fill are observed. Work will proceed at each test pit until these boundaries can be determined or until the water table is encountered. Field decisions between the TtNUS FOL and the Navy may also be required during excavation of the test pits.

3.2.3.1 Logging Procedures

During test pit logging, the backhoe operator and all nearby site personnel will remain upwind or crosswind of the pit and spoils pile. Wind direction will be monitored by a windsock or other banner located in a prominent position visible to all personnel.

Features exposed in the test pits will be logged as they are excavated. Records of each test pit will be made on forms (Appendix C) or in a field notebook. If the log is made in a fieldbook, it will contain the same information required by the form. The records will contain plan and profile sketches of the test pit showing materials encountered, their depth and distribution, and sample locations. Procedures outlined in SOP SA-6.3 will be followed.

At a minimum, the test pit log will include the following information:

- Plan and profile sketches of the test pit showing materials encountered the depth and distribution of these materials in the test pit, and locations,

- Sketch of the test pit location showing permanent and identifiable location marks,

- The presence or absence of groundwater or surface water entering the pit,

- Items such as any odors, staining, or other evidence of potential environmental contamination encountered,

- Notation of reason for terminating the test pit.

3.2.3.2 Sampling Procedures

Samples for visual classification will be obtained by the TtNUS FOL from the bucket of the backhoe or excavator. Personnel will not enter the test pit trench. The TtNUS FOL will direct the backhoe operator to remove material from the selected depth or location within the test pit. The bucket will be brought to the surface and moved away from the pit edge. The sampler will approach the bucket and monitor its contents with a PID meter for potential hazardous substance. If granular or loose soils and/or uniform materials are encountered, a sample can be obtained directly from the bucket. A sample collected from the center of the bucket will be visually classified and detailed on the test-pit log form.

If an intact or a ruptured drum is encountered, then the TtNUS FOL will contact Navy personnel. The TtNUS Subcontractor will be responsible for the removal and staging of up to 6 drums. The Navy will be responsible for sampling and disposal of the drum and their contents. If more than 6 drums are uncovered, then the work will be suspended until the Navy implement a drum removal action. The Navy will be prepared to go below the groundwater table if site conditions exist that warrant additional investigation below the groundwater table. This additional scope may result in a delay of the investigation and the mobilization of additional equipment or contractors.

Upon completion of each test pit excavation, the test pit will be backfilled with the material that was excavated from the location. Compaction of the backfill material will be achieved using the bucket and tracks of the excavator. The top several feet of each excavation will be backfilled with materials consistent with the existing landfill.

3.2.4 Piezometer Installation

A total of 22 piezometers (P-1 through P-22) will be installed at locations shown on Figure 3-2. Direct Push Technology (DPT, e.g., Geoprobe Macrocore) will be used as the method to install the piezometers. Various sampling devices and push techniques (i.e. dual tube) may be used to facilitate the advancement, collection of samples, and installation of the piezometers. The TtNUS FOL, USACE field representative, and the subcontractor will make decisions during the activities to determine the appropriate equipment and method for the subsurface conditions. The boreholes will be advanced using this procedure to approximately 10 feet below the water-table depth for P-1 through P-18 and until bedrock is reached for P-19 through P-22 in accordance with SA-2.5. Soil cores will be collected in clear, disposable acetate or HDPE liners that are two to five feet in length depending on the DPT rig and DPT method. These liners will be placed in a steel sampling tube that is driven into the ground. At the end of each section, the Macrocore device will be withdrawn from the hole and the soil core enclosed inside the liner will be retrieved and logged by the TtNUS FOL (or designee). This procedure will be repeated until a depth of approximately 10 feet below the water table is reached for P-1 through P-14; a minimum of 5 feet within the tidal mudflats for P-15, P-16, P-17, and P-18; and until bedrock is reached for P-19 through P-22. As each core is removed from the boring, the liner will be slit open and a description of the soil core will be entered by the TtNUS FOL (or designee) onto the soil boring log (provided in Appendix C). Head-space screening will be performed as discussed in Section 3.2.2.1.3.

After the boring has been advanced, a piezometer consisting of 1-inch inside diameter PVC flush-joint casing and 10 slot (.010 inch) screen will be placed at the bottom of the boring. P-1 through P-14 and P-19 through P-22 will be screened at a depth interval of 5 to 10 feet below the estimated low-tide depth of groundwater. P-15, P-16, P-17, and P-18 will be screened with the mudflats. The screen will be 5 feet in length and supplied with an end cap. Once the screen and riser pipe are in place, the annulus of the boring will be backfilled with clean silica sand from the bottom of the boring to the depth at which water was encountered. A bentonite pellet seal (minimum 2-foot thick) will then be placed and allowed to hydrate as per the manufacturer's recommendations.

In the event that the hole collapses prior to installation of the piezometers, the DPT contractor will be equipped with the appropriate size casing to be inserted to the final depth of the boring. After the casing is set, the PVC screen and riser will be placed as described above.

In the piezometers where the boring will be advanced to bedrock (P-19 through P-22), the space created from the bottom of the boring to the planned bottom of the piezometer screen will be backfilled as described in Section 3.2.2.1.6.

Each riser section will be extended to approximately 2-feet above surrounding ground surface to aid in the identification and protection of the piezometer. A well cap will be used on each piezometer to protect the piezometer from foreign objects entering the casing. Protective devices are not planned around the piezometers. The casing above grade will be flagged for visibility.

The newly installed piezometers will be developed to remove fines and to evacuate standing water. Piezometers will be developed by bailing or by using a peristaltic pump as determined by the TtNUS FOL. The piezometers will be developed until the water is visibly clear or as determined by the TtNUS FOL. No water quality parameters are necessary for the piezometers because they will only be used for water level measurements. The water from development will be collected in drums provided by PNS and disposed of appropriately by PNS personnel.

Surface water tide data will be collected during the measurement and collection of piezometer data. A section of piezometer riser will be installed on a pier in Clark Cove at a location to be determined during the field activities. The same type of equipment used to measure the water level information in the piezometers will be used in the tidal gauge casing.

Following development, each piezometer will be equipped with a transducer/data logger (In-Situ Mini Troll 0.72 in. OD or equivalent) capable of fifteen-minute interval readings for a minimum of one month. The data loggers will be positioned approximately one-foot above the bottom of the screen section. TtNUS will be responsible for installing the transducers, setting up the readings and downloading the data and presenting this data into the final report. Each of the piezometers will be surveyed as discussed in Section 3.2.1.

The piezometers will be left in place after the water level study and will be removed and abandoned or used during the implementation of the OU3 capping activities.

3.2.5 Cone Penetration Testing

CPT (CPT-1 through CPT-54) will be conducted at 54 locations as shown on Figure 3-3. The tests will be conducted in accordance with ASTM D5778 (Electronic Friction Cone/Piezocone). CPT will be used to collect information regarding the parameters needed to perform engineering analysis and landfill cap system design. Parameters that will be determined using the CPT probe include soil stratigraphy and behavior type, equivalent Standard Penetration Test (SPT) blow count, relative density, overconsolidation ratio, friction angle, and undrained shear strength. The collection of additional dissipation data allows for the determination of soil compressibility, permeability, and the location of the groundwater table. These parameters will be used to determine soil strength, correlate type of waste encountered and correlate to a

stress-strain relationship, which will be used to estimate settlement potential of the landfill caused by construction of the cover.

Initially, two points per acre will be attempted at locations established by the pre-work survey. Offset locations will be attempted if refusal is reached prior to bedrock at the initial location. CPT testing will start at the ground surface, will be advanced in most locations through waste, and will continue to the top of bedrock. The TtNUS FOL (or designee) will oversee the CPT subcontractor during the testing operations. The CPT operator will monitor the CPT advancement and will halt the test if conditions are not conducive to CPT testing as determined by the operator's best professional judgement.

Of the approximately 54 CPT locations, five are planned to be located close to the traditional soil borings as paired in the following list: DB-1/CPT-30, DB-2/CPT-17, DB-6/CPT-38, DB-7/CPT-9, and DB-8/CPT-28. The similar location of the CPT and soil boring advancement will allow a correlation of the soil-type data collected during the CPT activities. Additional correlation of borings, CPT, and other investigation data may be performed and evaluated after the collection of all the field investigation activities.

The CPT will measure and collect data including tip stress, sleeve friction stress, and pore water pressure. Additionally, dissipation tests (pore pressure response versus time) will be performed. The dissipation test involves recording the dissipation of pore pressure as it approaches static equilibrium. Dissipation tests will be performed at the top of the mud flats material and at other depths within the mud flats material as directed by the filed geologist. Dissipation test data determines the groundwater table, compressibility and permeability within the subsurface strata.

The CPT probe will consist of a 15 cm^2 (modified version) cross-section area with a 4.4 cm diameter. This modified cone is selected to minimize push-pipe friction and eliminate use of oversized collar. The CPT system will also consist of a 4-channel probe to gather cone/tip, sleeve friction, inclinometer, and pore pressure data. The probe will use compression load cells. The probe will also be designed and prepared for retraction grouting (see grouting information).

The CPT equipment, hardware, and software will acquire, analyze, and clearly present penetrometer data. Data will be displayed and plotted in real time on-screen and on hard copy. Calibration and analysis will be performed during CPT activities. Pre and post CPT zero readings will be taken and recorded on each CPT test file to check for electronics drift. Additional calibration checks will include the measurement of probe diameters of cone after each test and general visual inspection and checking of all CPT equipment.

All data collected will be provided in the report, including all charts, data, quality control information, calibration, and results/interpretation of data. All processed data will be analyzed and checked by qualified personnel highly familiar with CPT interpretation.

Several options (pressure grout, retraction grout, and tremie grout) for grouting the penetrometer hole are available and are typical at environmental sites. Typical cement grout or a mixture of bentonite and cement is used in these standard methods. CPT grouting will be done with retraction grouting for this project. It is planned that the CPT locations will be grouted with a second push into the completed CPT location with a dedicated grout tube.

All equipment (i.e., CPT rods and probe) will be decontaminated and cleaned during the extraction of the equipment from each CPT location. The CPT truck will be capable of decontaminating all equipment upon its exiting the hole using a steam cleaning module attached to the bottom of the guide tube underneath the CPT truck. The steam equipment will be a high temperature, high-pressure water system. The rinse water will be contained and collected and will only be applied when the rods are in motion. Decontamination water will be characterized, handled, and disposed of appropriately.

3.2.6 Landfill Gas Survey

A methane soil gas survey will be conducted by a subcontractor, at the site along a grid pattern at one sample point per acre as shown on Figure 3-3. At each survey point (LGS-1 through LGS-31), a 24-inch long, ½-inch inside diameter (ID) tube will be driven 30-inches into the ground by means of a pointed solid steel slam bar fitted into the tube. The tube will then purged with air and the top will be sealed with a polyethylene twistcock in the closed position.

At a predetermined time, the subcontractor's field team will begin sequentially sampling the captured gas in each shallow depth tube with a methane gas analyzer. The subcontractor will then read the analyzer and record the results i.e., date, time, location, and measurements. Specifically at each sample location, a member of the field crew will connect the analyzer to the twistcock; twist the cock to the open position; leave it open for 30 seconds; return the stopcock to the closed position; and then disconnect the analyzer from the stopcock. With the stopcock in the open position, measurements of the analyzers readings will be taken and recorded. The field team will then move to the next sample location and repeat the procedure until all probes have been sampled.

The sampling will be conducted on a predetermined schedule, generally every 4 hours for 12 hours. Once the sampling cycles have been completed, the subcontractor's field team will recover all probes and will seal the abandoned holes by filling with granulated bentonite chips.

The subcontractor will record the average percent methane at each sample location. This field data will be converted to an emission flux rate at the surface (in $mg/cm^2/sec$) at each location. Finally, this data will be interpolated across the survey area to determine the annual methane production rate in cubic feet per year. The final report will include a base map and a color contour map showing the distribution of methane.

3.2.7 Functions and Values Assessment

Functions and Values Assessment consists of two components. A "functional assessment" and a "value assessment". Functional assessment is the process of evaluating wetlands for their capacity to perform specific actions that benefit other ecological systems (such as adjoining waterways or upland habitats) or society (such as providing flood control, erosion control, or scenic beauty). Functions are physical, chemical, and biological processes or attributes that are vital to the integrity of a wetland system (Adamus et al., 1991). An example of a wetland function is the ability of certain wetlands to detain surface runoff and thereby reduce downstream flood levels. Values are attributes that are not necessarily important to the integrity of a wetland system but that are perceived as valuable to society (Adamus et al., 1991). An example of a wetland value is the aesthetic beauty of many wetlands. The distinction between functions and values is not clearly defined. In particular, most functions can also be considered to be values. For example, the ability of a wetland to reduce flood levels is generally regarded as a function but is also generally perceived as valuable to society.

For this assessment, The New England District of the U.S. Army Corps of Engineers' procedure termed the Highway Methodology will be used. Specific functions and values addressed in this methodology include:

- Groundwater Recharge/Discharge (Function): the ability of a wetland to direct surface runoff into the water table or to provide a conduit by which the water table can discharge to streams and other surface water bodies,

- Floodflow Alteration (Function): the ability of a wetland to reduce downstream flood levels,

- Fish & Shellfish Habitat (Function): the ability of a wetland to provide favorable habitat for fish and shellfish,

- Sediment/Toxicant/Pathogen Retention (Function): the ability of a wetland to improve water quality by sequestering suspended sediment, toxicants, or pathogens,

- Nutrient Removal/Retention/Transformation (Function): the ability of a wetland to reduce excessive nutrient concentrations in water (reduce eutrophication) by sequestering dissolved nutrients such as nitrogen and phosphorus,

- Production Export (Function): the ability of a wetland to supply detritus and small organisms to support aquatic food chains,

- Sediment/Shoreline Stabilization (Function): the ability of a wetland to protect stream banks and shorelines against erosion,

- Wildlife Habitat (Function): the ability of a wetland to provide favorable habitat for birds, mammals, reptiles, amphibians, and other wildlife,

- Recreation (Value): the contribution of a wetland to recreation such as hunting, fishing, and boating,

- Educational/Scientific Value (Value): the utility of a wetland for educational endeavors or scientific research,

- Uniqueness/Heritage (Value): the uniqueness of a wetland or its contribution to a regional identity (e.g. possessing historical or archaeological sites, rare plants or wildlife, or unusual geological features),

- Visual Quality/Aesthetics (Value): the aesthetic beauty of a wetland, and

- Threatened or Endangered Species Habitat (Value): the ability of a wetland to provide habitat for Federally or state-listed threatened or endangered species.

Each of the functions and values presented above must be considered, but the evaluation is subjective. The developers of Highway Methodology provided a standard Wetland Function-Value Evaluation Form, but users may present their findings in any suitable way. The form allows evaluators to indicate whether each function or value is provided by the subject wetland and which are the principal functions and values provided by the wetland.

3.2.8 Other Field Investigation Activities

Other field investigation activities include obtaining site utility clearance and digging permits, cleaning and decontaminating equipment, calibrating and maintaining field equipment, inspecting and accepting supplies/sample containers, and managing IDW.

3.2.8.1 Site Utility Clearance and Digging Permit

Before any intrusive drilling, test pitting, or subsurface sampling activities commence at the site, utility maps of the facility will be obtained and thoroughly reviewed. A person designated by the Navy will review the planned drilling and sampling locations and determine whether the planned locations are acceptable with respect to buried utilities. No intrusive activities will occur until the planned areas intended for drilling have been completely cleared in accordance with SOP HS-1.0.

3.2.8.2 Cleaning and Decontamination of Equipment

Equipment decontamination will follow the procedures described in the TtNUS decontamination SOP SA-7.1, which is provided in Appendix B. However, since no chemical sampling is required decontamination of equipment will only take place prior to and following field activities. Nondisposable equipment items that come in contact with subsurface materials that will require decontamination to prevent contaminants from being taken off-site include:

- hand augers (in contact with soils),
- split-barrel samplers (in contact with soils),
- water level indicators (in contact with groundwater),
- Pressure Sensitive Transducers and cables (In-Situ Mini-Troll or Equivalent) (in contact with groundwater)
- CPT Device (from the selected subcontractor)

3.2.8.3 Inspection and Acceptance Requirements for Supplies/Sample Containers

It will be the responsibility of the TtNUS FOL (or designee) to inspect all supplies to be used as part of the field program during mobilization and use. Supplies to be inspected include sampling equipment, field meters, and sample containers.

If the TtNUS FOL encounters any problem with the supplies, he or she will inform the TtNUS PM and the laboratory supplying the containers. The TtNUS PM, in consultation with the Navy RPM and QA/QC officer, will instruct the FOL on any corrective actions that will be implemented.

3.2.8.4 Management of IDW

Five types of IDW will be generated during this investigation that could be potentially contaminated: soil cuttings, well development water (from piezometers), drill rig decontamination wastewater, sampling equipment decontamination wastewaters, and personnel protective equipment and clothing (PPE). Based on the historical site activities and types of contaminants present, none of these IDW materials is expected to present a significant risk to human health or the environment if properly managed.

Excess soil materials resulting from the hand augering and DPT activities will be placed back in the holes from which they originated and will be thoroughly tamped down to reduce void space in the backfill. Bentonite chips will be used to fill the hole to the ground surface. Soil cuttings and excess soil core material resulting from the hollow stem auger drilling activity will be placed in plastic garbage bags, properly labeled, and placed in 55-gallon sealable steel drums. The drum(s) of soil IDW will be labeled, sealed, and transported to a central location at the PNS designated by the Navy.

Piezometer development waters and waste water from decontamination will be pumped into 55-gallon sealable drums, which will be properly labeled and transported to a central location to be designated by the Navy in accordance with SOP SA-7.1.

Any IDW soils or water will be sent to the PNS hazardous waste transfer facility for sampling and analysis. The waste will be properly disposed of based on the results of this analysis.

3.3 SAMPLE HANDLING, TRACKING, AND CUSTODY REQUIREMENTS

The sample handling, field documentation, and chain-of-custody procedures are documented in this section.

3.3.1 Sample Collection Documentation

The following sections outline the procedures that will be used by field personnel to document project activities and sample collection procedures during the pre-design investigation project. Detailed and accurate documentation is necessary in order to ensure data integrity.

3.3.1.1 Field Notes

Documentation of field observations will be recorded in a field logbook and/or field log sheets including sample collection logs, boring logs, test pit logs, and piezometer construction logs. Bound, water-resistant field logbooks utilized on this project. All pages of the logbook will be numbered sequentially

and observations will be recorded with indelible ink. Field logbooks will be maintained according to SOP SA-6.3. Field sample log sheets will be used to document sample collection details. Other observations and activities will be recorded in the field logbook. Instrument calibration logs will be used to record the daily instrument calibration.

For sampling and field activities, the following types of information will be recorded as appropriate:

- Site name and location
- Date and time of logbook entries
- Personnel and their affiliations
- Weather conditions
- Activities involved with the sampling
- Subcontractor information
- Site observations including site entry and exit times
- Site sketches
- Visitors
- Health & Safety issues including PPE and Confined Space Entry
- Log of photographs, if any

The following sections outline the information that will be documented in the field according to the media to be sampled and the activities to be performed.

Soil sample collection and piezometer installation will be recorded on sampling logs as noted in Section 3.2. The field logbooks and sample log sheets will remain on-site for the duration of the investigation. Field notes recorded by the CPT, LGS, functions and valves assessment, and land/hydrographical survey subcontractors will be archived in the project file.

3.3.1.2 Field Documentation Management

After the investigation is completed, the field sampling log sheets will be organized by date and media and placed in the project file. The field logbooks for this project will be used only for this site, and will also be categorized and maintained in the project file after the completion of the field program. Project personnel completing concurrent field sampling activities may maintain multiple field logbooks. When possible, logbooks will be segregated by sampling activity. The field logbooks will be given titles based on date and activity.

3.3.2 Sample Identification and Tracking System

This section outlines the procedures that will be followed to identify and track samples taken during field activities. The term “sample” refers to a representative part of the media quantity that is extracted from a larger group as a whole and presented for quantitative analysis. In this field investigation, soil samples for geotechnical analyses will be collected. Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of three or four alphanumeric code segments, with each segment separated by a hyphen. The sample tracking number will identify the site, the sample medium, the sample area/location, the sample depth (if appropriate), the sample date, and quality control sample designation (if appropriate). Other pertinent information regarding sample identification, such as the time the sample was collected and measurements of sample locations and observations, will be recorded on the sample collection log sheets and in the site logbook.

The sample tracking number format will be as follows:

EEE	-	AA	-	EE or EEEE	-	NNNN or NN
Site Identifier		Sample Medium		Sample Location		Sample Depth Code or Sample Round (for groundwater)

Where:		
	A	alpha character
	N	numeric character
	E	either alpha or numeric character

Site Identifier – This first segment will consist of a code identifying the site and activity: OU3 DSN (for OU3 design)

The sample medium will consist of a two-character code as follows:

Sample Medium:		
	SS	surface soil
	SB	subsurface soil

Sample Location Number: The sample location numbers shown on the sampling plan figures will be used. For a "disturbed" soil sample, a letter "D" will be attached. For an "undisturbed" soil sample, a letter "U" will be attached.

Sample Depth Code – For soil samples, the fourth segment will be four digits consisting of the upper and lower limits of the sample interval below the ground surface in feet, rounded down to the nearest whole number.

The following examples illustrate how the sample identification numbers would be applied:

- Surface soil sample collected from surface soil location number SS-1, from 0.5 to 2.0 feet bgs, using a hand auger (disturbed sample) would be designated as: OU3DSN-SS-SS1D–0002

- Subsurface soil sample collected from DB-1, from 25 to 27 feet bgs, using a shelby tube (undisturbed sample) would be designated as: OU3DSN-SB-DB1U-2527

3.3.3 Sample Handling and Custody

Sample custody procedures are designed to provide documentation of preparation, handling, storage, and shipping of all samples collected. Field chain-of-custody procedures are described in SOP SA-6.3. Laboratory chain-of-custody procedures are described in laboratory SOP L18.

Integrity of the samples collected during the site investigation will be the responsibility of identified persons from the time the samples are collected until they, or their derived data, are incorporated into the final report. Stringent chain-of-custody procedures will be followed to document sample possession.

3.3.3.1 Field Custody

The FOL is responsible for the care and custody of the samples collected until they are delivered to the laboratory or are entrusted to a carrier.

Sample logs or other records will be signed and dated by the persons making the entries.

Chain-of-custody forms will be completed to the fullest extent possible before sample shipment. They will include the following information: project name, sample number, date and time collected, source of sample and location, tests to be conducted, description of sample location, matrix, type of sample, grab or composite designation, and name of sampler. Sample depths will be indicated on the chain-of-custody form because the depth will be rounded off in the sample tracking number.

These forms will be filled out in a legible manner, using waterproof ink, and will be signed by the sampler. Similar information will be provided on the sample label, which will be securely attached to the sample

bottle. The label will also include the tests to be conducted. Copies of all forms used during field activities are provided in Appendix C.

3.3.3.2 Transfer of Custody

The following procedures will be used when transferring custody of samples:

- Samples will be custody-sealed for security according SOP SA-6.3 and accompanied by a chain-of-custody form. When transferring samples, the individuals relinquishing and receiving them will sign, date, and note the time on the chain-of-custody form. This record documents the sample custody transfer from the sampler to the laboratory, often through another person or agency (common carrier). Upon arrival at the laboratory, internal sample custody procedures will be followed as defined in the laboratory SOP L18.

- Prior to shipment to the laboratory for analysis, samples will be properly packaged. Individual custody records will accompany each shipment. Shipping containers will then be sealed for shipment to the laboratory. The methods of shipment, courier name, and other pertinent information will be entered in the “remarks” section of the custody record.

- All shipments will be accompanied by the chain-of-custody form identifying the contents. The original record will accompany the shipment and a copy will be retained by the field sampler.

- Proper documentation will be maintained for shipments by common carrier.

3.3.3.3 Sample Shipment Procedures

It is anticipated that the selected laboratory will pickup the samples in the field. Therefore, sample shipment procedures are not applicable for this project.

3.3.3.4 Field Documentation Responsibilities

It will be the responsibility of the TtNUS FOL to secure all documents produced in the field (e.g., sampling logs, calibration forms) at the end of each work day. Copies of all forms used during field activities are included in the SOPs. Copies of all field logbooks will be sent to EFANE to the attention of Mr. Fred Evans (Navy RPM). Sample logs, chain-of-custody records, and test pit logs will be included as an appendix to the report that will be prepared based on results of this investigation.

At the completion of field activities, the TtNUS FOL will send Ms. Deborah Cohen (the TtNUS PM) or designee, all field records, data, field notebooks, logbooks, chain-of-custody forms, sample log sheets, daily logs, etc. The PM will ensure that these materials are entered into the TtNUS document control system in accordance with appropriate administrative guidelines.

Changes in project operating procedures may be necessary as a result of changed field conditions or unanticipated events. A summary of the sequence of events associated with field changes is as follows:

- The TtNUS FOL (or designee) will communicate to the TtNUS PM and TtNUS Lead Engineer of the need for the change.

- The TtNUS PM will discuss the change with the pertinent individuals (e.g., Navy RPM, TtNUS Maine PE, TtNUS QA Officer, TtNUS Health and Safety) and will provide a verbal approval or denial to the TtNUS FOL for the proposed change. The USEPA and MEDEP will be consulted by the Navy of any major scope changes that may occur while field work is ongoing. Communications and correspondences to the RAB will be handled through inclusion on the distribution list or written correspondence and updates at RAB meetings.

- The TtNUS FOL will document the change on a Task Modification Request form and forward the form to the TtNUS PM at the earliest convenient time.

- The TtNUS PM will sign the form and distribute copies to the Navy RPM, TtNUS FOL, and project file.

- A copy of the completed Task Modification Request form will be attached to the field copy of the affected document.

The possession of all records will be documented; however, only the TtNUS FOL or designee may remove field data from the site for reduction and evaluation.

3.3.3.5 Laboratory Sample Custody

A summary of sample custody procedures of the laboratory is provided here. Please refer to SOP L18 for details.

When samples enter the Geo Testing Express laboratory, a determination is made by the person accepting them: the samples are either part of an existing project or they are part of a new project. If the samples are part of a new project, the Project Log-In Clerk proceeds to create a project folder and

assigns a Geo Testing Express Project Number to that project. Information such as client name, address, phone and fax numbers, contact, project name, and project location are logged in with the project.

After receiving a new project folder or determining that samples received are part of an existing project, the samples are logged-in.

TABLE 3-1

SAMPLING AND TEST METHOD/SOP REQUIREMENTS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 1 OF 2

Investigation Location	Sample ID Number [1]	Medium/ Matrix	Depth (feet bgs) [1]	No. of Samples	Sampling SOP [2]	Testing Method/ SOP[3]	Sample Quantity	Containers (Number, size, and type)	Preservation Requirements (temperature, light protected)	Maximum Holding Time (Preparation/ testing)
SS-1 through SS-4 (surface soil)	OU3DSN-SS-SSXD-0002	Surface Soil (Disturbed Sample)	0.5-2.0	1 per location	GH-1.3, SA-1.3, ASTM 01452 (hand auger)	ASTM D2487, D2216, D4318, D422, D854, D2850, D1557, D5084.	100 pounds	five-gallon bucket(s)	Standard lab atmosphere, out of direct sunlight, air tight container	None if no loss of water
	OU3DSN-SS-SSXU-0002	Surface Soil (Undisturbed Sample)	0.5-2.0	1 per location	SA-1.3, ASTM D1587 (shelby tube)	ASTM D2937	>24 inches recovery from Shelby tube (s)	2 three-inch diameter, 30 inch long Shelby tubes	Standard lab atmosphere, out of direct sunlight, air tight (wax) container, minimize disturbance	None if no loss of water
P-1 through P-22 (piezometers)	NSID[4]	Subsurface Soil	Continuous length of borehole	N/A	SA-2.5	ASTM D2488 (field test only)	N/A	N/A	N/A	N/A
DB-1 through DB-8 (deep borings)	NSID[4]	Subsurface Soil	Continuous length of borehole	N/A	SA-2.5	ASTM D2488 (field test only)	N/A	N/A	N/A	N/A
	OU3DSN-SB-DBXU-NNNN OU3DSN-SB-DBXU-NNNN	Subsurface Soil	Tidal mudflat interval	2 per borehole – One at top of mubflat and other at bottom	SA-1.3, ASTM D1587 (shelby tube)	ASTM D2487, D2216, D4318, D422, D854, D2850, D2937, D2435, D4767.	>24 inches recovery from Shelby tube (s)	three-inch diameter, 30 inch long Shelby tube per interval	Standard lab atmosphere, out of direct sunlight, air tight (wax) container, minimize disturbance	None if no loss of water
	NSID [4]	Rock	Bedrock	1	GH-1.3	ASTM D6032 (field test only)	5-foot core	NX Core barrel	NA	NA

TABLE 3-1

SAMPLING AND TEST METHOD/SOP REQUIREMENTS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 2 OF 2

1 The depth of the tidal mudflat samples will be determined in the field and accordingly documented. The sample numbers will be accordingly documented to include the top and bottom of the sampling interval in the "NNNN" field. (See Section 3.3.2 for ID details.)
2 Refer to Table 9-1 for Sampling SOP reference
3 Refer to Table 12-1 for Analytical Method/SOP reference
4 NSID: No Sample ID, field test results will be recorded on a boring log.
5 "X" refers to sample location number.

TABLE 3-2

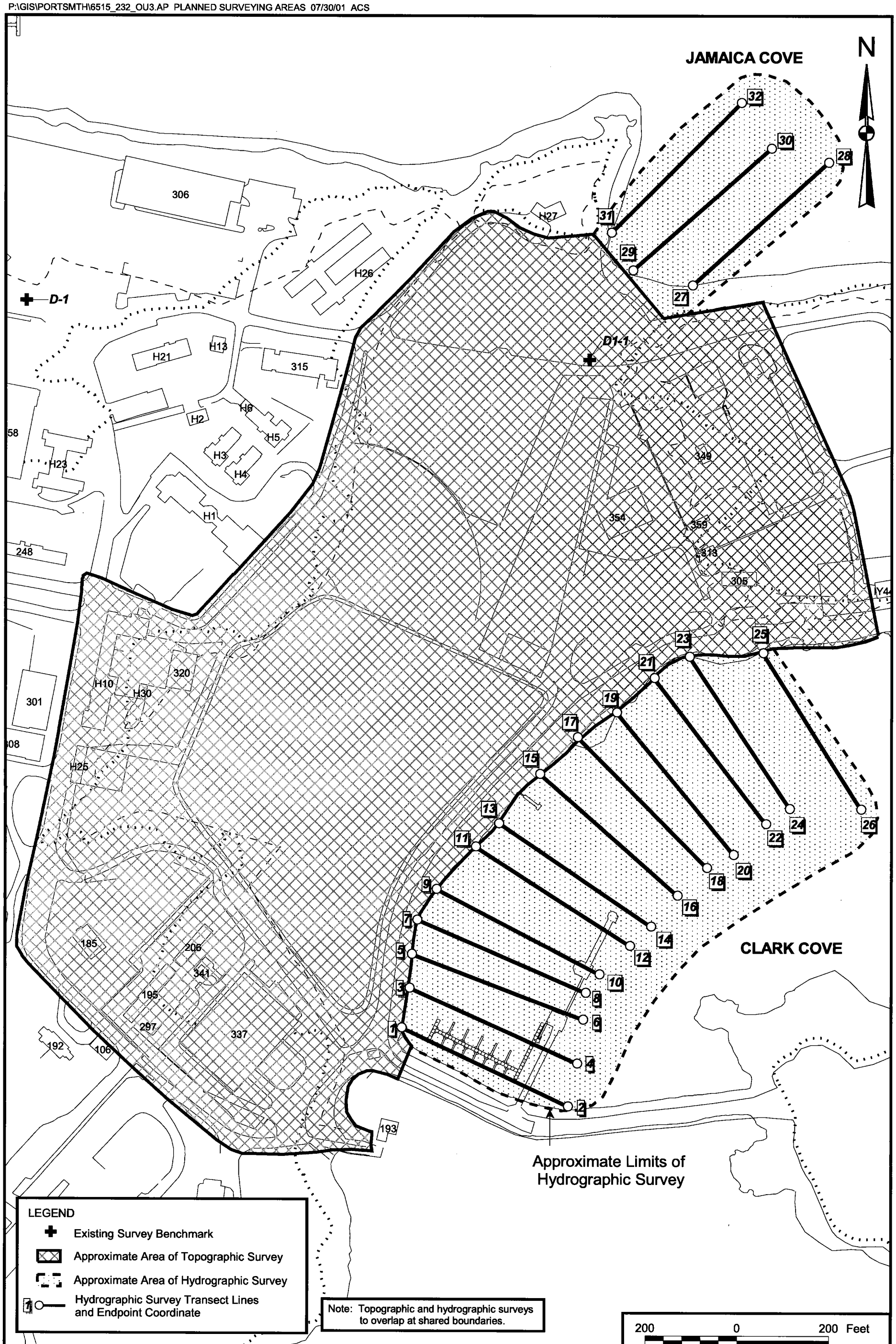
**PROJECT SAMPLING SOP REFERENCE
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 1 OF 2**

Reference Number	Title, Revision Date and/or Number	Originating Organization	Equipment Identification	Modified for Project Work (Y or N)
CT-04	Sample Nomenclature, SOP CT-04, March 1996	TtNUS	NA	N
HS-1.0	Utility Locating and Excavation Clearance, SOP HS-1.0, March 2000	TtNUS	geophysical instruments	N
GH-1.2	Evaluation of Existing Monitoring Wells and Water Level Measurement, SOP GH-1.2, June 1999	TtNUS	water level indicator	N
GH-1.3	Soil and Rock Drilling Methods, SOP GH-1.3, June 1999	TtNUS	hand augers, hollow-stem augers, split-barrel samplers	N
GH-1.5	Borehole and Sample Logging, SOP GH-1.5, June 1999	TtNUS	camera, borehole log form	N
GH-2.3	Aquifer Pumping Tests, SOP GH-2.3, June 1999	TtNUS	pressure transducer, data recorder	N
GH-2.8	Groundwater Monitoring Point Installation, SOP GH-2.8, June 1999	TtNUS	well construction materials, hollow stem auger	N
GH-2.9	Well Abandonment, SOP GH-2.9, June 1999	TtNUS	grout pump	N
SA-2.5	Direct Push Technology (Geoprobe/Hydropunch), SOP SA-2.5, January 2000	TtNUS	DPT rig, Macrocore sampler	N
SA-6.1	Non-Radiological Sample Handling, SOP SA-6.1, March 2000	TtNUS	water filtration canisters, sample containers, preservatives, shipping coolers	N
SA-6.3	Field Documentation SOP SA-6.3, January 2000	TtNUS	field notebooks, log forms, camera	N
SA-7.1	Decontamination of Field Equipment and Waste SOP SA-7.1, March 1998	TtNUS	steam cleaner, decon solutions, 55-gal. drums	N
ME-12	Photovac 2020 Photoionization Air Monitor, SOP ME-12, March 1998	TtNUS	PID	N

TABLE 3-2

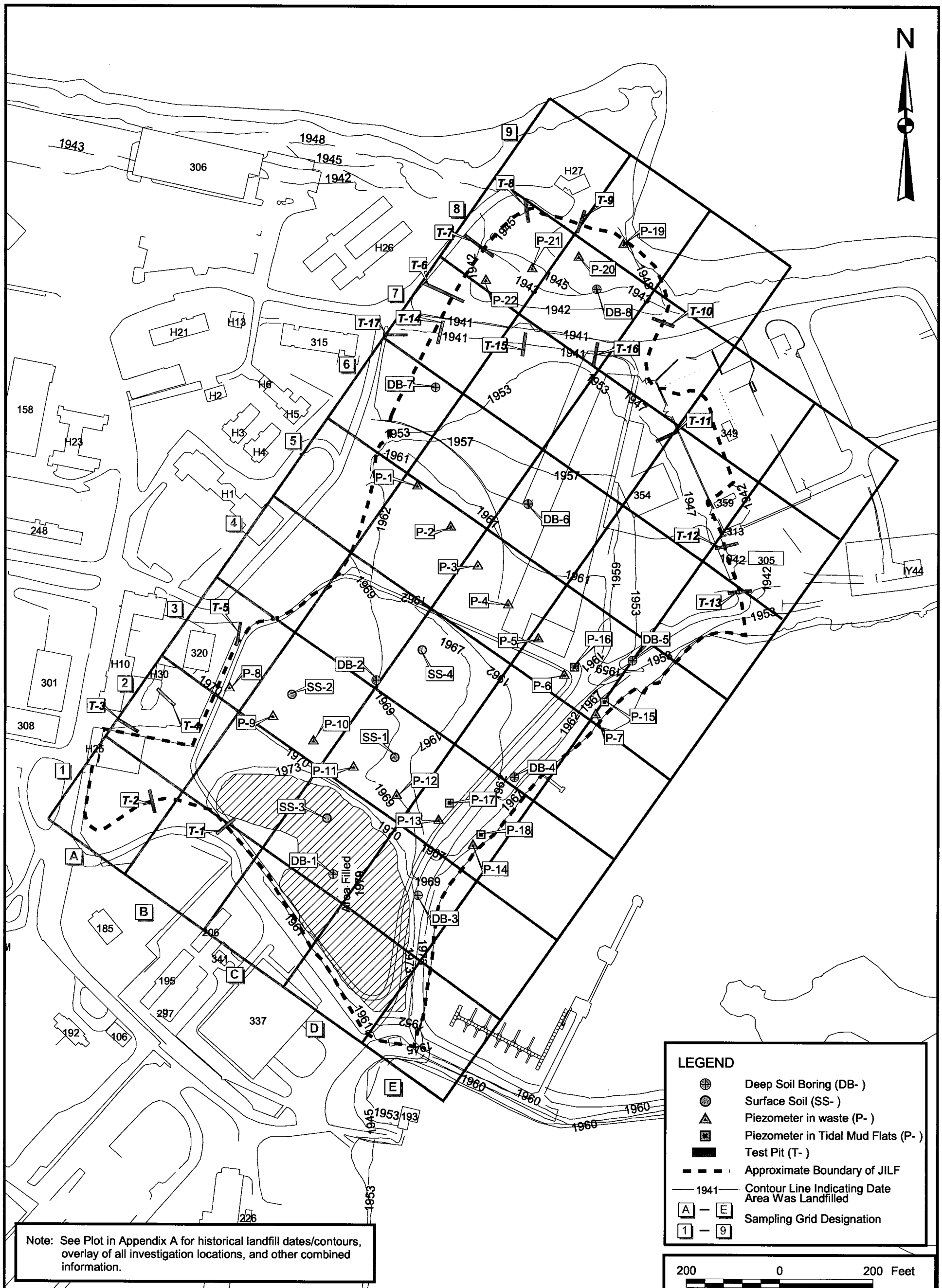
**PROJECT SAMPLING SOP REFERENCE
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 2 OF 2**

Reference Number	Title, Revision Date and/or Number	Originating Organization	Equipment Identification	Modified for Project Work (Y or N)
GA-90	SOP for Measurement of Landfill Gases and Determination of Annual Methane Generation Rates, GA-90 Operation Manual, Version MK2B 1.02, 1994	Beacon Environmental	GA-90 Infrared Landfill Gas Analyzer, battery charger, 1/2 inch i.d. shallow ground probes (typically 24 inches long), sampling valves	N
TBD	SOP for Cone Penetration Testing	Applied Research Associates	TBD	



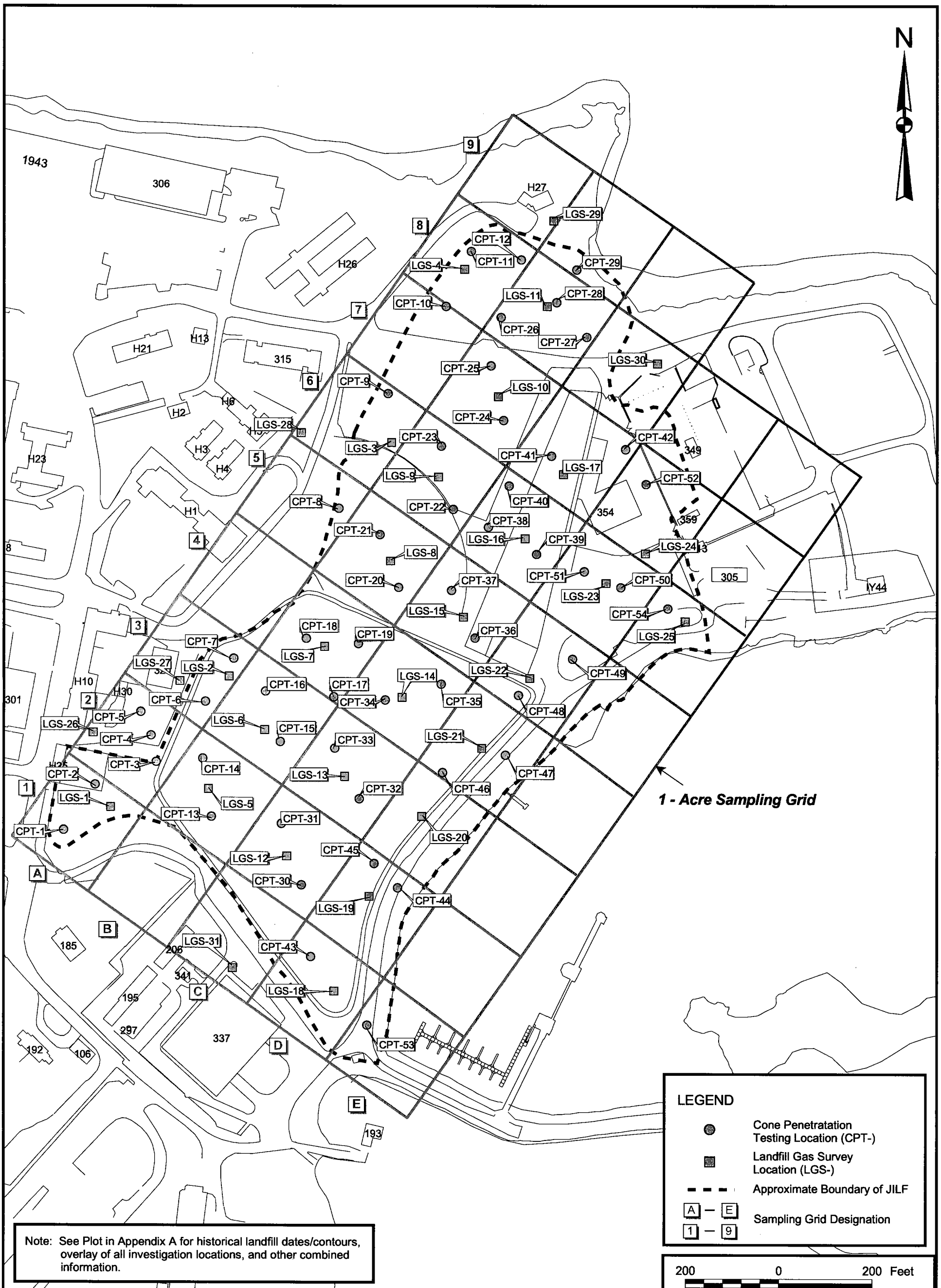
DRAWN BY J. LAMEY	DATE 5/23/01	Tetra Tech NUS, Inc.	CONTRACT NUMBER 1549	OWNER NUMBER —
CHECKED BY J. WRIGHT	DATE 5/29/01	PLANNED SURVEYING AREAS OU3 PRE-DESIGN INVESTIGATION PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE	APPROVED BY —	DATE —
COST/SCHEDULE-AREA			APPROVED BY —	DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 3-1	REV 1

P:\GIS\PORTSMTH\6515_232_OU3.APR PROPOSED SOIL, PIEZOMETER, AND TEST PIT LOCATIONS 07/31/01 ACS



DRAWN BY J. LAMEY	DATE 5/24/01	Tetra Tech NUS, Inc.	CONTRACT NUMBER 1549	OWNER NUMBER —
CHECKED BY J. WRIGHT	DATE 5/29/01	PLANNED SOIL, PIEZOMETER, AND TEST PIT LOCATIONS OU3 PRE-DESIGN INVESTIGATION PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE	APPROVED BY —	DATE —
COST/SCHEDULE-AREA			APPROVED BY —	DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 3-2	REV 1

P:\GIS\PORTSMTH\6515_232_OU3.APR PROPOSED CPT AND LANDFILL GAS SURVEY LOCATIONS 07/31/01 ACS



Note: See Plot in Appendix A for historical landfill dates/contours, overlay of all investigation locations, and other combined information.

DRAWN BY J. LAMEY DATE 5/24/01	Tetra Tech NUS, Inc.	CONTRACT NUMBER 1549	OWNER NUMBER —
CHECKED BY J. WRIGHT DATE 5/29/01	PLANNED CPT AND LANDFILL GAS SURVEY LOCATIONS OU3 PRE-DESIGN INVESTIGATION PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE	APPROVED BY — DATE —	
COST/SCHEDULE-AREA		APPROVED BY — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 3-3	REV 1

4.0 TESTING METHOD REQUIREMENTS AND QUALITY CONTROL

This section presents the requirements for the pre-design investigation field tests and laboratory tests. This section also presents the quality control requirements for the testing procedures.

4.1 FIELD TESTING METHOD REQUIREMENTS

This section of the QAPP describes the procedures that will be used in the field to obtain measurements using the following instruments:

- Photovac 2020 PID organic vapor monitoring instrument
- Electronic Water Level Indicator (Heron) or equivalent
- Pressure Sensitive Transducers (In-Situ Mini-Troll or Equivalent)
- CPT Device (from the selected subcontractor)
- GA-90 Infrared Landfill Gas Analyzer

Photovac 2020

Field measurements of organic vapors will be performed during the soil borings and test pits as described in Section 3.2. These measurements will be made using a Photovac 2020 organic vapor analyzer as described in SOP ME-12. The Photovac 2020 measures the concentration of airborne photoionizable gases and automatically displays and records these concentrations.

Electronic Water Level Indicator

All water level measurements will be taken using an electronic water level indicator as described in SOP GH-1.2. The water level measurements will be taken to measure water levels in the piezometers and as a check on the accuracy of the pressure transducers.

Pressure Sensitive Transducers (In-Situ Mini-troll or Equivalent)

The pressure sensitive transducers will be placed in each of the piezometers to measure fluctuation of water levels over a period of one month. Readings will be recorded at fifteen-minute intervals. A portable lap-top computer will be used in the field to set up each of the transducers. After all the readings are taken, the information will be downloaded in the field onto the portable computer.

CPT Device

CPT will be conducted at the site as described in Section 3.2.5. The CPT equipment will acquire, analyze, and present penetrometer data. Data will be displayed and plotted in real time on-screen and on hard copy.

GA-90 Infrared Landfill Gas Analyzer

A methane soil gas survey will be conducted at the site as described in Section 3.2.6. The GA-90 infrared landfill gas analyzer will be used to obtain real time methane concentrations and flow rates.

4.1.1 Field Testing Methods and SOPs

The test results from the following field methods will be used to obtain the data for the design as described below:

- CPT testing will be used to correlate the strength properties of the waste mass for use in settlement and slope stability analyses. CPT testing will also extend through the underlying tidal mud flat. That information will be used to confirm the thickness and strength properties of the layer.

- ASTM D1586 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils prescribes the procedure for driving a split-barrel sampler to obtain a representative soil sample and measure the resistance of the soil to penetration of the sampler. This method is used extensively throughout the U.S. and abroad, many published sources are available to correlate the SPT blow count (N value) to engineering properties of the soil.

- ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) describes how to identify soils using standardized visual and manual procedures and criteria. This information is used to evaluate the areal variability of soils.

- ASTM D1556 Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method is used to determine the in-place density and unit weight of soils. In-place density is used in settlement and slope stability analyses and to evaluate the weight-volume relationship.

- ASTM D1587 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes is used to recover relatively undisturbed samples suitable for laboratory testing of engineering properties such as laboratory strength and consolidation testing and soil identification.

- ASTM D6032 Standard Method for Determining Rock Quality Designation (RQD) of Rock Core. This method is used to denote the percentage of intact rock retrieved from a borehole. This information will be used for slope stability analysis.

4.1.2 Field Testing Method/SOP Modifications

No modification of the testing methods or SOPs is anticipated.

4.1.3 Field Testing Instrument Calibration

Checks that need to be performed on the field equipment are listed in Table 4-1.

Photovac 2020

The Photovac 2020 will be calibrated as per the manufacturer's user's manual. The meter will be calibrated daily or prior to each use. The calibration will be checked against a standard solution (Isobutylene). Records of instrument calibration will be maintained on a field instrument calibration log sheet provided in Appendix C. If the meter does not maintain an acceptable level of calibration during a single day's use, then the meter will be calibrated more frequently or it will be replaced.

Electronic Water Level Indicator

The water level meter does not typically need to be calibrated; however, a check will be made with a measuring tape to assure that the depth markings on the probe line are correct. Records of all water level readings will be entered into the field notebook or onto a water level measurement sheet included in Appendix C.

Pressure Sensitive Transducers

The pressure transducers are calibrated by the manufacturer and the field measurements are verified by comparing transducer data (converted into equivalent fresh-water head elevations) against measurements made simultaneously with a water level indicator. Each transducer will be calibrated or checked periodicaly during field activities with a water level indicator to ensure accuracy. The procedures in SOP GH2.3 will be followed.

CPT Device

Calibration of the CTP device will be conducted during field activities by the CPT subcontractor. Pre and post zero readings will be taken and recorded on each CPT test file to check for electronics drift.

Additional calibration checks will include the measurement of probe diameters of cone after each test and general visual inspection and checking of all CPT equipment. All calibration will be performed by the subcontractor according to ASTM D-5778. All calibration information will be provided in the report supplied by the subcontractor.

Landfill Gas Survey Instruments

Calibration of the infra-red landfill gas analyzer (GA-90) will be performed by the subcontractor as follows:

First, a methane concentration of zero is established. The zero point is established by sampling air free of methane and verifying that the instrument is zeroed to methane. This establishes the bottom point of the methane gas curve. After the zero point is set, the instrument is then calibrated to methane using calibration gas at a concentration most likely to be encountered in field samples. The instrument's sampling port is connected with tygon tubing to the methane calibration gas flow meter and the GA-90 samples the gas for two minutes. After two minutes the methane gas concentration reading on the instrument should be stable and not changing more than plus-or-minus three tenths of one percent. The methane concentration of the calibration gas is then entered into the instrument using its keyboard. The instrument will verify that the calibration is acceptable. If not, the instrument will instruct to retry. No field measurements will be taken until the calibration is accepted. Calibration of the instrument will be performed by the subcontractor prior to each round of sampling.

4.1.4 Field Testing Instrument/Equipment Maintenance, Testing, and Inspection Requirements

The field instruments will be serviced for preventive maintenance in accordance with the manufacturer's recommendations. Manufacturer's procedures typically identify the schedule for servicing critical items in order to minimize the downtime of the measurement system. It will be the responsibility of the field geologist to adhere to this maintenance schedule and to arrange any necessary and prompt service required.

Equipment, instruments, gauges, and other items requiring preventive maintenance will be serviced, when appropriate, by the equipment supplier, the TtNUS FOL (or designee), and/or drilling subcontractor in accordance with the manufacturer's recommendations as noted in Table 4-2. Manufacturer's procedures identify the schedule for servicing critical items to minimize the downtime of the measurement system. It will be the responsibility of the TtNUS FOL to adhere to this maintenance schedule and to arrange any necessary and prompt service required. Service of the equipment, instruments, tools, gauges, etc. will be performed to the extent possible by the TtNUS FOL (or designee). If the service requires a more qualified person, then the supplier or the manufacturer will be contacted for assistance.

Logs will be established by the TtNUS FOL (or designee) to record maintenance, service procedures, and schedules. Maintenance records will be documented and traceable to the specific equipment, instruments, and gauges.

4.1.5 Field Testing Inspection and Acceptance Requirements for Supplies

The field testing supplies to be used are the standards of Isobutylene gas for calibration of the Photovac 2020 and methane gas for the GA-90 infrared landfill gas analyzer. The calibration gases will be checked for adequate volume and expiration date by the TtNUS FOL and LGS subcontrator. If the volume is inadequate or the expiration date is questionable, then the TtNUS FOL or the LGS subcontractor will obtain replacement supplies.

4.2 FIXED LABORATORY TESTING METHOD REQUIREMENTS

This section of the QAPP describes the geotechnical testing methods that will be used by the laboratory to generate the data for the project. It documents the laboratory test methods and SOPs that will be used. Laboratory SOPs (from Geo Testing Express, Inc.) are not included with this QAPP, but are available upon request.

4.2.1 Fixed Laboratory Testing Methods and SOPs

Table 4-3 lists the testing methods/SOPs. The test results from the following laboratory tests will be used to support the design:

- ASTM D 2487 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System) describes the system of classifying soils for engineering purposes based on laboratory determination of particle size, liquid limit and plasticity index. Soils are classified into three major divisions; coarse grained, fine grained and highly organic. Soils are further classified into one of 15 basic soil groups. Soil type determines behavior.

- ASTM D 2216 Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. Soil moisture content is a basic property necessary for determination of other properties and moisture-density relationships.

- ASTM D 2937 Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method describes a method of determining soil density. In-place density is used in settlement and slope stability analyses and to evaluate the weight-volume relationship.

- ASTM D 4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils is used to classify soil types.

- ASTM D422 Standard Test Method for Particle-Size Analysis of Soils is used to classify soils.

- ASTM D 854 Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer. Specific gravity of the soil particles is a basic soil property necessary for determination of other properties.

- ASTM D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 [2,700 kN-m/m^3]) describes the laboratory method used to determine the relationship between water content and dry unit weight of soils (also known as the compaction curve). The compaction curve is used to determine the optimum soil density and moisture content for field compaction of soils.

- ASTM D 5084 Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter. This method is used to determine the hydraulic conductivity (also known as the coefficient of permeability) of water saturated porous materials. This testing will be conducted on potential barrier soil materials.

- ASTM D 2435 Standard Test Method for One-Dimensional Consolidation Properties of Soils describes procedures used to determine the magnitude and rate of consolidation of soil. The underlying tidal mudflat soils will be analyzed in this manner to determine the magnitude and rate of settlement expected from the added weight of the landfill cover.

- ASTM D 2850 Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils. This method describes the determination of the unconsolidated, undrained compressive strength of soils. This information will be used in the slope stability analysis. Unconsolidated-undrained strength represents short-term loading conditions where pore water pressure can build-up in a fine grained soil, reducing strength.

- ASTM D 4767 Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils. This test method describes the determination of strength and stress-strain relationships of a soil sample. This information will be used in the slope stability analysis and represents long term loading conditions.

4.2.2 Fixed Laboratory Testing Method/SOP Modifications

No modifications of test methods or SOPs are anticipated for the fixed laboratory.

4.2.3 Fixed Laboratory Testing Instrument Calibration

Table 4-4 lists the calibration requirements specific to each instrument. The overall calibration program and corrective action procedures followed by Geo Testing Express, Inc., is as follows (details are provided in SOP L20):

As a means to control and maintain that laboratory equipment is functioning properly, test equipment is subjected to a reference check. Reference checks are performed with the use of internal reference materials (IRMs) or verification. IRMs are traceable and have known values. Verification checks the critical dimensions and functionality of equipment. The frequency at which these reference checks and verifications are performed varies depending upon the piece of equipment, volume of testing performed with that equipment and likelihood of that piece of equipment to yield results which stray from accepted ranges. Reference and verification checks are recorded in the Laboratory Equipment Calibration Log. Reference checks can be performed by laboratory technicians or management.

Calibration of laboratory equipment is performed internally by the use of basic calibration instruments which are traceable to National Institute of Standards and Technology (NIST) standards. This approach permits internal calibration and periodic checks by trained personnel. Equipment is marked with calibration labels with at least the following information: calibration agency, calibration date, and due date for next calibration. Calibration certificates and records are kept in the Laboratory Equipment Calibration Log. Calibration and/or verification procedures are located in the Laboratory Manager's office.

If, after performing a reference check or verification, a piece of equipment is found to be yielding unacceptable results, the Laboratory Manager is consulted and a calibration check is performed. If this does not resolve the problem, the Quality Manager is consulted and a new course of action is determined. Actions taken to resolve the problem include: checking to determine if any previous test results may be affected and documenting corrective actions.

4.2.4 Fixed Laboratory Testing Instrument/Equipment Maintenance, Testing, and Inspection Requirements

Geo Testing Express, Inc. participates in various on-site inspection programs, namely: American Association of State Highway and Transportation Officials (AASHTO) and Geosynthetic Accreditation

Institute (GAI). Three aspects of the laboratory are checked during these inspections: equipment, procedures, and the quality system.

If deficiencies are found the following steps are taken:

- Equipment is replaced or repaired
- Correct procedures are discussed and reviewed with the technician; the technician is observed performing the test properly
- The Laboratory Manager reviews deficiencies in the Quality Manual with responsible individuals; corrections are made

Corrective actions are documented and maintained by the Laboratory Manager in the Laboratory Manager's office. Results of on-site inspections are maintained by the Laboratory Manager in the Laboratory Manager's office. An inventory list of sampling, testing, calibration and verification equipment is maintained and located in the Laboratory Manager's Office.

Laboratory personnel are responsible for verifying the following prior to performing tests:

- Equipment is in working order
- Equipment maintenance records are kept and up to date
- Equipment is calibrated per requirements
- The calibrated equipment to be used is accurate for the range needed for the test
- Calibration records are current

Computers used to collect data for testing are checked prior to being placed into service for testing. This is performed by the Laboratory Manager, Quality Manager or the Geo Testing Express, Inc. software engineer. Software used to collect data is documented. Software used for testing is checked for accuracy prior to being used in the laboratory and then periodically thereafter. Maintenance records are kept for each computer performing data collection for testing. These records are located in the Laboratory Manager's office.

4.2.5 Fixed Laboratory Inspection and Acceptance Requirements for Supplies

Supplies needed to perform the tests, if any, will be obtained in accordance with requirements specified in ASTM standards.

4.3 QUALITY CONTROL REQUIREMENTS

The quality control requirements for this project are discussed in terms of field procedures and laboratory procedures. Field or laboratory QC samples are not typically required for geotechnical purposes.

4.3.1 Field Quality Control

Procedures related to sample integrity in the field and quality of data obtained from field test procedures are described here. Sample integrity will be maintained by ensuring that the undisturbed soil samples are not subjected to mechanical shock or loss of moisture. Periodic checks of the water level data recorded in the piezometers will be performed (i.e. twice each week). A manual water level reading will be taken and compared to the most recent reading to ensure that the pressure transducer and data logger are functioning normally.

Daily Quality Control Reports (DQCRs) will be filled out by the TtNUS FOL (or designee) and provided to the TtNUS PM, Navy RPM, and USACE field support on a daily basis to provide a summary of daily field activities. The DQCRs will be maintained in the project file and used at the end of the project to support the evaluation of whether the project objectives are met as described in Section 6.3.

4.3.2 Fixed Laboratory Quality Control

GeoTesting Express, Inc. performs periodic Internal Reference Material (IRM) checks. These checks are summarized in SOP L28. Table 4-4 provides detail on the checks (frequency, acceptance criteria, procedures, etc.). SOP L20 describes the methods of maintaining the laboratory equipment. Results of triplicate analyses for select tests for quality control purposes are available.

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TABLE 4-1

FIELD TESTING EQUIPMENT CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Equipment	Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA	SOP References
Pressure transducers	Pressure values checked against manual water level readings	Once at beginning and ending of monitoring period, and at intermediate points when convenient	Transducer readings should not deviate more than 0.1 foot elevation from manual measurements	Replace transducer if readings do not correspond to manual measurements	Field geologist with oversight by Project Manager	GH-2.3
Water level indicator	Check cable for breaks, splices, or other potential changes in cable length	NA	Measurements on cable correspond to lengths on 100 foot tape measure to within 0.05 feet	Replace instrument if criteria exceeded	Field geologist with oversight by Project Manager	GH-1.2
Infrared landfill gas analyzer	Set bottom of curve using Methane free air, set top of curve using Methane calibration gas.	Prior to each round of sampling	Stable reading with variation no more than 0.3 percent of calibration value.	Send instrument to an authorized service center for repair.	Subcontractor with TtNUS FOL overnight	GA-90
Cone Penetration Testing	Per ASTM D-5778	Per ASTM D-5778	Per ASTM D-5778	Per ASTM D-5778	Subcontractor with TtNUS FOL overnight	NA

NA Not applicable

TABLE 4-2

FIELD EQUIPMENT, MAINTENANCE, TESTING AND INSPECTION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Sampling Equipment/ Instrument	Maintenance Activity	Testing Activity	Inspection Activity	Responsible Person	Frequency	Acceptance Criteria	Corrective Action	SOP Reference
Pressure transducers	NA	Operation	Visual	Field geologist	Prior to use	No visual defect: conformance with manufacturer standards	Repair or use alternate equipment	GH-2.3
Water level indicator	Cleaning	Operation	Visual	Field geologist	Prior to use	No visual defect: conformance with manufacturer standards	Repair or use alternate equipment	GH-1.2
Infrared landfill gas analyzer	Factory servicing every six months, replace filters, charge battery	Operation	Visual	Subcontractor	Prior to use	No visual defect: conformance with manufacturer standards	Repair or use alternate equipment	GA-90
Cone Penetration Testing	Per ASTM D-5778	Per ASTM D-5778	Per ASTM D-5778	Subcontractor	Per ASTM D-5778	Per ASTM D-5778	Per ASTM D-5778	NA

NA Not applicable

TABLE 4-3

LABORATORY TESTING METHOD / SOP REFERENCE TABLE
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 1 OF 2

Reference Number	Title, Revision Date and / or Number	Definitive or Screening Data	Region I NESTS Method Code	Test Method/SOP	Test Property	Modified for Project Work (Y or N)
L1	Test Method for Particle-Size Analysis of Soils, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 422	grain size analysis	N
L2	Test Method for Specific Gravity of Soils, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 854	specific gravity	N
L3	Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3), Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 1557	optimum moisture content and maximum dry density	N
L4	Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 2216	moisture content	N
L5	Test Method for One-Dimensional Consolidation Properties of Soils, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 2435	magnitude and rate of consolidation of soil	N
L6	Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 2487	engineering classification of soils	N
L7	Test Method for Unconsolidated Undrained Triaxial Compression Test on Cohesive Soils, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 2850	strength and stress-strain relationships of cohesive soil	N
L8	Density of Soil in Place by the Drive Cylinder Method, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 2937	density	N
L9	Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 4318	plasticity of soils	N
L10	Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 4767	strength and stress-strain relationships of saturated cohesive soil	N
L11	Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, Geo Testing Express, Inc. SOP, Revision #1, April 1999	NA	NA	ASTM D 5084	hydraulic conductivity	N
L12	Mangement Responsibility, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001, Section 1.0	NA	NA	Mangement Responsibility	NA	N
L13	Quality System, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 2.0	NA	NA	Quality System	NA	N
L14	Contracting Review, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 3.0	NA	NA	Contracting Review	NA	N
L15	Document and Data Control, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 4.0	NA	NA	Document and Data Control	NA	N

TABLE 4-3

LABORATORY TESTING METHOD / SOP REFERENCE TABLE
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
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Reference Number	Title, Revision Date and / or Number	Definitive or Screening Data	Region I NESTS Method Code	Test Method/SOP	Test Property	Modified for Project Work (Y or N)
L16	Purchasing, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 5.0	NA	NA	Purchasing	NA	N
L17	Control of Customer-Supplied Product, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 6.0	NA	NA	Control of Customer-Supplied Product	NA	N
L18	Product Identification and Traceability, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 7.0	NA	NA	Product Identification and Traceability	NA	N
L19	nspection and Testing, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 8.0	NA	NA	Inspection and Testing	NA	N
L20	Control of Inspection, Measuring and Testing Equipment, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 9.0	NA	NA	Control of Inspection, Measuring and Testing Equipment	NA	N
L21	Inspeciton and Testing Status, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 10.0	NA	NA	Inspeciton and Testing Status	NA	N
L22	Control of Nonconforming Product, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 11.0	NA	NA	Control of Nonconforming Product	NA	N
L23	Corrective Action, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 12.0	NA	NA	Corrective Action	NA	N
L24	Handling, Storage, Packaging, Preservation and Delivery, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 13.0	NA	NA	Handling, Storage, Packaging, Preservation and Delivery	NA	N
L25	Control of Quality Records, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 14.0	NA	NA	Control of Quality Records	NA	N
L26	Internal Quality Audits, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 15.0	NA	NA	Internal Quality Audits	NA	N
L27	Training, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 16.0	NA	NA	Training	NA	N
L28	Statistical Techniques, Geo Testing Express, Inc. Quality Manual, Version 8.0, May 2001 Section 17.0	NA	NA	Statistical Techniques	NA	N
L29	AASHTO - AMRL Proficiency Tests Final Report	NA	NA	Proficiency Tests	NA	N
L30	AASHTO Audit	NA	NA	Audit	NA	N
L31	United States Corps of Engineers Audit	NA	NA	Audit	NA	N

NA - Not Applicable

TABLE 4-4

LABORATORY INSTRUMENT MAINTENANCE AND CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 1 OF 6

CALIBRATED INSTRUMENT	ASTM METHOD	List Maintenance, Testing and Inspection Activities *(Refer to SOP L20)*	Frequency of Calibration (Accuracy Verification)	Acceptance Criteria (Accuracy Verification)(1)	Corrective Action (CA) *(Refer to SOP L20)*	Person Responsible for CA	METHOD/SOP REFERENCE
Hydrometer	ASTM D 422 Test Method for Particle-Size Analysis for Soils		Not Specified (1/12 months)	Refer to GTX-4 (Check critical dimensions and temperature.)		Laboratory Manager	L1
Various Sieves			Not Specified (1/6 months)	Refer to GTX-2 (Check critical dimensions.)			
Sieve Shaker			Not Specified (1/12 months)	Refer to GTX-3 (Checked for thoroughness.)			
Oven			Not Specified (Daily)	Refer to GTX-12 (Temperature checked to be 110°C.)			
Thermometer			Not Specified (1/6 months)	Refer to GTX Standard Procedures (Checked against NIST temperatures.)			
Balance			1/12 months (1/3 months)	Outside Agency/Refer to GTX-1 (Checked for accuracy against dead weight.)			
Oven	ASTM D 854 Test Method for Specific Gravity of Soils		Not Specified (Daily)	Refer to GTX-12 (Temperature checked to be 110°C.)		Laboratory Manager	L2
Balance			1/12 months (1/3 months)	Outside Agency/Refer to GTX-1 (Checked for accuracy against dead weight.)			

TABLE 4-4

LABORATORY INSTRUMENT MAINTENANCE AND CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 2 OF 6

CALIBRATED INSTRUMENT	ASTM METHOD	List Maintenance, Testing and Inspection Activities *(Refer to SOP L20)*	Frequency of Calibration (Accuracy Verification)	Acceptance Criteria (Accuracy Verification)(1)	Corrective Action (CA) *(Refer to SOP L20)*	Person Responsible for CA	METHOD/SOP REFERENCE
Thermometer			Not Specified (1/6 months)	Refer to GTX Standard Procedures (Checked against NIST temperatures.)			
Vacuum Pump			Not Specified (1/12 months)	Refer to GTX-8 (Checked for 26 Hg in vacuum.)			
Proctor Mold	ASTM D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort		Not Specified (1/12 months)	Refer to GTX-5 (Check critical dimensions.)		Laboratory Manager	L3
Rammer			Not Specified (1/12 months)	Refer to GTX-7 (Check critical dimensions.)			
Balance			1/12 months (1/3 months)	Outside Agency/Refer to GTX-1 (Checked for accuracy against dead weight.)			
Oven			Not Specified (Daily)	Refer to GTX-12 (Temperature checked to be 110°C.)			
Straight Edge			Not Specified (1/6 months)	Refer to GTX-6 (Check critical dimensions.)			

TABLE 4-4

LABORATORY INSTRUMENT MAINTENANCE AND CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 3 OF 6

CALIBRATED INSTRUMENT	ASTM METHOD	List Maintenance, Testing and Inspection Activities *(Refer to SOP L20)*	Frequency of Calibration (Accuracy Verification)	Acceptance Criteria (Accuracy Verification)(1)	Corrective Action (CA) *(Refer to SOP L20)*	Person Responsible for CA	METHOD/SOP REFERENCE
Oven	ASTM D 2216 Test Method for Laboratory Determination of Moisture Content of Soil and Rock		Not Specified (Daily)	Refer to GTX-12 (Temperature checked to be 110°C.)		Laboratory Manager	L4
Balance			1/12 months (1/3 months)	Outside Agency/Refer to GTX-1 (Checked for accuracy against dead weight.)			
Load Cell	ASTM D 2435 Test Method for One-Dimensional Consolidation Properties of Soil		1/12 months (1/3 months)	Refer to GTX-11 (Compared to dead weight.)		Laboratory Manager	L5
Displacement Transducer			1/12 months (1/3 months)	Refer to GTX-11 (Check against gauge blocks.)			
Load Frame			Not Specified (1/3 months)	Refer to GTX Standard Procedure (Check for a displacement rate of 0.04 inches per minute, ipm.)			
Equipment the same as needed for D 422 and D 4318	ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes					Laboratory Manager	L6

TABLE 4-4

LABORATORY INSTRUMENT MAINTENANCE AND CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 4 OF 6

CALIBRATED INSTRUMENT	ASTM METHOD	List Maintenance, Testing and Inspection Activities *(Refer to SOP L20)*	Frequency of Calibration (Accuracy Verification)	Acceptance Criteria (Accuracy Verification)(1)	Corrective Action (CA) *(Refer to SOP L20)*	Person Responsible for CA	METHOD/SOP REFERENCE
Load Cell	ASTM D 2850 Test Method for Unconsolidated Undrained Triaxial Compression Test on Cohesive Soils		1/12 months (1/3 months)	Refer to GTX-11 (Compared to dead weight.)		Laboratory Manager	L7
Displacement Transducer			1/12 months (1/3 months)	Refer to GTX-11 (Check against gauge blocks.)			
Load Frame			Not Specified (1/3 months)	Refer to GTX Standard Procedure (Check for a displacement rate of 0.04 ipm.)			
Flow Pump Unit			Not Specified (1/3 months)	Refer to GTX Standard Procedure (Visual inspection.)			
Pressure Transducer			1/12 months (1/3 months)	Refer to GTX-11 (Check pressure gauge to be 50 psi.)			
Oven	ASTM D 2937 Density of Soil in Place by the Drive Cylinder Method		Not Specified (Daily)	Refer to GTX-12 (Temperature checked to be 110°C.)		Laboratory Manager	L8
Balance			1/12 months (1/3 months)	Outside Agency/Refer to GTX-1 (Checked for accuracy against dead weight.)			

TABLE 4-4

LABORATORY INSTRUMENT MAINTENANCE AND CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 5 OF 6

CALIBRATED INSTRUMENT	ASTM METHOD	List Maintenance, Testing and Inspection Activities *(Refer to SOP L20)*	Frequency of Calibration (Accuracy Verification)	Acceptance Criteria (Accuracy Verification)(1)	Corrective Action (CA) *(Refer to SOP L20)*	Person Responsible for CA	METHOD/SOP REFERENCE
Liquid Limit Device	ASTM D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils		Not Specified (1/12 months)	Refer to GTX-13 (Check critical dimensions.)		Laboratory Manager	L9
Balance			1/12 months (1/3 months)	Outside Agency/Refer to GTX-1 (Checked for accuracy against dead weight.)			
Oven			Not Specified (Daily)	Refer to GTX-12 (Temperature checked to be 110°C.)			
#40 Sieve			Not Specified (1/6 months)	Refer to GTX-2 (Check critical dimensions.)			
Load Cell	ASTM D 4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils		1/12 months (1/3 months)	Refer to GTX-11 (Compared to dead weight.)		Laboratory Manager	L10
Displacement Transducer			1/12 months (1/3 months)	Refer to GTX-11 (Check against gauge blocks.)			

TABLE 4-4

LABORATORY INSTRUMENT MAINTENANCE AND CALIBRATION
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 6 OF 6

CALIBRATED INSTRUMENT	ASTM METHOD	List Maintenance, Testing and Inspection Activities *(Refer to SOP L20)*	Frequency of Calibration (Accuracy Verification)	Acceptance Criteria (Accuracy Verification)(1)	Corrective Action (CA) *(Refer to SOP L20)*	Person Responsible for CA	METHOD/SOP REFERENCE
Load Frame			Not Specified (1/3 months)	Refer to GTX Standard Procedure (Check for a displacement rate of 0.04 inches per minutes)			
Flow Pump Unit			Not Specified (1/3 months)	Refer to GTX Standard Procedure (Visual inspection.)			
Pressure Transducer			1/12 months (1/3 months)	Refer to GTX-11 (Check pressure gauge to be 50 psi.)			
Pressure Gauge	ASTM D 5084 Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter		Not Specified (1/6 months)	Refer to GTX Standard Procedure (Check with PSI Tronix pressure gauge.)		Laboratory Manager	L11
Vacuum Pump			Not Specified (1/12 months)	Refer to GTX-8 (Checked for 26 Hg in vacuum.)			
Thermometer			Not Specified (1/6 months)	Refer to GTX Standard Procedures (Checked against NIST temperatures.)			

(1) GTX: Geo Testing Express internal procedures manual.

5.0 DATA ACQUISITION REQUIREMENTS AND DOCUMENTATION, RECORDS, AND DATA MANAGEMENT

5.1 DATA ACQUISITION REQUIREMENTS

This section of the QAPP identifies the sources of previously collected data and other information that will be used to make project decisions. Limitations on the data are also identified.

Sources of previously collected data that were reviewed for the development of this QAPP are as follows:

- Existing Conditions Map, U.S. Naval Activities Seavey Island, Kittery, Maine, NAVFAC DWG. No. 692161, November 1982 *(Offshore bathymetric map)*

- Operable Unit 3 Feasibility Study for Operable Unit 3, Portsmouth Naval Shipyard, Kittery, Maine, Tetra Tech NUS, Inc., November 2000

- Updated Monitoring Well Log Book, Portsmouth Naval Shipyard, Kittery, Maine, Tetra Tech NUS, Inc., April 2001

- Test Pitting Investigation Report, Jamaica Island Landfill February/March 2000 Activity, Portsmouth Naval Shipyard, Kittery, Maine, Tetra Tech NUS, Inc., October 2000

The limitation of the bathymetric map is that the information cannot be used for an accurate depiction of current hydrographical conditions in Clark Cove and Jamaica Cove because the information was generated in 1982 and the cove conditions are likely to have changed over a decade. Therefore, the information is used only to obtain an indication of how the depth to the sediments in the cove vary with distance from the shoreline. The information in this map cannot be used directly for design purposes.

Previous test pitting investigations were not conducted for the purpose of delineation of the extent of landfill. Therefore, the information was not suitable to determine where the landfill ends. Previous testing parameters for soil did not include all of the geotechnical characteristics required for design purposes. Topographic information has not been generated for the landfill surface.

5.2 DOCUMENTATION, RECORDS, AND DATA MANAGEMENT

This section describes how all project information will be managed, organized, and maintained for efficient use by the project personnel. The information management process is outlined, from the point of data generation to ultimate storage.

5.2.1 Project Documentation and Records

A summary of the OU3 pre-design investigation site records and documentation to be generated and stored in the TtNUS project files is provided in Table 5-1. Information to be maintained in the laboratory files is outlined in Section 5.2.3 of this QAPP.

5.2.2 Field Testing Data Package Deliverables

The following field testing data will be collected:

- Water-level and tidal measurements
- CPT results
- LGS readings
- Sand-cone Density measurements (by USACE), if shelby tube samples cannot be collected for laboratory measurement of in-situ density

The water-level measurements will be downloaded from the data loggers and a printout of the readings will be maintained in the project files. A copy will be included in the data package deliverable. The CPT results will be maintained in the project files. A copy will be included in the data package deliverable. The LGS readings will be obtained from the subcontractor as part of the report and maintained in the project files. A copy of the report and field readings will be included in the data package deliverable.

The sand-cone density test measurements will include mass, volume and moisture content readings and calculations of the density. A copy of these measured values will be obtained from the USACE representative and maintained in the project files. A copy will also be included in the data package deliverable.

5.2.3 Fixed Laboratory Data Package Deliverables

A turn-around time of 28 days will be requested for all the data. The itemized data package deliverables are presented in Table 5-1.

5.2.4 Data Reporting Formats

Field data will be recorded in the field log books and field forms. All log book and log sheet entries must be made in indelible ink (black pen is preferred). No erasures or liquid paper/white out are permitted. If an incorrect entry is made, the data will be crossed out with a single strike mark, initialed, and dated. The field personnel will sign and date the log book pages and field forms. Examples of the forms to be used in the field are presented in Appendix C of this QAPP.

5.2.5 Data Handling and Management

All field and fixed laboratory data will be maintained in the project files. The project files will contain hard copies of the chain-of-custody forms, sample log forms, sample location maps, and documentation of quality assurance of data manipulation, if any.

5.2.6 Data Tracking and Control

A “cradle-to-grave” sample tracking system will be used from the beginning to the end of the investigation. The sample identification system will consist of the format described in detail in Section 3.3.2. Before field mobilization, the TtNUS FOL will coordinate with the Sample Management Coordinator (SMC) to initiate the sample tracking process. All sample numbers, requested laboratory analyses, and other pertinent information will be entered into a sample tracking database before each sampling event. The SMC will use the database to print sample jar labels, if necessary, before field sampling. The TtNUS FOL and lead engineer (or designee) will review the labels for completeness of information, adherence to work plan requirements, and accuracy. The SMC will also send an advance paper copy of labels and sample tracking database to the laboratory.

Once field sampling is underway, the TtNUS FOL will forward the chain-of-custody forms to the SMC via facsimile at the end of each day. The lead engineer (or designee) will compare the entries on the chain-of-custody forms with the sample tracking database and enter the sample date and other sample information as appropriate. When the results arrive from the laboratory, the lead engineer (or designee) will verify whether the samples have been tested for the requested tests. The TtNUS PM will be notified of any discrepancies and corrective measures, if any discussed with the Navy team.

The geotechnical test results will be provided by the laboratory as paper printouts. Electronic results can be made available for specific tests, if required.

5.2.6.1 Geographical Information System (GIS) and Computer Aided Drafting/ Design

Data management systems consist of a relational database and GIS that are being used to manage environmental information pertaining to PNS. For this project, the surveyed piezometer locations will be included in the database. The GIS software used will be ARC View. The sampling locations will be assigned coordinates based on NAD 27 and NGVD 29 for Maine West State Planar Coordinates.

The water-level measurements obtained from the field will be used by a TtNUS geologist to generate average high-tide and low-tide contours. The contours will be generated using Auto CADD 2000 with the review of an experienced hydrogeologist.

5.2.6.2 Subcontractors Deliverables

Land survey and hydrographic survey data will be provided in electronic and hardcopy formats. The topographic information will also be included in the GIS system to update the site features for future use at PNS. The survey information provided by the subcontractors will contain raw point data and topographic contours.

The landfill gas survey and CPT locations will also be included in GIS database.

The Wetland Functions and Values Assessment will include a summary report, field data forms, sketches, and photographs.

TABLE 5-1

PROJECT DOCUMENTATION AND RECORDS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Sample Collection Records	Fixed Laboratory Records	Data Assessment Records	Other
Field Logbooks	Sample Receipt, Custody and Tracking Records	Audit Report and Quality Notices	All versions of QAPP
Sample Log Sheet-Soil	Equipment Calibration Logs	Data Verification and Quality Checks	Health and Safety Plan
Sample Log Sheet-"Low Flow" Groundwater	Equipment Maintenance and Testing Logs		All versions of project reports
Boring Logs	Corrective Action Forms		
Well Construction Logs	Instrument Print-outs (Raw Data)		
Well Development Logs	Sample Disposal Records		
Chain-Of Custody Records	Telephone Logs		
Telephone Logs			
Field Modification Records			
Field Instrument Calibration Logs			
Test Pit Logs			
CPT Readout			
LGS Readings			
Wetlands functions and values data forms, sketches and photographs.			

6.0 DATA VERIFICATION AND USABILITY

6.1 VERIFICATION AND VALIDATION REQUIREMENTS

Data verification is a process of evaluating the completeness, correctness, and contractual compliance of a data set against the method standard, SOP, or contract requirements documented in this QAPP. Data validation is an analyte- and sample-specific process that extends the qualification of data beyond data verification to determine the quality of a specific data set. The data to be obtained will be geotechnical in nature, therefore, validation as typically performed for chemical data cannot be conducted. However, the data obtained from the laboratory will be verified and checked for quality as described in Section 6.2.

The data and field records will also be reviewed by project personnel to ensure that the samples represent the intended sampling conditions and populations.

6.2 VERIFICATION AND VALIDATION PROCEDURES

This section describes the procedures that will be followed to meet the data verification requirements discussed in Section 6.1. Also, as discussed in Section 6.1, data validation will not be performed, but a check of the data quality will be performed.

6.2.1 Verification

Verification includes field data verification and laboratory data verification. The field data verification process for this project includes the maintenance and periodic review of field documentation, including the following:

- Field Logbook
- Instrument Calibration Log (TtNUS and subcontractors for CPT and LGS)
- Chain-of-Custody Form
- Field Summary Report
- Field Modification Record
- Field Log Sheets (TtNUS and subcontractors for CPT and LGS)

Field audits and laboratory internal data reviews are important elements of the data verification process. Each of these elements is discussed in detail in Table 6-1.

Field data will be generated as a result of real time measurement of PID (for health and safety monitoring), water levels, CPT, and LGS. The TtNUS FOL will document the PID readings and download the water level readings. Subcontractors will take readings of the CPT and LGS.

The PID readings will be recorded in the site logbook and on sample logsheets immediately after the measurements are taken. The water level data will be verified for completeness. If any readings are missed, then these will be noted.

Readings of CPT as obtained from the subcontractor will be verified for completeness and any obvious errors. Depth of termination of CPT will be verified against the expected depth to bedrock and if a significant deviation is noticed, then the field decision by the TtNUS FOL (or designee) to withdraw and offset the location or abandon the test point will be recorded.

At Geo Testing Express, Inc., the test data used to create a report is checked by the Laboratory Manager or Quality Manager. Final reports are checked, signed, and dated by the Laboratory Manager, Quality Manager, or Chief Engineer before being delivered to the client. Laboratory work sheets and test reports have a comments section where any out of ordinary, pertinent information is included concerning the test.

If an error is detected in the test data, the Laboratory Manager performs a preliminary investigation. If the preliminary investigation finds and resolves the problem, re-testing is performed. If, upon the preliminary investigation, there is no acceptable reason found for the error, the Quality Manager is consulted and a more in depth investigation is performed. Findings and resolutions are documented.

Nonconforming reports identified by the client are corrected, checked by the Laboratory Manager, and shipped to the client. Both the re-submitted report and the nonconforming report are kept in the project file. If re-testing is required to remedy the situation, it is done at no cost to the client. Again, nonconforming data and/or reports require documentation in the form of a corrective action report. Customer complaints require documentation by way of the corrective action report.

When the data is received at TtNUS, it will be verified for completeness, correctness, and contractual compliance of a data set against the method standard, SOP, or contract requirements documented in this QAPP. Completeness will entail a check for results from all requested tests for all samples. Correctness and contractual compliance will be verified by comparing the test conditions and parameters against the ASTM standards for each test, or laboratory SOP, or any specification issued by the Navy. Any graphical plots of data will be verified against raw data for obvious errors. All calculations will be checked for arithmetic correctness, units, and conversion factors.

The usability of such data will then be determined by the Navy, as discussed in Section 6.3.

6.3 DATA USABILITY/RECONCILIATION WITH PROJECT QUALITY OBJECTIVES

6.3.1 Overall Data Usability Review

This section describes how project data will be reconciled with the project quality objectives, how data quality issues will be addressed, and how limitations on the use of the data will be reported and handled. Field data will be examined immediately after generation for errors. Laboratory data will be examined upon receipt in a series of evaluations. The first step will be a data verification and quality check as described in Section 6.2.

6.3.2 Reconciliation with DQOs

After data verification and check for quality, the data will be reconciled with DQOs to determine whether sufficient data of acceptable quality are available for decision making. The data obtained from the field and the laboratory will be evaluated for its use in the decision rules discussed in Section 2.3. The following data reconciliation with DQOs will be addressed:

- Adequacy of water level data to prepare groundwater contours
- Consistency of test pit observations of waste/fill material upon termination
- Design input data will be evaluated for quality by the USACE

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TABLE 6-1

VERIFICATION TASKS AND PROCEDURES
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 1 OF 2

Verification Task	Description	I – INTERNAL E - EXTERNAL	Responsible for Verification (Name, Organization)
Site Logbook	The site logbook is a hardbound, paginated, controlled-distribution record book. Entries are made for every day that onsite activities take place. Upon completion of the fieldwork, the site logbook becomes part of the project's central file. All logbook entries are made in indelible ink. No erasures are permitted. If an incorrect entry is made, the data is crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook pages used are signed and dated. The TtNUS FOL signs the site logbook at the end of each day.	I	FOL, TtNUS
Instrument Calibration Log (TtNUS)	TtNUS FOL (or designee) calibrates or checks the calibration of monitoring instruments in accordance with the SOPs. The field team member completes a calibration logsheet, initials it, and dates it. Equipment which does not calibrate properly is taken out of service. The FOL collects and submits the calibration log sheets to the project file.	I	FOL, TtNUS
Instrument Calibration Log (Subcontractors)	Calibration logs will be obtained from the CPT and LGS subcontractors	E	Subcontractor team leaders for Applied Research Associates (CPT) and Beacon Environmental (LGS)
Chain-of-Custody Form	The TtNUS FOL with the assistance of the USACE representative organizes the samples into groups by testing method and fills out the C-O-C and signs it. The original C-O-C is shipped with the samples after the cooler is sealed. The geologist provides a copy of the C-O-C to the Lead Engineer (or designee) and submits a copy to the project file. The Lead Engineer (or designee) uses the C-O-C to track the progress of the samples and testing process. If the laboratory picks up the samples, then the receiving person signs the C-O-C.	I	FOL, TtNUS
Field Summary Report	Will be provided as part of the data package document field activities	I	FOL, TtNUS
Field Modification Record	Changes in field operating procedures may be necessary as a result of changed field conditions or unanticipated events. If a substantial change is required, the TtNUS FOL will notify the TtNUS PM and Lead Engineer of the need for the change. The TtNUS FOL will document the change on a Field Modification Record form and forward the form to the TtNUS PM and Lead Engineer at the earliest convenient time. The PM will sign the form and distribute copies to the QA Officer, Lead Engineer, FOL, Navy, and the project file. A copy of the completed Field Modification Record form will also be attached to the field copy of the QAPP.	I	FOL, TtNUS

TABLE 6-1

VERIFICATION TASKS AND PROCEDURES
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE
PAGE 2 OF 2

Verification Task	Description	I – INTERNAL E - EXTERNAL	Responsible for Verification (Name, Organization)
Field Audit	The QA officer or designated representative may audit fieldwork according to audit checklists or audit guides. The QA officer will immediately informs the TtNUS FOL and PM of any findings that require immediate corrective action. The audits will verify adherence to the QAPP and all applicable SOPs. The QA officer will record each finding of nonconformance on a Quality Notice report and submits it to the TtNUS PM. The QA officer will prepare an audit report summarizing the findings, which will be distributed to the Navy RPM, the PM, the Lead Engineer, the FOL, and the Program and Project QA/QC files.	I	QA Officer, TtNUS
Laboratory Internal Data Review	Laboratory work sheets are designed to minimize errors in performing and reporting the test results. Comment sections of the laboratory work sheets are used by technicians to record deviations from applicable test standards, problems arising during the performance of the test, etc. The Laboratory Manger or Director of Laboratories generally checks and approves most test reports before being shipped to the client. If it is impossible for the Laboratory Manager or Director of Laboratories to check and approve the report, the Chief Engineer will approve the report. If corrections are required, they are made and the report is checked again. In the even an incorrect report goes to a client, a new and corrected report is supplied to the client and a corrective action report is completed. Both the corrected report and the original report are retained in the project file.	E	Geo Testing Express, Inc.
Field log sheets (TtNUS)	The field log sheets include sampling logs, boring logs, and well construction logs. Entries are made onsite while activities are conducted. Upon completion of field work, the field log sheets are made part of the project's central file. All entries are made in indelible ink. No erasures are permitted. If an incorrect entry is made, the data is crossed out with a single strike mark, initialed and dated.	I	FOL, PM, TtNUS
Field log sheets (subcontractors)	Info to be filled in as appropriate from LGS and CPT subcontractors.	E	Subcontractor team leaders for Applied Research Associates (CPT) and Beacon Environmental (LGS)

7.0 ASSESSMENT AND OVERSIGHT

7.1 ASSESSMENTS AND RESPONSE ACTIONS

Assessment activities ensure that the resultant data quality is adequate for its intended use and that appropriate corrective actions are implemented to address nonconformances and deviations from the QAPP.

7.1.1 Planned Assessments

System audits will be performed as appropriate to ensure that work is being implemented in accordance with the approved project SOPs and in an overall satisfactory manner. These audits (as summarized on Table 7-1) will be performed in the following manner:

- The TtNUS FOL will supervise and check on a daily basis that the field instruments are calibrated and maintained, field measurements are made accurately, equipment is decontaminated as necessary, samples are collected and handled properly, and fieldwork is accurately and neatly documented.

- The TtNUS FOL (or designee) will record the subcontractors' activities and update the TtNUS PM of field activities on a daily basis.

- Variations to the QAPP based on field conditions will be communicated to the TtNUS PM.

At the discretion of and under the direction of the TtNUS QA Officer, an independent performance audit of field activities may be conducted. If a formal field audit is conducted, the QA Officer will check that sample collection, handling, decontamination and field documentation are being conducted according to approved SOPs.

No assessments of the selected laboratory, Geo Testing Express, Inc. are planned under the current project because of their participation in several proficiency testing programs. These programs help control and maintain that laboratory personnel are performing tests properly. GeoTesting Express, Inc. participates in the following proficiency testing programs:

ASTM/ISR	American Society for Testing and Materials/Institute for Standards Research (soils)
GAI-LAP	Geosynthetic Accreditation Institute - Laboratory Accreditation Program (geosynthetics)
AASHTO	American Association of State Highway and Transportation Officials (soils)

7.1.2 Assessment Findings and Corrective Action Responses

Assessment findings that require corrective action initiate a sequence of events that include documentation of deficiencies, notification of findings, request for corrective action, implementation of corrective action, and follow-up of assessment of the corrective action effectiveness. Potential problems could consist of non-conformance with SOPs, unforeseen difficulties, and field equipment breakdown. The following steps are proposed:

- If any malfunctioning of subcontractor equipment (CPT, drill rig, DPT rig, LGS samplers or excavator) or variations from their SOPs are noted by the TtNUS FOL, then he will question the subcontractor regarding the malfunction or deviation. The results of the query and a satisfactory reply, if any, will be documented in the field notes and communicated to the TtNUS PM. If a satisfactory resolution is not obtained, then the TtNUS FOL will promptly communicate the information to the TtNUS PM at the earliest opportunity. Likewise, if the USACE field representative notices any malfunctioning of subcontractor's equipment or operations in variance from their SOPs, the representative is expected to promptly communicate the information to the TtNUS FOL. If a satisfactory resolution is not obtained in the field, the TtNUS PM will discuss the situation with the Navy RPM and determine corrective measures, if any. Timely and accurate communication between the field personnel, the TtNUS PM, and Navy RPM is critical to ensure project objectives are met and the schedule is not affected.

If warranted by the severity of the problem (for example, if a change in the approved plan is required), the Navy will be notified in writing, and its approval will be obtained before implementing any change. The USEPA and MEDEP will be consulted about any scope changes that may occur while fieldwork is underway. Communications and correspondence to the RAB will be handled through inclusion on the distribution list or written correspondence and updates at RAB meetings. Minor changes will be documented for the main file by the TtNUS PM. Additional work that depends on a nonconforming activity will not be performed until the problem has been eliminated. The overall corrective action responsibility will reside with the TtNUS PM.

The proficiency testing programs that GeoTesting Express participates in provides the means to check quality of work whenever a question is raised. If results are outside the control limits (usually 2 standard deviations from the average) the following procedures are followed:

1) Determine if the agency conducting the program corrected reported results
2) Determine if the test result submitted was properly taken from laboratory data
3) Determine if the calculations of the results were correct
4) Determine if the equipment used to perform the test is in control

5) Determine if the procedures used to perform the test are in accordance with test standards
6) Take corrective action to repair or replace defective equipment or inform the technician of proper technique to follow
7) Document corrective actions in accordance with Section 12 of Geo Testing Express, Inc., Quality Manual (SOP L23)

GeoTesting Express retains results of participation in proficiency programs including: data sheets, reports, results, and documentation describing steps taken to determine the cause of poor test results and any corrective actions taken. Results for the most recent of each of these are available.

7.2 QA MANAGEMENT REPORTS

This section presents the activities that will be performed to keep management updated on the project status. Open communication pathways will benefit the project by allowing all appropriate personnel to be aware of activities and have the ability to provide input in a timely manner. Input from these parties will be used to make necessary corrective actions so project quality objectives are met.

The information to be included in each of the QA Management Reports listed in Table 7-2 is detailed as follows.

Verbal Status Reports

The TtNUS FOL and Lead Engineer will give verbal status reports to the TtNUS PM on a daily basis or more frequently if needed. The status reports will include the field activities completed for the day, the personnel who completed each activity, the anticipated activities to be completed during the next day, and any issues or problems identified. A summary of most significant progress in project activities will be sent via electronic mail to the PM.

Project Status Reports

DQCR will be prepared to provide the TtNUS PM with daily summaries. The DQCR will be maintained in the project file. The field logbooks will serve as records of field activities.

Field Audit Report

Field audits may be performed at the discretion of the QA Officer. The audits will be performed by the QA Officer or designee during field investigations. The audits will include checks on adherence to the QAPP and all applicable SOPs. The QA Officer will then prepare an audit report summarizing the findings. Nonconformance Quality Notices will be issued to document each observation, deficiency, or concern

discovered during the audit. This report is distributed to the Navy RPM, the TtNUS PM, and the project files. Any findings that require immediate corrective action will be communicated immediately to the TtNUS PM.

Data Validation Reports

No data validation will be required because chemical data will not be generated. However, the lab data will be verified for completeness and the results will be checked. Discrepancies will be brought to the attention of the TtNUS PM and corrective measures will be taken as necessary. The Navy RPM will be informed of the verification and the corrective measures to be taken. The results of the corrective measures will be documented in the project files. The data package will contain the corrected results.

TABLE 7-1

PROJECT ASSESSMENT
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Assessment Type	Frequency	Internal or External	Organization Performing Assessment	Person responsible for performing assessment, title and organizational affiliation	Person responsible for responding to assessment findings, title and organizational affiliation	Person responsible for identifying and implementing corrective actions (CA), title and organizational affiliation	Person responsible for monitoring effectiveness of CA, title and organizational affiliation
System Audit	Continuously	Internal	TtNUS	TtNUS PM: D. Cohen	TtNUS FOL	TtNUS FOL	TtNUS Program Manager: J. Trepanowski
Field Audit	Conducted at the discretion of the QA Officer	Internal	TtNUS	TtNUS QA Officer: P. Frank (or designate)	TtNUS PM: D. Cohen	TtNUS FOL	TtNUS QA Officer: P. Frank

TABLE 7-2

**QA MANAGEMENT REPORTS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**

Type of Report	Frequency	Project Delivery Date	Person Responsible for Report Preparation	Report Recipients
Verbal Status Report	Daily during field activities	At the end of every day of field activities or as needed	TtNUS FOL	TtNUS PM: D. Cohen
Written Status Report	Weekly during field activities and generation of data packages	TBD	TtNUS Lead Engineer	TtNUS PM: D. Cohen
Field Audit Report	Conducted at the discretion of the QA Officer	10 days after audit	TtNUS QA Officer: P. Frank	TtNUS PM: D. Cohen

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APPENDIX A

PLANNED INVESTIGATION LOCATIONS

- MASTER PLAN

- COORDINATES

TABLE A-1

SURFACE SOIL SAMPLE LOCATIONS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD

POINT ID	NORTHING	EASTING	ELEVATION	DESCRIPTOR
101	89958.3693	349731.7676	0.00	SS-01
102	90092.3151	349511.0678	0.00	SS-02
103	89827.8105	349586.5424	0.00	SS-03
104	90188.3397	349789.9178	0.00	SS-04

Note: Elevations are not needed for pre-work location survey activities - no value is listed.

TABLE A-2

DEEP BORING LOCATIONS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD

POINT ID	NORTHING	EASTING	ELEVATION	DESCRIPTOR
201	89707.9571	349599.9389	0.00	DB-01
202	90122.5404	349691.6055	0.00	DB-02
203	89663.1654	349782.2306	0.00	DB-03
204	89916.2904	349988.4806	0.00	DB-04
205	90166.2904	350241.6056	0.00	DB-05
206	90501.4009	350016.9895	0.00	DB-06
207	90751.4009	349818.0311	0.00	DB-07
208	90962.1238	350164.5222	0.00	DB-08

Note: Elevations are not needed for pre-work location survey activities - no value is listed.

TABLE A-3

PIEZOMETER LOCATIONS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD

POINT ID	NORTHING	EASTING	ELEVATION	DESCRIPTOR
301	90542.3104	349779.5422	0.00	P-01
302	90454.9264	349851.1581	0.00	P-02
303	90370.7349	349909.8583	0.00	P-03
304	90288.1674	349975.1724	0.00	P-04
305	90214.8304	350039.2651	0.00	P-05
306	90136.5658	350095.5917	0.00	P-06
307	90052.7560	350162.7728	0.00	P-07
308	90108.1388	349378.0035	0.00	P-08
309	90047.7174	349470.7383	0.00	P-09
310	89994.8540	349557.6018	0.00	P-10
311	89938.5760	349643.7365	0.00	P-11
312	89879.1124	349735.9092	0.00	P-12
313	89826.0407	349825.9791	0.00	P-13
314	89772.8441	349900.0171	0.00	P-14
315	90077.4076	350181.2615	0.00	P-15
316	90151.3623	350116.5511	0.00	P-16
317	89860.1173	349848.1862	0.00	P-17
318	89792.8946	349915.9780	0.00	P-18
319	91060.3889	350221.3203	0.00	P-19
320	91032.6559	350125.7954	0.00	P-20
321	91008.0043	350025.7827	0.00	P-21
322	90982.6978	349926.5214	0.00	P-22

Note: Elevations are not needed for pre-work location survey activities - no value is listed.

TABLE A-4

TEST PIT LOCATIONS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD

POINT ID	NORTHING	EASTING	ELEVATION	DESCRIPTOR
401	89793.4327	349351.0984	0.00	T-01 - END
402	89825.5595	349389.6225	0.00	T-01 - END
403	89886.6065	349207.7481	0.00	T-02 - END
404	89837.7537	349219.1919	0.00	T-02 - END
405	90037.7290	349140.5572	0.00	T-03 - END
406	90011.2967	349183.0051	0.00	T-03 - END
407	90068.1217	349260.8359	0.00	T-04 - END
408	90102.6687	349224.2909	0.00	T-04 - END
409	90246.7960	349401.8853	0.00	T-05 - END
410	90197.3534	349393.4439	0.00	T-05 - END
411	90935.5002	349878.4938	0.00	T-06 - END
412	90974.3533	349794.8857	0.00	T-06 - END
413	91031.9003	349942.3443	0.00	T-07 - END
414	91077.4116	349881.1780	0.00	T-07 - END
415	91105.3940	350017.9443	0.00	T-08 - END
416	91154.9599	350010.4790	0.00	T-08 - END
417	91131.0025	350138.3138	0.00	T-09 - END
418	91083.3644	350122.8574	0.00	T-09 - END
419	90900.5174	350283.8059	0.00	T-10 - END
420	90882.7070	350330.6173	0.00	T-10 - END
421	90657.6287	350338.9281	0.00	T-11 - END
422	90636.4830	350292.9362	0.00	T-11 - END
423	90418.4809	350468.3471	0.00	T-12 - END
424	90407.1487	350419.4771	0.00	T-12 - END
425	90311.8312	350447.1501	0.00	T-13 - END
426	90317.1348	350496.9527	0.00	T-13 - END
427	90844.4857	349823.1552	0.00	T-14 - END
428	90893.3916	349834.6341	0.00	T-14 - END
429	90868.6086	350011.5389	0.00	T-15 - END
430	90818.9040	350004.9117	0.00	T-15 - END
431	90847.3138	350166.3234	0.00	T-16 - END
432	90797.7983	350157.2312	0.00	T-16 - END
433	90863.5660	349707.6694	0.00	T-17 - END
434	90863.6821	349757.5343	0.00	T-17 - END

Note: Elevations are not needed for pre-work location survey activities - no value is listed.

TABLE A-5

CONE PENETRATION TEST LOCATIONS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD

POINT ID	NORTHING	EASTING	ELEVATION	DESCRIPTOR
501	89838.3374	349102.0984	0.00	CPT-01
502	89935.6347	349169.4970	0.00	CPT-02
503	89984.7342	349300.3228	0.00	CPT-03
504	90040.9842	349288.8645	0.00	CPT-04
505	90092.0259	349266.9895	0.00	CPT-05
506	90113.6752	349404.4632	0.00	CPT-06
507	90206.5806	349465.2740	0.00	CPT-07
508	90527.5266	349689.9362	0.00	CPT-08
509	90773.8667	349794.7785	0.00	CPT-09
510	90960.0568	349919.1477	0.00	CPT-10
511	91078.0022	349973.0656	0.00	CPT-11
512	91060.0295	350080.9013	0.00	CPT-12
513	89867.0536	349417.9767	0.00	CPT-13
514	89992.0536	349399.3957	0.00	CPT-14
515	90027.7799	349564.8517	0.00	CPT-15
516	90135.9725	349533.5173	0.00	CPT-16
517	90123.5196	349679.4563	0.00	CPT-17
518	90248.8104	349620.6794	0.00	CPT-18
519	90238.6752	349732.1659	0.00	CPT-19
520	90358.6077	349818.3146	0.00	CPT-20
521	90471.7833	349777.7740	0.00	CPT-21
522	90525.8374	349934.8686	0.00	CPT-22
523	90660.9725	349909.5308	0.00	CPT-23
524	90716.7158	350042.9767	0.00	CPT-24
525	90833.2698	350015.9497	0.00	CPT-25
526	90936.4677	350037.0930	0.00	CPT-26
527	90893.7827	350221.3125	0.00	CPT-27
528	90968.3112	350156.5396	0.00	CPT-28
529	91038.6871	350199.9700	0.00	CPT-29
530	89721.4455	349610.8258	0.00	CPT-30
531	89852.4140	349567.2729	0.00	CPT-31
532	89905.9049	349733.8551	0.00	CPT-32
533	90014.0131	349681.4903	0.00	CPT-33
534	90117.0536	349789.5984	0.00	CPT-34
535	90150.8374	349909.5308	0.00	CPT-35
536	90250.4995	349982.1659	0.00	CPT-36
537	90351.8509	349931.4903	0.00	CPT-37
538	90488.1029	350010.7063	0.00	CPT-38
539	90429.5536	350113.9227	0.00	CPT-39
540	90576.5412	350054.4069	0.00	CPT-40
541	90640.7023	350146.0173	0.00	CPT-41
542	90654.2158	350304.8011	0.00	CPT-42
543	89568.0671	349630.8146	0.00	CPT-43
544	89715.0266	349816.6254	0.00	CPT-44
545	89767.3914	349765.9497	0.00	CPT-45
546	89961.6482	349912.9092	0.00	CPT-46
547	89999.3171	350047.4812	0.00	CPT-47
548	90127.1887	350075.0713	0.00	CPT-48
549	90204.8914	350191.6254	0.00	CPT-49
550	90358.6077	350294.6659	0.00	CPT-50
551	90392.3914	350216.9632	0.00	CPT-51
552	90579.8914	350348.7200	0.00	CPT-52
553	89421.1076	349750.7470	0.00	CPT-53
554	90312.9995	350396.0173	0.00	CPT-54

Note: Elevations are not needed for pre-work location survey activities - no value is listed.

TABLE A-6

LANDFILL GAS SURVEY LOCATIONS
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD

POINT ID	NORTHING	EASTING	ELEVATION	DESCRIPTOR
601	89887.3239	349201.7605	0.00	LGS-01
602	90167.7293	349455.1389	0.00	LGS-02
603	90668.5176	349802.2391	0.00	LGS-03
604	91039.3509	349958.5173	0.00	LGS-04
605	89926.1752	349411.2200	0.00	LGS-05
606	90052.8644	349531.1524	0.00	LGS-06
607	90231.9185	349659.5308	0.00	LGS-07
608	90414.3509	349799.7335	0.00	LGS-08
609	90595.0941	349902.7740	0.00	LGS-09
610	90767.3914	350031.1524	0.00	LGS-10
611	90959.9590	350135.8821	0.00	LGS-11
612	89782.5941	349578.4497	0.00	LGS-12
613	89953.2022	349701.7605	0.00	LGS-13
614	90122.1212	349825.0713	0.00	LGS-14
615	90294.4185	349956.8281	0.00	LGS-15
616	90463.3374	350088.5848	0.00	LGS-16
617	90600.1617	350171.3551	0.00	LGS-17
618	89493.7428	349679.8011	0.00	LGS-18
619	89696.1926	349755.5311	0.00	LGS-19
620	89868.0676	349868.0311	0.00	LGS-20
621	90013.9009	349996.1561	0.00	LGS-21
622	90163.9009	350099.2811	0.00	LGS-22
623	90367.0536	350262.5713	0.00	LGS-23
624	90431.2428	350347.0308	0.00	LGS-24
625	90285.7759	350432.6145	0.00	LGS-25
626	90047.4027	349164.6265	0.00	LGS-26
627	90157.8194	349350.0432	0.00	LGS-27
628	90689.0694	349608.3765	0.00	LGS-28
629	91143.2360	350150.0432	0.00	LGS-29
630	90836.9860	350372.9599	0.00	LGS-30
631	89543.2360	349462.5432	0.00	LGS-31

Note: Elevations are not needed for pre-work location survey activities - no value is listed.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	NO.	RELEASED FOR	BY	DATE

DRAWN BY	DATE
J. LAMEY	5/29/01
CHECKED BY	DATE
J. WRIGHT	5/29/01
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

Tetra Tech NUS, Inc.

MASTER INVESTIGATION PLAN
OU3 PRE-DESIGN INVESTIGATION
PORTSMOUTH NAVAL SHIPYARD
KITTERY, MAINE

CONTRACT NO.	OWNER NO.
1549	—
APPROVED BY	DATE
JSW	07/26/01
APPROVED BY	DATE
—	—
DRAWING NO.	REV.
FIGURE A-1	1

APPENDIX B
STANDARD OPERATING PROCEDURES
- TtNUS, Inc.

SAMPLE NOMENCLATURE
SOP CT-04
MARCH 1996

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1.0 PURPOSE

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

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

2.0 SCOPE

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

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

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

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

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

5.0 PROCEDURES

5.1 Introduction

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

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

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

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

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

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

Site Type Location Depth Round

5.2 Sample Number Field Requirements

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

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

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

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

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

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

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

5.3 Example Sample Field Designations

Examples of each of the fields are as follows:

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

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

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

Sample Type - Examples of sample types are as follows:

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

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

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

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

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

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

Location - Examples of the location field are as follows:

A01 - Grid node A1
001 - Monitoring Well 1

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

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

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

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

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

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

5.4 Example Sample Numbers

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

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

UTILITY LOCATING AND EXCAVATION CLEARANCE

SOP HS-1.0

MARCH 2000

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1.0 PURPOSE

Utilities such as electric service lines, natural or propane gas lines, water and sewage lines, telecommunications, and steam lines are very often in the immediate vicinity of work locations. Contact with underground or overhead utilities can have serious consequences including employee injury/fatality, property and equipment damage, substantial financial impacts, and loss of utility service to users.

The purpose of this procedure is to provide minimum requirements and technical guidelines regarding the appropriate procedures to be followed when performing subsurface and overhead utility locating services. It is the policy of Tetra Tech NUS, Inc. (TtNUS) to provide a safe and healthful work environment for the protection of our employees. The purpose of this Standard Operating Procedure (SOP) is to aid in achieving the objectives of the TtNUS Utility Locating and Clearance Policy. The TtNUS Utility Locating and Clearance Policy must be reviewed by anyone potentially involved with underground or overhead utility services.

2.0 SCOPE

This procedure applies to all TtNUS field activities where there may be potential contact with underground or overhead utilities. This procedure provides a description of the principles of operation, instrumentation, applicability, and implementability of typical methods used to determine the presence or absence of utility services. This procedure is intended to assist with work planning and scheduling, resource planning, field implementation, and subcontractor procurement. Utility locating and excavation clearance requires site-specific information prior to the development of detailed operating procedures. This guidance is not intended to provide a detailed description of methodology and instrument operation. Specialized expertise during both planning and execution of several of the geophysical methods may also be required.

3.0 GLOSSARY

Electromagnetic Induction (EMI) Survey - A geophysical exploration method whereby electromagnetic fields are induced in the ground and the resultant secondary electromagnetic fields are detected as a measure of ground conductivity.

Magnetometer – A device used for precise and sensitive measurements of magnetic fields.

Magnetic Survey – A geophysical survey method that depends on detection of magnetic anomalies caused by the presence of buried ferromagnetic objects.

Metal Detection – A geophysical survey method that is based on electromagnetic coupling caused by underground conductive objects.

Vertical Gradiometer – A magnetometer equipped with two sensors that are vertically separated by a fixed distance. It is best suited to map near surface features and is less susceptible to deep geologic features.

Ground Penetrating Radar – Ground Penetrating Radar (GPR) involves specialized radar equipment whereby a signal is sent into the ground via a transmitter. Some portion of the signal will be reflected from the subsurface material, which is then recorded with a receiver and electronically converted into a graphic picture.

4.0 RESPONSIBILITIES

Project Manager (PM)/Task Order Manager (TOM) - Responsible for ensuring that all field activities are conducted in accordance with this procedure and the TtNUS Utility Locating and Clearance Policy.

Site Manager (SM)/Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved SOPs or as otherwise directed by the approved project plan(s).

Site Health & Safety Officer (SHSO) – Responsible to provide technical assistance and verify full compliance with this SOP and the TtNUS Utility Locating and Clearance Policy. The SHSO is also responsible for reporting any deficiencies to the Corporate Health and Safety Manager (HSM) and to the PM/TOM.

Health & Safety Manager (HSM) – Responsible for preparing, implementing, and modifying corporate health and safety policy.

Site Personnel – Responsible for understanding and implementing this SOP and the TtNUS Utility Locating and Clearance Policy.

5.0 PROCEDURES

This procedure addresses the requirements and technical procedures that must be performed to minimize the potential for contact with underground and overhead utility services. These procedures are addressed individually from a buried and overhead standpoint.

5.1 Buried Utilities

Buried utilities present a heightened concern because their location is not typically obvious by visual observation, and it is common that their presence and/or location is unknown or incorrectly known on client properties. The following procedure must be followed prior to beginning any excavation that might potentially be in the vicinity of underground utility services. In addition, the Utility Clearance Form (Attachment 3) must be completed for every location or cluster of locations where intrusive activities will occur.

Where the positive identification and de-energizing of underground utilities cannot be obtained and confirmed using the following steps, the PM/TOM is responsible for arranging for the procurement of a qualified, experienced, utility locating subcontractor who will accomplish the utility location and demarcation duties specified herein.

1. A comprehensive review must be made of any available property maps, blue lines, or as-builts prior to site activities. Interviews with local personnel familiar with the area should be performed to provide additional information concerning the location of potential underground utilities. Information regarding utility locations shall be added to project maps upon completion of this exercise.

2., A visual site inspection must be performed to compare the site plan information to actual field conditions. Any findings must be documented and the site plan/maps revised. The area(s) of proposed excavation or other subsurface activities must be marked at the site in white paint or pin flags to identify those locations of the proposed intrusive activities. The site inspection should focus on locating surface indications of potential underground utilities. Items of interest include the presence of nearby area lights, telephone service, drainage grates, fire hydrants, electrical service vaults/panels, asphalt/concrete scares and patches, and topographical depressions. Note the location of any emergency shut off switches. Any additional information regarding utility locations shall be added to project maps upon completion of this exercise and returned to the PM/TOM.

3. If the planned work is to be conducted on private property (e.g., military installations, manufacturing facilities, etc.) the FOL must identify and contact appropriate facility personnel (e.g., public works or facility engineering) before any intrusive work begins to inquire about (and comply with) property owner requirements. It is important to note that private property owners may require several days to several weeks advance notice prior to locating utilities.

4. If the work location is on public property, the state agency that performs utility clearances must be notified (see Attachment 1). State "one-call" services must be notified prior to commencing fieldwork per their requirements. Most one-call services require, by law, 48- to 72-hour advance notice prior to beginning any excavation. Such services typically assign a "ticket" number to the particular site. This ticket number must be recorded for future reference and is valid for a specific period of time, but may be extended by contacting the service again. The utility service will notify utility representatives who then mark their respective lines within the specified time frame. It should be noted that most military installations own their own utilities but may lease service and maintenance from area providers. Given this situation, "one call" systems may still be required to provide location services on military installations.

5. Utilities must be identified and their locations plainly marked using pin flags, spray paint, or other accepted means. The location of all utilities must be noted on a field sketch for future inclusion on project maps. Utility locations are to be identified using the following industry-standard color code scheme, unless the property owner or utility locator service uses a different color code:

white	excavation/subsurface investigation location
red	electrical
yellow	gas, oil, steam
orange	telephone, communications
blue	water, irrigation, slurry
green	sewer, drain

6. Where utility locations are not confirmed with a high degree of confidence through drawings, schematics, location services, etc., the work area must be thoroughly investigated prior to beginning the excavation. In these situations, utilities must be identified using such methods as passive and intrusive surveys, physical probing, or hand augering. Each method has advantages and disadvantages including complexity, applicability, and price. It also should be noted that in many states, initial excavation is required by hand to a specified depth.

7. At each location where trenching or excavating will occur using a backhoe or other heavy equipment, and where utility identifications and locations cannot be confirmed prior to groundbreaking, the soil must be probed with a hand auger or pole (tile probe) made of non-conductive material. If these efforts are not successful in clearing the excavation area of suspect utilities, hand shoveling must be performed for the perimeter of the intended excavation.

8. All utilities uncovered or undermined during excavation must be structurally supported to prevent potential damage. Unless necessary as an emergency corrective measure, TtNUS shall not make any repairs or modifications to existing utility lines without prior permission of the utility owner, property owner, and Corporate HSM. All repairs require that the line be locked-out/tagged-out prior to work.

5.2 Overhead Power Lines

If it is necessary to work within the minimum clearance distance of an overhead power line, the overhead line must be de-energized and grounded, or re-routed by the utility company or a registered electrician. If protective measures such as guarding, isolating, or insulating are provided, these precautions must be

adequate to prevent employees from contacting such lines directly with any part of their body or indirectly though conductive materials, tools, or equipment.

The following table provides the required minimum clearances for working in proximity to overhead power lines.

Nominal Voltage	Minimum Clearance
0 -50 kV	10 feet, or one mast length; whichever is greater
50+ kV	10 feet plus 4 inches for every 10 kV over 50 kV or 1.5 mast lengths; whichever is greater

6.0 UNDERGROUND LOCATING TECHNIQUES

6.1 Geophysical Methods

Geophysical methods include electromagnetic induction, magnetics, and ground penetrating radar. Additional details concerning the design and implementation of electromagnetic induction, magnetics, and ground penetrating radar surveys can be found in one or more of the TtNUS SOPs included in the References (Section 8.0).

Electromagnetic Induction

Electromagnetic Induction (EMI) line locators operate either by locating a background signal or by locating a signal introduced into the utility line using a transmitter. A utility line acts like a radio antenna, producing electrons, which can be picked up with a radiofrequency receiver. Electrical current carrying conductors have a 60HZ signal associated with them. This signal occurs in all power lines regardless of voltage. Utilities in close proximity to power lines or used as grounds may also have a 60HZ signal, which can be picked up with an EM receiver. A typical example of this type of geophysical equipment is an EM-61.

EMI locators specifically designed for utility locating use a special signal that is either indirectly induced onto a utility line by placing the transmitter above the line or directly induced using an induction clamp. The clamp induces a signal on the specific utility and is the preferred method of tracing since there is little chance of the resulting signals being interfered with. A good example of this type of equipment is the Schonstedt® MAC-51B locator. The MAC-51B performs inductively traced surveys, simple magnetic locating, and traced nonmetallic surveys.

When access can be gained inside a conduit to be traced, a flexible insulated trace wire can be used. This is very useful for non-metallic conduits but is limited by the availability of gaining access inside the pipe.

Magnetics

Magnetic locators operate by detecting the relative amounts of buried ferrous metal. They are incapable of locating or identifying nonferrous utility lines but can be very useful for locating underground storage tanks (UST's), steel utility lines, and buried electrical lines. A typical example of this type of equipment is the Schonstedt® GA-52Cx locator. The GA-52Cx is capable of locating 4-inch steel pipe up to 8 feet deep.

Non-ferrous lines are often located by using a typical plumbing tool (snake) fed through the line. A signal is then introduced to the snake that is then traced.

Ground Penetrating Radar

Ground Penetrating Radar (GPR) involves specialized radar equipment whereby a signal is sent into the ground via a transmitter. Some portion of the signal will be reflected from the subsurface material, which is then recorded with a receiver and electronically converted into a graphic picture. In general, an object which is harder than the surrounding soil will reflect a stronger signal. Utilities, tunnels, UST's, and footings will reflect a stronger signal than the surrounding soil. Although this surface detection method may determine the location of a utility, this method does not specifically identify utilities (i.e., water vs. gas, electrical vs. telephone); hence, verification may be necessary using other methods. This method is somewhat limited when used in areas with clay soil types or with a high water table.

6.2 Passive Detection Surveys

Acoustic Surveys

Acoustic location methods are generally most applicable to waterlines or gas lines. A highly sensitive Acoustic Receiver listens for background sounds of water flowing (at joints, leaks, etc.) or to sounds introduced into the water main using a transducer. Acoustics may also be applicable to determine the location of plastic gas lines.

Thermal Imaging

Thermal (i.e., infrared) imaging is a passive method for detecting the heat emitted by an object. Electronics in the infrared camera convert subtle heat differentials into a visual image on the viewfinder or a monitor. The operator does not look for an exact temperature; rather they look for heat anomalies (either elevated or suppressed temperatures) characteristic of a potential utility line.

The thermal fingerprint of underground utilities results from differences in temperature between the atmosphere and the fluid present in a pipe or the heat generated by electrical resistance. In addition, infrared scanners may be capable of detecting differences in the compaction, temperature and moisture content of underground utility trenches. High-performance thermal imagery can detect temperature differences to hundredths of a degree.

6.3 Intrusive Detection Surveys

Vacuum Excavation

Vacuum excavation is used to physically expose utility services. The process involves removing the surface material over approximately a 1' x 1' area at the site location. The air-vacuum process proceeds with the simultaneous action of compressed air-jets to loosen soil and vacuum extraction of the resulting debris. This process ensures the integrity of the utility line during the excavation process, as no hammers, blades, or heavy mechanical equipment comes into contact with the utility line, eliminating the risk of damage to utilities. The process continues until the utility is uncovered. Vacuum excavation can be used at the proposed site location to excavate below the "utility window" which is usually 8 feet.

Hand-auger Surveys

When the identification and location of underground utilities cannot be positively confirmed through document reviews and/or other methods, borings must be hand-augered for all locations where there is a potential to impact buried utilities. The minimum hand-auger depth that must be reached is to be determined considering the geographical location of the work site. This approach recognizes that the

placement of buried utilities is influenced by frost line depths that vary by geographical region. Attachment 2 presents frost line depths for the regions of the contiguous United States. At a minimum, hand-auger depths must be at least to the frost line depth plus two (2) feet, but never less than 4 feet below ground surface (bgs). For augering, the hole must be reamed by hand to at least the diameter of the drill rig auger or bit prior to drilling. For soil gas surveys, the survey probe shall be placed as close as possible to the cleared hand-auger. It is important to note that a post-hole digger must not be used in place of a hand-auger.

Tile Probe Surveys

For some soil types, site conditions, and excavation requirements, tile probes may be used instead of or in addition to hand-augers. Tile probes must be performed to the same depth requirements as hand-augers. Depending upon the site conditions and intended probe usage, tile probes should be made of non-conductive material such as fiberglass.

7.0 INTRUSIVE ACTIVITIES SUMMARY

The following list summarizes the activities that must be performed prior to beginning subsurface activities:

1. Map and mark all subsurface locations and excavation boundaries using white paint or markers specified by the client or property owner.

2. Notify the property owner and/or client that the locations are marked. At this point, drawings of locations or excavation boundaries shall be provided to the property owner and/or client so they may initiate (if applicable) utility clearance.

   Note: Drawings with confirmed locations should be provided to the property owner and/or client as soon as possible to reduce potential time delays.

3. Notify "One Call" service. If possible, arrange for an appointment to show the One Call representative the subsurface locations or excavation boundaries in person. This will provide a better location designation to the utilities they represent. You should have additional drawings should you need to provide plot plans to the One Call service.

4. Complete Attachment 3, Utility Clearance Form. This form should be completed for each excavation location. In situations where multiple subsurface locations exist within the close proximity of one another, one form may be used for multiple locations provided those locations are noted on the Utility Clearance Form. Upon completion, the Utility Clearance Form and revised/annotated utility location map becomes part of the project file.

8.0 REFERENCES

TtNUS Utility Locating and Clearance Policy
TtNUS SOP GH-3.1; Resistivity and Electromagnetic Induction
TtNUS SOP GH-3.2; Magnetic and Metal Detection Surveys
TtNUS SOP GH-3.4; Ground-penetrating Radar Surveys

ATTACHMENT 1
LISTING OF UNDERGROUND UTILITY CLEARANCE RESOURCES

ALABAMA
Alabama Line Location (800) 292-8525

Tucson Blue Stake Center (800) 782-5348

Alaska
Locate Call Center of Alaska Inc. (800) 478-3121

Arizona
Arizona Blue Stake Inc. (800) 782-5348

Arkansas
Arkansas One Call System Inc. (800) 482-8998

California
Underground Service Alert North (800) 227-2600

Underground Service Alert South (800) 227-2600

Colorado
Utility Notification Center of Colorado
(800) 922-1987

Connecticut
Call Before You Dig (800) 922-4455

Delaware
Miss Utility of Delmarva
(800) 282-8555

District of Columbia
Miss Utility (800) 257-7777

Florida
Call Sunshine (800) 432-4770

Georgia
Utilities Protection Center Inc.
(800) 282-7411

Idaho
Palouse Empire Underground Coordinating Council
(800) 882-1974

Utilities Underground Location Center
(800) 424-5555

Kootenai Country Utility Coordinating Council
(800) 428-4950

Shoshone County One Call (800) 398-3285

Dig Line (800) 342-1585

One Call Concepts (800) 626-4950

Illinois
Julie Inc. (800) 892-0123

Digger (Chicago Utility Alert Network)
(312) 744-7000

Indiana
Indiana Underground Plant Protection Services
(800) 382-5544

Iowa
Underground Plant Location Service Inc.
(800) 292-8989

Kansas
Kansas One-Call Center (800) 344-7233

Kentucky
Kentucky Underground Protection Inc.
(800) 752-6007

Louisiana
Louisiana One Call (800) 272-3020

Maine
Dig Safe – Maine (800) 225-4977

Maryland
Miss Utility (800) 257-777

Miss Utility of Delmarva (800) 282-8555

Massachusetts
Dig Safe – Massachusetts (800) 322-4844

Michigan
Miss Dig System (800) 482-7171

Minnesota
Gopher State One Call (800) 252-1166

Mississippi
Mississippi One-Call System Inc. (800) 227-6477

Missouri
Missouri One Call System Inc. (800) 344-7483

Montana
Utilities Underground Location Center
(800) 424-5555

Montana One Call Center (800) 551-8344

Nebraska
Diggers Hotline of Nebraska (800) 331-5666

Nevada
Underground Service Alert North (800) 227-2600

New Hampshire
Dig Safe – New Hampshire (800) 225-4977

New Jersey
New Jersey One Call (800) 272-1000

New Mexico
New Mexico One Call System Inc.
(800) 321-ALERT

Las Cruces-Dona Utility Council (505) 526-0400

New York
Underground Facilities Protection Organization
(800) 962-7962

New York City: Long Island One Call Center
(800) 272-4480

North Carolina
The North Carolina One-Call Center Inc.
(800) 632-4949

North Dakota
Utilities Underground Location Center
(800) 795-0555

Ohio
Ohio Utilities Protection Service
(800) 362-2764

Oil & Gas Producers Underground Protection Service
(800) 925-0988

Oklahoma
Call Okie (800) 522-6543

Oregon
Utilities Underground Location Center
(800) 424-5555

Douglas Utilities Coordinating Council
(503) 673-6676

Josephine Utilities Coordinating Council
(503) 476-6676

Rogue Basin Utility Coordinating Council
(503) 779-6676

Utilities Notification Center
(800) 332-2344

Pennsylvania
Pennsylvania One Call System Inc.
(800) 242-1776

Rhode Island
Dig Safe – Rhode Island (800) 225-4977

South Carolina
Palmetto Utility Protection Service Inc.
(800) 922-0983

South Dakota
South Dakota One Call (800) 781-7474

Tennessee
Tennessee One-Call System (800) 351-1111

Texas
Texas One Call System (800) 245-4545

Texas Excavation Safety System (800) 344-8377

Lone Star Notification Center (800) 669-8344

Utah
Blue Stakes Location Center (800) 662-4111

Vermont
Dig Safe – Vermont (800) 225-4977

Virginia
Miss Utility of Virginia (800) 552-7001

Miss Utility (800) 257-7777

Miss Utility of Delmarva (800) 441-8355

Washington
Utilities Underground Location Center
(800) 424-5555

Grays Harbor & Pacific County
Utility Coordinating Council
(206) 535-3550

Utilities County of Cowlitz County
(360) 425-2506

Chelan-Douglas Utilities Coordinating Council
(509) 663-6111

Upper Yakima County
Underground Utilities Council
(800) 553-4344

Inland Empire Utility Coordinating Council
(509) 456-8000

Palouse Empire Utilities Coordinating Council
(800) 822-1974

Utilities Notification Center (800) 332-2344

West Virginia
Miss Utility of West Virginia Inc. (800) 245-4848

Wisconsin
Diggers Hotline Inc. (800) 242-8511

Wyoming
West Park Utility Coordinating Council
(307) 587-4800

Call-In Dig-In Safety Council (800) 300-9811

Fremont County Utility Coordinating Council
(800) 489-8023

Central Wyoming Utilities Coordinating Council
(800) 759-8035

Southwest Wyoming One Call (307) 362-8888

Carbon County Utility
Utility Coordinating Council (307) 324-6666

Albany County Utility Coordinating Council
(307) 742-3615

Southeast Wyoming Utilities Coordinating Council
(307) 638-6666

Wyoming One-Call
(800) 348-1030

Utilities Underground Location Center
(800) 454-5555

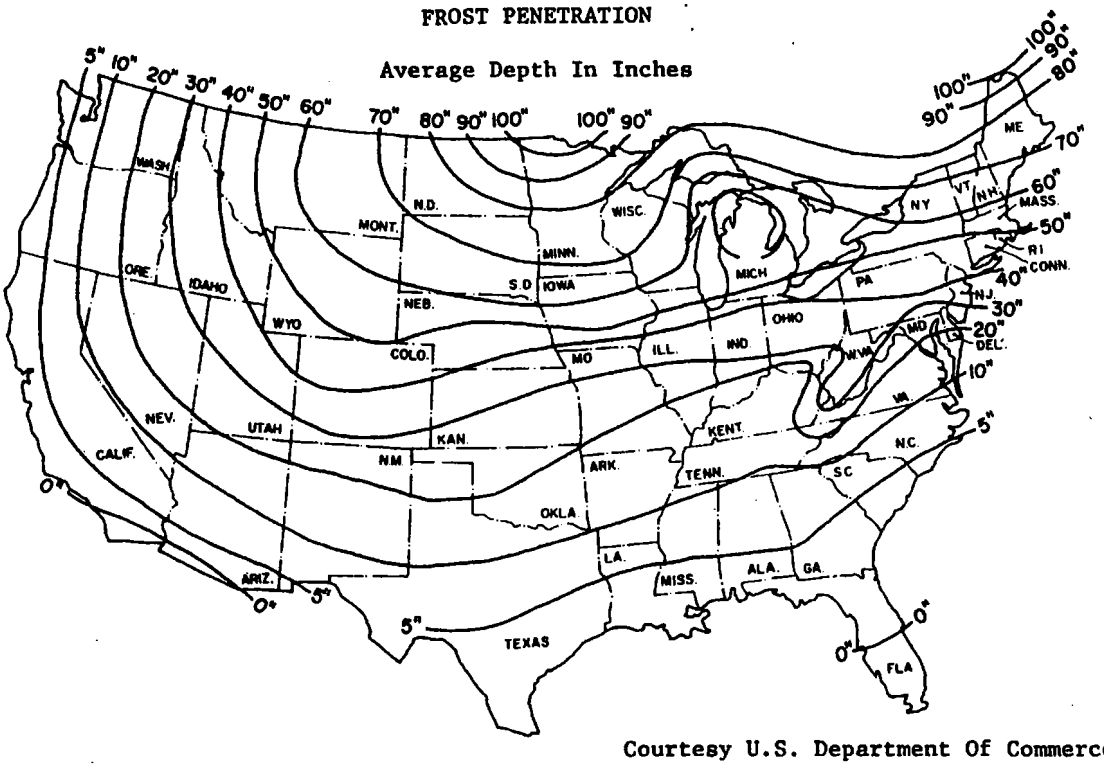
Converse County Utility Coordination Council
(800) 562-5561

ATTACHMENT 2

FROST LINE PENETRATION DEPTHS BY GEOGRAPHIC LOCATION

FROST PENETRATION

Average Depth In Inches



Courtesy U.S. Department Of Commerce

ATTACHMENT 3
UTILITY CLEARANCE FORM

Client: _____ Project Name: _____

Project No.: _____ Completed By: _____

Location Name: _____ Work Date: _____

Excavation Method/Overhead Equipment: _____

1. Underground Utilities — Circle One

a)	Review of existing maps?	yes no N/A
b)	Interview local personnel?	yes no N/A
c)	Site visit and inspection?	yes no N/A
d)	Excavation areas marked in the field?	yes no N/A
e)	Utilities located in the field?	yes no N/A
f)	Located utilities marked/added to site maps?	yes no N/A
g)	Client contact notified Name _____ Telephone: _____ Date: _____	yes no N/A
g)	State One-Call agency called? Caller: _____ Ticket Number: _____ Date: _____	yes no N/A
h)	Geophysical survey performed? Survey performed by: _____ Method: _____ Date: _____	yes no N/A
i)	Hand augering performed? Augering completed by: _____ Total depth: _____ feet Date: _____	yes no N/A
j)	Trench/excavation probed? Probing completed by: _____ Depth/frequency: _____ Date: _____	yes no N/A

2. Overhead Utilities — Present Absent

a)	Determination of nominal voltage	yes no N/A
b)	Marked on site maps	yes no N/A
c)	Necessary to lockout/insulate/re-route	yes no N/A
d)	Document procedures used to lockout/insulate/re-route	yes no N/A
e)	Minimum acceptable clearance (SOP Section 5.2): _____	

3. Notes:

_____

_____

_____

Approval:

_____ _____

Site Manager/Field Operations Leader Date

c: PM/Project File
Program File

EVALUATION OF EXISTING MONITORING WELLS AND WATER LEVEL MEASUREMENT

SOP GH-1.2

JUNE 1999

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1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the proper methods for evaluating the physical condition and project utility of existing monitoring wells and determining water levels.

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 the evaluation of existing wells, 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 and location of data points which shall be used for constructing 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 or objectives.

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 project 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 condition, 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 drilling 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.
- The presence of a survey mark on the well casing.

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 unless the time when leakage started can be precisely determined.

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 purging 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 to weather changes.

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 to be best, and thus should be utilized. Other, less precise methods, such as the popper or bell sound, or bailer line methods, should be avoided. 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 a float recorder or pressure transducer. 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. Never remove an air-tight lock (such as a J-plug) with your face over the well. Pressure changes within the well may explosively force the cap off once loosened.

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. If the J-plug was on the well very tightly, it may take several minutes for the water level to stabilize.
   - Time and day of the measurement.

Water level measuring devices with permanently marked intervals shall be used. The devices shall be free of kinks or folds which will affect the ability of the equipment to hang straight in the well pipe.

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.

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). Another disadvantage includes the introduction of air into a monitoring well. This may not be acceptable to achieve specific project objectives.

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 Equipment Decontamination

Equipment used for water level measurements provide a mechanism for potentially cross contaminating wells. Therefore, all portions of a device which project down the well casing must be decontaminated prior to advancing to the next well. Decontamination procedures vary based on the project objectives but must be defined prior to conducting any field activities including the collection of water level data. Consult the project planning documents.

5.5 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. Under certain conditions, air-tight well caps may explosively fly off the well when the pressure is relieved. Never stand directly over a well when uncapping it.

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 MESUREMENT 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): _____

SOIL AND ROCK DRILLING METHODS

SOP GH-1.3

JUNE 1999

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1.0 PURPOSE

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

2.0 SCOPE

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

The sampling methods described within this procedure are applicable to collecting surface and subsurface soil samples, and obtaining rock core samples for lithologic and hydrogeologic evaluation, excavation/foundation design, remedial alternative 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 the known or suspected 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). Depending on the subcontract, the Project Manager may need to obtain written authorization from appropriate administrative personnel before approving any changes.

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 site 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 site 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 may be the prime 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. Backfilling requirements may also be driven by state or local regulations.

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.
- Large amounts of Investigation Derived Waste (IDW) may be generated which may require containerization, sampling, and off-site disposal.

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 construction 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 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, cobble 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.
- 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 vehicles 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 site 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).

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 25.4.

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

FIGURE 1
STANDARD SIZES OF CORE BARRELS AND CASING
PAGE TWO

Size Designations			Casing Coupling					Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings	Casing O.D., Inches	O.D., Inches	I.D., Inches	Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.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 25.4.

__\|__/ 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

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.

- 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.

BOREHOLE AND SAMPLE LOGGING

SOP GH-1.5

JUNE 1999

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1.0 PURPOSE

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

2.0 SCOPE

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

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist. Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used 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.

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

* When rock coring, enter rock brokeness.

** Include monitor reading in 5 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

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)

Identification Procedures on Fraction Smaller Than No. 40 Sieve Size

	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
	Medium to High	None to Very Slow	Medium
	Slight to Medium	Slow	Slight
SILTS AND CLAYS Liquid Limit >50	Slight to Medium	Slow to None	Slight to Medium
	High to Very High	None	High
	Medium to High	None to Very Slow	Slight to Medium
HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		

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	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	
Very Soft	Less than 0.25	0 to 2	Easily penetrates
Soft	0.25 to 0.50	2 to 4	Easily penetrates
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated
Stiff	1.0 to 2.0	8 to 15	Readily indented
Very Stiff	2.0 to 4.0	15 to 30	Readily indented
Hard	More than 4.0	Over 30	Indented with

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)

Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects
Soft	Easily Gouged	Crushes when pounded 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 considerably (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	(Ma.)	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.) 12/18

Q-HQ (Wireline) Core (~1-7/8" O.D.)

Z - Other Core Sizes, Specify in Remarks 12/18

WATER LEVELS

▽ 12.0' Initial Level w/Date & Depth

▽ 12.0' Stabilized Level w/Date & Depth

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).
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.

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

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

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).

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

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)

5.3 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.

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

5.3.2 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.

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)

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

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.

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.

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	Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS*	Remarks	PID/FID Reading (ppm) Sample	Sampler BZ	Borehole**	Driller BZ**
S-1 @ 0800	0.0	7/6	1.5/2.0		M DENSE	BRN TO BLK	SILTY SAND - SOME	SM	MOIST SL. ORG. ODOR	5	0	0	0
	2.0	9/10					ROCK FR - TR BRICKS (FILL)		FILL TO 4'±				
	4.0			4.0									
S-2 @ 0810	6.0	5/7	2.9/2.0		M DENSE	BRN	SILTY SAND - TR FINE GRAVEL	SM	MOIST - W ODOR NAT. MATL. TOOK SAMPLE SB01-0406 FOR ANALYSIS	10	0	-	-
	•	9/8		7'± ▽									
	8.0			8.0									
S-3 @ 0820	10.0	6/8	1.9/2.0		DENSE	TAN BRN	FINE TO COARSE SAND TR. F. GRAVEL	SW	WET HIT WATER: 7'±	0	0	0	0
	12.0	17/16		12.0									
S-4 @ 0830	14.0	7/6	1.6/2.0		STIFF	GRAY	SILTY CLAY	CL	MOIST → WET	0	.5	-	-
	15.0	5/8		15.0					AUGER REF @ 15'				
				LIMESTONE 16	M HARD	BRN	SILTSTONE	VER	WEATHERED LO X 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		①		HARD	GRAY	SANDSTONE - SOME SILTSTONE	BR	DRILL H2O @ 17'± SET TEMP 6" CAS TO 15.5				
4.9/5.0	②		5.0/5.0						SET 2" ⌀ PVC SCREEN 16-25	0	0	0	0
									SAND 14-25				
	25.0			25					PELLETS 12-14				

* When rock coring, enter rock brokeness.
** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

• 1-20Z
1-80Z

Drilling Area Background (ppm): 0

Remarks: CME-55 R16, 4 1/4" ID HSA - 9" OD±
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP
NX CORE IN BEDROCK RUN ① = 35 MIN. RUN ② = 15 MIN

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

- Enter color of the material in the appropriate column.
- Describe material using the USCS. Limit this column for sample description only. The predominant 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.

AQUIFER PUMPING TESTS
SOP GH-2.3
JUNE 1999

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1.0 PURPOSE

The objective of this procedure is to provide general reference information and technical guidance on the performance and evaluation of pumping tests.

2.0 SCOPE

This procedure gives overall technical guidance for the performance and evaluation of pumping tests. The methodologies presented should be modified to meet the requirements/constraints of specific projects.

Pumping test data analysis is subject to much interpretation. Therefore, evaluation of the test results should be performed by an experienced hydrogeologist familiar with pumping test analytical techniques and interpretation. Due to the complexity of some of the evaluation methods and the wide variety of corrections which may be required to be factored into the data obtained, this guideline presents only a general overview of the pumping test evaluation process. The references provided in Section 6.0 should be consulted for detailed discussions regarding pumping test evaluation techniques.

3.0 GLOSSARY

Cone of Depression - The area around a discharging well where the hydraulic head in the aquifer has been lowered by pumping. Also called cone of influence.

Confined Aquifer - An aquifer that is completely saturated and is overlain and underlain by strata of lower permeability. The potentiometric surface of a confined aquifer is higher than the base of the upper confining layer at any given point.

Discharge (Q) - Volume of water removed per unit time.

Drawdown (S) - Difference between the initial static water level and the water level position at a given time during pumping.

Hydraulic Conductivity (K) - A quantitative measure of the ability of porous material to transmit water. Volume of water that will flow through a unit cross sectional area of porous material per unit time under a head gradient. Hydraulic conductivity is dependent upon properties of the medium and fluid.

Pumping Test - A test made by pumping a well for a period of time and observing the resulting change in hydraulic head in the aquifer. A pumping test may be used to determine the hydraulic characteristics of the aquifer and the capacity of the pumped well.

Specific Capacity (SC) - Rate of yield per unit drawdown. Often expressed as gallons per minute per foot of drawdown. The pumping time prior to measurement of drawdown should be stated, e.g., SC = 5 gal/ft after 12 hrs pumping.

Specific Storage - The amount of water released from or taken into storage per unit volume of aquifer per unit change in head.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the total volume of the rock or soil.

Storage Coefficient (S) - Volume of water an aquifer releases from or takes into storage per unit volume of aquifer per unit change in head. The product of specific storage times saturated thickness. Also called storativity.

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. The product of the hydraulic conductivity times saturated thickness.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The Project Hydrogeologist, in conjunction with the Project Manager, has the responsibility of determining the need to perform a pumping test or tests for investigative purposes. Factors that should be taken into account when considering whether a pumping test should be performed or not include:

- Project objectives and the data required to meet these objectives.
- The amount and accuracy of hydrogeologic data currently available.
- Cost and schedule constraints.
- Physical site limitations (discharge of contaminated/uncontaminated water, aquifer water yielding capability, access, etc.)

Pumping tests (especially long-term tests) can be time-consuming, labor intensive, and costly. On the other hand, pumping tests generally yield the most accurate data regarding aquifer characteristics that can be obtained, when designed, performed, and evaluated properly. Specific uses for pumping tests include:

- Determination of aquifer hydraulic characteristics.
- Determination of the extent of influence of a pumped well.
- Design of groundwater withdrawal systems (for groundwater treatment or water supply).
- Determination of the interconnection between water bearing formations.
- Identification of aquifer boundaries (recharge/discharge boundaries).

Once the need to perform a pumping test has been established, the Project Hydrogeologist is responsible for the design and oversight of the pumping test, including identifying the wells to be used, designing and locating the pumping and observation wells as needed, specifying methodologies to be used, and determining the length of time of the test. The Project Hydrogeologist should ensure that all field personnel involved are familiar with the planned test and the field operations related to the performance of the test. During the startup of the pumping test, the Project Hydrogeologist may need to be onsite to ensure that proper field procedures are used. Data generated during the performance of the pumping test should be concurrently reviewed by the Project Hydrogeologist to identify any modifications to the planned procedure that may be required during the performance of the test. Data reduction/evaluation should be performed under the supervision of the Project Hydrogeologist.

Field Personnel - All field personnel should be familiar with the overall methodology of performing pumping tests, as well as being familiar with the specific requirements of each individual test that they will participate in. The field personnel should be familiar with the types and uses of the various field equipment required for the performance of a pumping test (surface or submersible pumps, generators, water level measuring devices, flow measuring devices, support equipment). It is the responsibility of the field personnel to alert the Project Hydrogeologist to any unexpected conditions that may be encountered that would require modifications to the planned procedure. The field personnel are responsible for performing the test as described in the approved project plans and any approved modifications. Once the

pumping test has been completed, field personnel are to assist the Project Hydrogeologist in the process of data reduction/evaluation.

5.0 PROCEDURES

5.1 Planning for a Pumping Test

The need for and design of a pumping test is determined largely by the project goals and geologic/hydrogeologic conditions within the study area. The pumping test should be designed so the results obtained will be representative of the area under study.

As much information as possible should be collected and evaluated before running a pumping test. This includes data regarding physical and hydraulic characteristics of the aquifer, groundwater flow direction, hydraulic gradients, velocity, regional water level trend, the existence of other pumping wells in the vicinity of the test area, and the expected quality/quantity of the discharge water.

The placement and design of the pumping well is critical to the success of the pumping test. Placement of the well is dependent on pumping test objectives and local geologic conditions. In general, the pumping well should fully penetrate the aquifer to be pumped, and be screened across the entire saturated interval of the aquifer. Due to project constraints and physical practicality, this is often not the case, and corrections must be factored into the data analysis for partially penetrating wells.

If an existing well is to be used for a test, the well should closely conform to the requirements for aquifer testing. Boring logs, construction data, and performance characteristics of other wells in the area should be examined to develop a preliminary estimate of the aquifer characteristics. Transmissivities can be estimated from the boring logs and preliminary testing.

Any number of observation wells may be used. The number chosen depends on maintaining a balance between cost and need to obtain the maximum amount of accurate and reliable data. If three or four observation wells are to be installed in the pumped aquifer, all but one well should be installed along a radial line from the pumping well, with the remaining well placed along a line normal to the line of observation wells and passing through the pumping well, to detect any radial anisotropy within the aquifer. If two observation wells are to be installed, they should be placed in a straight line away from the pumping well. In a fracture controlled bedrock flow system; fracture orientations should be considered when deciding where to place observation wells. In general, observation wells for an unconfined aquifer test should be placed closer to the pumping well than for a confined aquifer test.

When a pumping well does not fully penetrate an unconfined aquifer (any well with an 85 percent or more open or screened hole in the saturated thickness may be considered as fully penetrating), the observation wells should be located at a minimum distance equal to 1-1/2 to 2 times the aquifer thickness from a partially penetrating pumping well if partial penetration corrections are to be avoided. This minimizes the effect of flow field distortions resulting from pumping a partially penetrating well.

If the confined aquifer is not thick, the pumping well should be screened for the entire thickness of the aquifer. The nearest observation well should be located at least 25 feet from the pumping well and should penetrate and be screened in the middle portion of the aquifer.

Observation wells screened within the aquifer being pumped will provide information regarding aquifer characteristics. Wells screened in an overlying or underlying aquifer will provide information regarding the degree of interconnection between aquifers. If an observation well is screened in an overlying aquifer, it

should be placed close to the pumping well so the response of the overlying aquifer is monitored at a point where the difference in head between aquifers is relatively large.

The pumping and observation well configurations and locations described above are not requirements, but are suggested setups to maximize the accuracy of the data generated. In many instances, less than ideal conditions regarding screened intervals/depths and observation well numbers/locations will be encountered due to project constraints. Valid pumping tests can still be performed if the wells used do not conform to the ideal setup.

Single well pumping tests can be performed when project constraints do not allow for the installation of observation wells. The data obtained from these tests is less accurate than for tests performed using observation wells, and specific yield/specific storage cannot be determined. Drawdown measurements in a pumped well are generally greater than the actual drawdown in the adjacent aquifer due to well inefficiency, so this factor must be considered when interpreting results.

5.2 Preparation for a Test

For a few days before starting a long-term pumping test, water levels in the pumping well and observation wells should be measured at about the same time each day to determine whether there is a measurable trend in groundwater levels. If such a trend is apparent, a graph of the change in water level versus time should be prepared and used to correct the water levels obtained during the test.

Pumping wells should undergo a preliminary pumping prior to the actual test to ensure that the well will function at it's maximum efficiency. This will enable fines to be flushed from the formation and a steady flow rate to be established. The preliminary pumping should determine the maximum drawdown in the well at a given pumping rate and establish the pumping rate for the later test. The aquifer should then be given adequate time to fully recover before the pumping test is begun.

Step-drawdown tests can be performed prior to the actual pumping test, to determine the optimum pumping rate for the test. A step-drawdown test consists of pumping a well at several successively higher rates, for a given time period (1/2-2 hours for each rate), and measuring the rate of drawdown for each pumping rate. If possible, the well should be allowed to recover between tests. The resulting data generated can be used to predict drawdown versus time over an extended period for various pumping rates.

Barometric changes may affect water levels in wells, particularly those screened in confined aquifers. An increase in barometric pressure may cause a decrease in the water level. The response of wells to changes in barometric pressure should be determined in order to correct the measurement of water levels during a long-term pumping test.

A record should be maintained of the pumping times and discharge rates of other pumping wells in the vicinity, if their radius of may influence potentially intersect the cone of depression of the pumping test well.

In areas of severe winter climate, where the frostline may extend to depths of several feet, pumping tests should be avoided during the winter in areas where the water table is near ground surface. Under some circumstances, the frozen soil acts as a confining bed, combining with leaky aquifer and delayed yield characteristics to make the results of the test unreliable.

5.3 Conducting a Test

Immediately before the pump is started, the water levels should be measured in the pumping well and all observation wells to determine the static water levels upon which drawdowns will be based. These data and the time of measurement should be recorded on a pumping test data sheet (see Attachment A for an example).

It may be useful to collect water samples from the pumping well (at least) before and after pumping. This data can give an indication of changes in groundwater quality due to pumpage.

Critical data that must be collected for each pumping test include the time that pumping started and ended, water level measurements during the test, periodic measurements of the pumping rate, and the distances between the pumping well and the observation wells.

Pump selection depends on the expected pumping rate and the physical constraints of the test (e.g., depth to water, expected total drawdown, pumping well diameter). Pump size is related to the required discharge capacity and the well diameter. Submersible pumps or air-lift set-ups are required when the drawdown of the water level is expected to exceed 25 feet below ground surface. Suction pumps can be used if total drawdown plus well headspace is not expected to exceed 25 feet.

Once pumping is initiated, the flow rate should immediately be measured and adjusted as necessary to achieve a constant discharge at the desired rate. The discharge rate should be checked, adjusted, and recorded frequently during the performance of the test, especially during the early stages of the test. The initial pumping rate should not be the maximum rate that the pump is capable of, as progressive drawdown may decrease the pump's efficiency, and as a result reduces the discharge rate. If the pump is initially operating at less than full capacity, the decrease in efficiency can be countered by increasing the pump speed or, if the discharge rate is controlled through a valve (as is more typical), opening the valve further. Pumping rates can be monitored using a flowmeter or, for low volume pumping tests, a stopwatch and calibrated bucket can be used to measure discharge rates.

The tone or rhythm of a pump or generator motor engine provides a check of performance. If there is sudden change in tone, the discharge should be checked immediately and proper adjustments made to the gate valve or to the engine speed if necessary.

At least 10 observations of drawdown within each log cycle of time should be measured in the pumping well and observation wells. Continuous water level recording for the observation wells nearest to the pumping well can be extremely useful. A suggested schedule for measurements is as follows:

- 0 to 10 minutes: 0.0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6.5, 8, and 10 minutes. It is important in the early part of the test to record with maximum accuracy the time at which readings are taken.
- 10 to 100 minutes: 10, 15, 20, 25, 30, 40, 50, 60, 80, and 100 minutes.
- to 2-hour intervals: To the end of the first day.
- 500- to 1,000-minute intervals: After the first day.

In addition, water level measurements should be collected periodically (every 4-8 hrs) from one or more background wells located outside the cone of depression.

Initially, there should be enough personnel available to measure flow rates/adjust pump rates continuously and to station a person at each nearby well used in the pumping test, unless continuous water level recorders or pressure transducers and data loggers are used. After the first two hours of the pumping test, two people are usually sufficient to continue the test.

The total pumping time for a test depends on the type of aquifer and degree of accuracy desired, and can range from less than 2 hours to several days. Economizing on the period of pumping is not recommended. More reliable results are obtained if pumping continues until the cone of depression reaches a stabilized condition, however, this is not always practical or necessary. The cone of depression will continue to expand at a progressively slower rate until recharge of the aquifer equals the pumping rate and a steady state condition is established. The time required to achieve steady state flow conditions may vary from less than an hour to beyond the practical limits of a pumping test. Under average conditions, it is good practice to run a large scale pumping test in a confined aquifer for at least 24 hours and in an unconfined aquifer, for a minimum of 72 hours. A longer period of pumping may reveal the presence of boundary conditions not previously known. Single well pumping tests or small scale tests may be run for shorter time periods. Preliminary field plotting of drawdown data should be conducted during the test to evaluate how the test is progressing and how much longer it should continue.

Water pumped from an unconfined aquifer during a pumping test should be disposed of in such a way so that the aquifer is not recharged by discharge water infiltration during the test, as recharge may offset drawdown effects. Also, if contaminated water is pumped during the test, the water may have to be stored, treated, or disposed of in an acceptable manner.

The method of disposal of discharge water from the pumping well should be planned. The discharge water could be routed to a storm sewer or surface water body if uncontaminated, or temporarily stored in tanks, drums or in a lined pit if collection is required. Contaminated water can also be treated and discharged in an appropriate manner, with client/regulatory approval. If necessary, contaminated discharge water should be transported and deposited into a designated secure area.

5.4 Recovery Test

When pumping is stopped after completing the drawdown portion of the pumping test, the cumulative drawdown and time at which pumping was discontinued are recorded. The rate of recovery of the water levels in the wells should then be measured.

The same procedure and time pattern are followed as at the beginning of a pumping test; that is, the depth-to-water is periodically measured during the recovery test in the pumping well and observation wells, with readings obtained more frequently during the early phase of recovery. Recovery data should follow the same general trend as drawdown data, and is considered in many cases to be more accurate and useful for pumping test analysis than drawdown data.

The recovery data should be recorded until the aquifer fully recovers, or as long as possible within project constraints.

5.5 Data Analysis

A constant rate pumping test can be run to determine transmissivity and hydraulic conductivity. If the effects of pumping the well can be measured in one or more observation wells at known distances from the pumping well, the specific yield or storage coefficient can also be determined. A good check of the transmissivity value can be made using recovery data from the pumped well and of transmissivity and storage coefficient from recovery rate measurements in observation wells.

Example data collection forms for a pumping test are illustrated in Attachments A and B. The forms can be used to record data for the pumping well or an observation well. It should be noted that there are some differences in the types of data recorded for pumping versus observation wells.

The effects of all extraneous factors such as barometric pressure, tidal influence, injection interference, or other pumpage in the nearby area, can be adjusted for and corrected from the measured data by using applicable correlation techniques.

After correction of the raw data to eliminate or reduce the amount of extraneous interference, graphs are prepared showing resulting drawdowns versus time and/or distance; these are plotted on semi-log or log-log paper. The graphs are used to determine aquifer characteristics by matching type curves or by straight line slope analysis procedures. Analytical methods not requiring the use of a graph have also been developed. Selection of the most appropriate evaluation technique is dependent on the test setup and results. In addition to manual methods of analysis, there are numerous computer programs available for data analysis. Selection and application of the proper analysis method(s) requires the judgement and guidance of an experienced hydrogeologist.

5.6 Records

The Pumping Test Data Sheet exhibited on Attachment A should be used to record data from pumping wells, and the Pumping Test Data Sheet exhibited on Attachment B should be used to record data from observation wells. A written log of the field setup and performance of the pumping test must also be kept in a bound site logbook or notebook. Descriptions of procedures used, daily activities, and any other pertinent observations made prior to, during, and following the test should also be recorded.

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ATTACHMENT A
EXAMPLE PUMPING TEST DATA SHEET, PUMPING WELL

PUMPING TEST DATA SHEET
PUMPING WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
PUMPING TEST: [ ]
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DEPTH CORRECTION: _____

PUMPING WELL NUMBER: _____
DATE(s): _____
STEP DRAW DOWN TEST [ ]
MONITORING POINT: _____
ELEVATION OF MONITORING POINT: _____ MSL
PUMP SETTING (Ft. below monitoring point): _____

PUMPING TEST PERFORMED BY: _____
REMARKS: _____

TIME (Hour:Min.)	(t) ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	(s) DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	(Q) PUMPING RATE (GPM)	REMARKS

SIGNATURES: _____

ATTACHMENT B
EXAMPLE PUMPING TEST DATA SHEET, OBSERVATION WELL

PUMPING TEST DATA SHEET
OBSERVATION WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DEPTH CORRECTION: _____

OBSERVATION WELL NUMBER: _____
DATE(s): _____
MONITORING POINT: _____
ELEVATION OF MONITORING POINT: _____ MSL

CORRESPONDING PUMPING WELL NUMBER: _____
DISTANCE FROM PUMPING WELL (Ft.) (r): _____
REFERENCE POINT MEASUREMENTS BY: _____
REMARKS: _____

TIME (Hour:Min.)	(t) ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	(s) DRAW DOWN OR RECOVERY (Ft.)	REMARKS

SIGNATURES: _____

GROUNDWATER MONITORING POINT INSTALLATION

SOP GH-2.8

JUNE 1999

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1.0 PURPOSE

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

2.0 SCOPE

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

3.0 GLOSSARY

Monitoring Well - A well which is screened, cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored. Some monitoring wells may be constructed as open boreholes.

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

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

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

4.0 RESPONSIBILITIES

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

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

5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well or piezometer:

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

5.2 Well Design

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

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

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

5.2.1 Well Depth, Diameter, and Monitored Interval

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

The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

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

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (5 feet or less) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

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

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

Standard monitoring well diameters are 2, 4, 6, or 8 inches. Drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole bedrock monitoring wells are used. With smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced; however, the sampling devices that can be used are limited.

In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples), particularly if the monitored formation is known to be a low-yielding formation. The unit volume of water contained within a monitoring well is dependent on the well diameter as follows:

Casing Inside Diameter (Inch)	Standing Water Length to Obtain 1 Gallon Water (Feet)
2	6.13
4	1.53
6	0.68

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

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

5.2.2 Riser Pipe and Screen Materials

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

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel. Properties of these two materials are compared in Attachment B. Stainless steel is a good choice where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, ease of manipulation, and widespread acceptance. The crushing strength of PVC may limit the depth of installation, but the use of Schedule 80 materials may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe may corrode and release metal ions or chemically react with organic constituents, but this is considered a minor issue. Galvanized steel is not recommended where samples may be collected for metals analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

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

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary, and the annular borehole space around the screened interval is artificially packed with an appropriately sized sand, selected based on formation grain size. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The site geologist

shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. For example, as a standard procedure, a Morie No. 1 or No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a medium- to coarse-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

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

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

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of one or two assemblages of material, (e.g., cement and/or bentonite). A cement-bentonite grout, which is the most common type of grout used in monitoring well completions, normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus 3 to 5 pounds of granular or flake-type bentonite, and 6-7 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6-7 gallons of water. A bentonite slurry (bentonite and water mixed to a thick but pumpable mixture) is sometimes used instead of grout for deep well installations where placement of bentonite pellets is difficult. Bentonite chips are also occasionally used for annular backfill in place of grout.

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

5.2.4 Protective Casing

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

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

5.3 Monitoring Well Installation

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

5.3.1 Monitoring Wells in Unconsolidated Sediments

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

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

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

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack. Pellets should be added slowly and their fall monitored closely to ensure that bridging does not occur.

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

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between aquifers. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 5 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting a large-diameter casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells. Sufficient time (determined by the field geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 –10 feet into bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued into bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. If a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be removed when the final well installation is completed.

5.3.4 Drive Points

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

Direct push sampling/monitoring point installation methods, using a direct push rig or drilling rig, are described in SOP SA-2.5.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only small-diameter tubes extending to the surface. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. Four manufacturers of these samplers include Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, BARCAD Systems, Inc., of Concord, Massachusetts, Westbay Instruments Ltd. of Vancouver, British Columbia, Canada and the University of Waterloo at Waterloo, Ontario, Canada.. Each manufacturer offers various construction materials.

5.4 Well Development Methods

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

5.4.1 Overpumping and Backwashing

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

5.4.2 Surging with a Surge Plunger

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

5.4.3 Compressed Air

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

5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire

screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 RECORDS

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

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed, ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information will need to be recorded, depending on whether the well is completed in overburden (single- or double-cased), as a cased well in bedrock, or as an open hole in bedrock.

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

7.0 REFERENCES

Scalf, M. R., J. F. McNabb, W. J. Dunlap, R. L. Cosby, and J. Fryberger, 1981. Manual of Groundwater Sampling Procedures. R. S. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Ada, Oklahoma.

Barcelona, M. J., P. P. Gibb and R. A. Miller, 1983. A Guide to the selection of Materials for Monitoring Well Construction and Groundwater Sampling. ISWS Contract Report 327, Illinois State Water Survey, Champaign, Illinois.

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

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

ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

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

Preliminary Ranking of Rigid Materials:

1 Teflon®
2 Stainless Steel 316
3. Stainless Steel 304
4 PVC 1
5 Lo-Carbon Steel
6 Galvanized Steel
7 Carbon Steel

* Trademark of DuPont

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

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

Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

1 Teflon®
2 Polypropylene (PP)
3. PVC Flexible/PE Linear
4 Viton®
5 PE Conventional
6 Plexiglas/Lucite (PMM)
7 Silicone/Neoprene

* Trademark of DuPont

Source: Barcelona et al., 1983

ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

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

* See also Attachment A.

WELL ABANDONMENT
SOP GH-2.9
JUNE 1999

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1.0 PURPOSE

Well abandonment is that procedure by which any monitoring well is permanently closed. Abandonment procedures are designed to prevent fluids from entering or migration within the monitoring well. Therefore, an abandoned monitoring well must be sealed in such a manner that it can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers.

It is important that the appropriate state or local agency be notified of monitoring well abandonment. The application of and adherence to this SOP must be tailored to applicable state, local, and Federal regulatory requirements.

2.0 SCOPE

The methods described in this procedure shall be used for all projects requiring well abandonment where specific state, local, or Federal regulations are unavailable. An abandoned well shall be filled and sealed so that it will not act as a pathway for the interchange of water between the surface and subsurface or present a hazard to the environment.

3.0 GLOSSARY

Well - Any constructed access point to an aquifer, confined or unconfined, including, but not limited to, test borings, hydropunch holes, monitoring points, and production wells.

Abandon - To permanently discontinue the use of a well. Any well shall require abandonment when it is no longer serving as a monitoring point or is in such a state of disrepair that continued use for the purpose of obtaining groundwater is impracticable, or when it has been permanently disconnected from any water supply system or irrigation system.

4.0 RESPONSIBILITIES

Project Manager - It shall be the responsibility of the Project Manager and/or Project Hydrogeologist to determine the applicability of well abandonment, based on the established scope and objective of the project and program-specific requirements. It shall be the responsibility of the Project Manager (or designee) to ensure that the procedures established for well abandonment are thoroughly specified and/or referenced in the relevant project planning documents. It shall be the responsibility of the Project Manager to ensure that the Field Operations Leader is familiar with the proper procedures for well abandonment and confirm the supervising project geologist or the subcontractor performing the well abandonment are qualified to perform such activities.

Field Operations Leader (FOL) - It shall be the responsibility of the Field Operations Leader to ensure that all field technicians and/or drilling personnel are thoroughly familiar with this Standard Operating Procedure. It shall be the responsibility of the FOL to ensure that the procedures identified in this SOP are used during well abandonment.

5.0 PROCEDURES

5.1 General

Well abandonment is warranted when the project team has reason to believe, on the basis of local conditions, that the well is causing or is a potential source of pollution to an aquifer; is a production well

that is producing water that is polluted; or does not have a certificate of potability, if required. Wells may also be abandoned once their designed purposes have been fulfilled and are determined to no longer be of use.

Well abandonment is conducted to eliminate physical hazards, prevent groundwater contamination, prevent intermixing of aquifer waters, and conserve aquifer yield and hydrostatic head.

5.2 Material for Sealing

Acceptable sealing materials include concrete, portland cement grout, sodium-base bentonite clay, or combinations of these materials. These materials are defined as follows:

- Concrete may be used for filling the upper part of a well or water bearing formation, or plugging short sections of casing and filling large diameter wells.

- Portland cement grout is superior for sealing small openings, penetrating any annular space outside the casing, and for filling voids in the surrounding formation. Portland cement grout shall be composed of one bag of Type I cement per 6 to 8 gallons of water. Two parts sand to one part cement may be added.

- Bentonite clay, when applied as a heavy mud-laden fluid under pressure, has most of the advantages of cement grout, but under some conditions may be carried away into the surrounding formation. A bentonite clay mixture shall be composed of not less than 2 pounds of clay per gallon of water. Bentonite clay may not be used where it will come in contact with water of a pH below 5.0 or total dissolved solids (TDS) content greater than 1,000 mg/L or both. Bentonite may also be added to cement grout to add flexibility.

Fill materials include clay, silt, sand, gravel, crushed stone, or a mixtures of these materials may be used as a filler in sealing a well when used in conjunction with the sealing materials described above. Organic material may not be used and fill material may be required to be disinfected or certified clean prior to use. Spent drilling muds or drill cuttings are not to be used to seal a well.

5.3 Procedures for Sealing Wells

5.3.1 Preliminary Considerations

Several factors should be considered to determine the appropriate well abandonment method. These factors include:

- Conditions of the well.
- Details of well construction, including casing material, diameter of casing, depth of well, and well plumbness.
- Obstructions within the well that may interfere with filling or sealing.
- Hydrogeologic setting.
- Level of contamination and the zone or zones where it occurs.
- Regulatory requirements.

Degraded wells may not permit casing removal by pulling. Also, the casing material may dictate whether a casing can be removed intact. Stainless steel will have a higher tensile strength than PVC and may hold together while pulling the casing; PVC well casing may break under pulling and may need to be overdrilled to remove it. The depth of the well and well plumbness may limit casing removal depending on

whether a casing is pulled or overdrilled. In some cases, casings can be left in-place if they are properly filled with appropriate backfill.

The formation lithology influences the selection of casing removal. Unconsolidated materials can be drilled with hollow-stem augering techniques whereas consolidated materials cannot. Unconsolidated materials may also cave-in during well casing removal.

5.3.2 Filling and Sealing Procedures

Drilled wells (all wells not dug) shall be filled with sealing material or a combination of sealing material and fill material.

In some cases, well casing removal is necessary for well abandonment. If the borehole is unstable and may cave-in, scaling material will be emplaced simultaneously during casing removal. If the well is not grouted, casing may be pulled with hydraulic jacks or a drilling rig. It may also be pulled by sandlocking. Sandlocking consists of lowering a pipe wrapped with burlap approximately 2/3 of the well depth and filling the burlap wrap with sand. The pipe is slowly lifted and locks the sand, pulling the casing. Well casings can also be removed by overdrilling. Wells can be overdrilled with larger diameter hollow steam or solid stem augers or direct rotary techniques, using air or mud. Augers used for overdrilling should be at least 2 inches larger in diameter than the diameter of the well casing.

If well casing is in poor condition or is grouted in place, the casing may be ripped or perforated and filled and pressure grouted in place.

Abandoned wells shall be filled with the appropriate filling and sealing material placed from the bottom of the well upward. When Portland cement grout or concrete is used, it shall be placed in continuous operation using a tremie pipe. Sealing material shall be placed in the interval or intervals to be sealed by methods that prevent free fall, dilution, and/or separation of aggregates from cementing material.

A well constructed in unconsolidated material in an unconfined groundwater zone shall be filled and sealed by placing fill material in the well to the level of the water table, and filling the remainder of the well with sealing material. If the water table is at a depth greater than 40 feet, a minimum of 40 feet of sealing material shall be required.

A well which penetrates several aquifers or formations shall be filled and sealed in such a way as to prevent the vertical movement of water from one aquifer or formation to another. If the casing has been removed, sealing material shall be placed opposite the confining formations and from the surface down to the first confining formation. Sand and other suitable fill material may be placed opposite the producing aquifer. Ideally, the entire well can be filled with sealing material. If the casing has not been removed, the entire well shall be fill with sealing material.

A well penetrating creviced or cavernous rock shall be filled using coarse fill material opposite the cavernous or creviced rock portions of the well. Sealing material shall extend from the top of the unfractured rock portion of the well or base of the casing, whichever is deeper, to the surface. The minimum depth of sealing material may not be less than 10 feet.

In the case where wells penetrate specific aquifers where conditions necessitate the sealing of specific aquifers or formations, the annular space in the area of the specific aquifer or formation shall be sealed during the abandonment of the well.

A dug well exceeding 24 inches in diameter shall be filled and sealed by placing fill material (excluding clay or silt) in the well to a level approximately 5 feet below the land surface, and placing a 3 foot plug of sealing material above the fill. The remainder of the well shall be back filled with soil material.

6.0 REFERENCES

Maryland Department of the Environment (MDE Regulations); Title 26, Subtitle 04; Regulation of Water Supply, Sewage Disposal, and Solid Waste; Chapter 4--Well Construction.

U.S. EPA, February 1990. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.

DIRECT PUSH TECHNOLOGY
(GEOPROBE/HYDROPUNCH)
SOP SA-2.5
JANUARY 2000

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on Direct Push Technology (DPT). DPT is designed to collect soil, groundwater, and soil gas samples without using conventional drilling techniques. The advantage of using DPT over conventional drilling includes the generation of little or no drill cuttings, sampling in locations with difficult accessibility, reduced overhead clearance requirements, no fluid introduction during probing, and typical lower costs per sample than with conventional techniques. Disadvantages include a maximum penetration depth of approximately 15 to 40 feet in dense soils (although it may be as much as 60 to 80 feet in certain types of geological environments), reduced capability of obtaining accurate water-level measurements, and the inability to install permanent groundwater monitoring wells. The methods and equipment described herein are for collection of surface and subsurface soil samples and groundwater samples. Soil gas sampling is discussed in SOP SA-2.4.

2.0 SCOPE

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

3.0 GLOSSARY

Direct Push Technology (DPT) - DPT refers to sampling tools and sensors that are driven directly into the ground without the use of conventional drilling equipment. DPT typically utilizes hydraulic pressure and/or percussion hammers to advance the sampling tools. A primary advantage of DPT over conventional drilling techniques is that DPT results in the generation of little or no investigation derived waste.

Geoprobe® - Geoprobe® is a manufacturer of a hydraulically-powered, percussion/probing machines utilizing DPT to collect subsurface environmental samples. Geoprobe® relies on a relatively small amount of static weight (vehicle) combined with percussion as the energy for advancement of a tool string. The Geoprobe® equipment can be mounted in a multitude of vehicles for access to all types of environmental sites.

HydroPunch™ - HydroPunch™ is a manufacturer of stainless steel and Teflon® sampling tools that are capable of collecting representative groundwater and/or soil samples without requiring the installation of a groundwater monitoring well or conventional soil boring. HydroPunch™ is an example of DPT sampling equipment.

Flame Ionization Detector (FID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing a flame as the energizing source.

Photo Ionization Detector (PID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing ultraviolet radiation as the energizing source.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for selecting and/or reviewing the appropriate DPT drilling procedure required to support the project objectives.

Field Operations Leader (FOL)- The FOL is primarily responsible for performing the DPT in accordance with the project-specific plan.

5.0 SOIL SAMPLING PROCEDURES

5.1 General

The common methodology for the investigation of the vadose zone is soil boring drilling and soil sampling. However, drilling soil borings can be very expensive. Generally the advantage of DPT for subsurface soil sampling is the reduced cost of disposal of drilling cuttings and shorter sampling times.

5.2 Sampling Equipment

Equipment needed for conducting DPT drilling for subsurface soil sampling includes, but is not limited to, the following:

- Geoprobe® Sampling Kit
- Cut-resistant gloves
- 4-foot x 1.5-inch diameter macrocore sampler
- Probe sampling adapters
- Roto-hammer with 1.5-inch bit
- Disposable acetate liners for soil macrocore sampler
- Cast aluminum or steel drive points
- Geoprobe® AT-660 Series Large Bore Soil Sampler, or equivalent
- Standard decontamination equipment and solutions

For health and safety equipment and procedures, follow the direction provided in the Safe Work Permit in Attachment 1, or the more detailed directions provided in the project's Health and Safety Plan.

5.3 DPT Sampling Methodology

There are several methods for the collection of soil samples using DPT drilling. The most common method is discussed in the following section. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project-specific plan.

- Macrocore samplers fitted with detachable aluminum or steel drive points are driven into the ground using hydraulic pressure. If there is concrete or pavement over a sampling location, a Roto-hammer is used to drill a minimum 1.5-inch diameter hole through the surface material. A Roto-hammer may also be used if very dense soils are encountered.

- The sampler is advanced continuously in 4-foot intervals or less if desired. No soil cuttings are generated because the soil which is not collected in the sampler is displaced within the formation.

- The sampler is retracted from the hole, and the 4-foot continuous sample is removed from the outer coring tube. The sample is contained within an inner acetate liner.

- Attach the metal trough from the Geoprobe® Sampling Kit firmly to the tail gate of a vehicle. If a vehicle with a tail gate is not available, secure the trough on another suitable surface.

- Place the acetate liner containing the soils in the trough.

- While wearing cut-resistant gloves (constructed of leather or other suitable material), but the acetate liner through its entire length using the double-bladed knife that accompanies the Geoprobe® Sampling Kit. Then remove the strip of acetate from the trough to gain access to the collected soils. Do not attempt to cut the acetate liner while holding it in your hand.

- Field screen the sample with an FID or PID, and observe/examine the sample (according to SOP GH-1.3). If appropriate, transfer the sample to sample bottles for laboratory analysis. If additional volume is required, push an additional boring adjacent to the first and composite/mix the same interval. Field compositing is usually not acceptable for sample requiring volatile organics analysis.

- Once sampling has been completed, the hole is backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch is used to cap holes through paved or concrete areas. All holes should be finished smooth to existing grade.

- In the event the direct push van/truck cannot be driven to a remote location or a sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with battery/electric operated equipment (e.g., jack hammer).

- Sampling equipment is decontaminated prior to collecting the next sample.

6.0 GROUNDWATER SAMPLING PROCEDURES

6.1 General

The most common methodology for the investigation of groundwater is the installation and sampling of permanent monitoring wells. If only groundwater screening is required, the installation and sampling of temporary well points may be performed. The advantage of temporary well point installation using DPT is reduced cost due to no or minimal disposal of drilling cuttings and well construction materials, and shorter installation/times sampling.

Two disadvantages of DPT drilling for well point installation are:

- In aquifers with low yields, well points may have to be sampled without purging or development.
- If volume requirements are high, this method can be time consuming for low yield aquifers.

6.2 Sampling Equipment

Equipment needed for temporary well installation and sampling using DPT includes, but is not limited, to the following:

- 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point
- Connecting rods
- Roto-hammer with 1.5-inch bit
- Mechanical jack
- 1/4-inch OD polyethylene tubing
- 3/8-inch OD polyethylene tubing
- Peristaltic pump
- Standard decontamination equipment and solutions

6.3 DPT Temporary Well Point Installation and Sampling Methodology

There are several methods for the installation and sampling of temporary well points using DPT. The most common methodology is discussed below. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project specific plan.

- A 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point attached to connecting rods is driven into the ground to the desired depth using a rotary electric hammer or other direct push drill rig. If there is concrete or pavement over a sampling location, a Roto-hammer or electric coring machine is used to drill a hole through the surface material.

- The well point will be allowed to equilibrate for at least 15 minutes, after which a measurement of the static water level will be taken. The initial measurement of the water level will be used to assess the amount of water which is present in the well point and to determine the amount of silt and sand infiltration that may have occurred.

- The well point will be developed using a peristaltic pump and polyethylene tubing to remove silt and sand which may have entered the well point. The well point is developed by inserting polyethylene tubing to the bottom of the well point and lifting and lowering the tubing slightly while the pump is operating. The pump will be operated at a maximum rate of approximately 2 liters per minute. After removal of sediment from the bottom of the well point, the well point will be vigorously pumped at maximum capacity until discharge water is visibly clear and no further sediments are being generated. Measurements of pH, specific conductance, temperature, and turbidity shall be recorded every 5 minutes during the purging process. After two consistent readings of pH, specific conductance, temperature and turbidity ($\pm$10 percent), the well may be sampled.

- A sample will be collected using the peristaltic pump set at the same or reduced speed as during well development. Samples (with the exception of the samples to be analyzed for volatile organic compounds, VOCs) will be collected directly from the pump discharge. Sample containers for VOCs will be filled by (first shutting off the pump) crimping the discharge end of the sample tubing when filled, removing the inlet end of the sample tubing from the well, suspending the inlet tubing above the vial, and allowing water to fill each vial by gravity flow.

- Once the groundwater sample has been collected, the connecting rods and well point will be removed from the hole with the direct push rig hydraulics. The hole will be backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch will be used to cap holes through paved or concrete areas. All holes will be finished smooth to existing grade.

- In the event the direct push van/truck cannot be driven to a remote location or sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with battery/electric-operated equipment (e.g., jack hammer).

- Decontaminate the equipment before moving to the next location.

7.0 RECORDS

A record of all field procedures, tests, and observations must be recorded in the field logbook, boring logs, and sample log sheets, as needed. Entries should include all pertinent data regarding the investigation. The use of sketches and field landmarks will help to supplement the investigation and evaluation.

ATTACHMENT 1
SAFE WORK PERMIT FOR DPT OPERATIONS

Permit No. _____ Date: _____ Time: From _____ to _____

SECTION I: General Job Scope

I. Work limited to the following (description, area, equipment used): **Monitoring well drilling and installation through direct push technology**

II. Required Monitoring Instruments: _____

III. Field Crew: _____

IV. On-site Inspection conducted ☐ Yes ☐ No Initials of Inspector _____ _____ TtNUS

SECTION II: General Safety Requirements (To be filled in by permit issuer)

V. Protective equipment required

Level D ☒ Level B ☐
Level C ☐ Level A ☐
Detailed on Reverse

Respiratory equipment required

Full face APR ☐ Escape Pack ☐
Half face APR ☐ SCBA ☐
SKA-PAC SAR ☐ Bottle Trailer ☐
Skid Rig ☐ None ☒

Level D Minimum Requirements: Sleeved shirt and long pants, safety footwear, and work gloves. Safety glasses, hard hats, and hearing protection will be worn when working near or sampling in the vicinity of the DPT rig.

Modifications/Exceptions.

VI. Chemicals of Concern | Action Level(s) | Response Measures

VII. Additional Safety Equipment/Procedures

Hard-hat	☒ Yes	☐ No	Hearing Protection (Plugs/Muffs)	☒ Yes	☐ No
Safety Glasses	☒ Yes	☐ No	Safety belt/harness	☐ Yes	☒ No
Chemical/splash goggles	☐ Yes	☒ No	Radio	☐ Yes	☒ No
Splash Shield	☐ Yes	☒ No	Barricades	☒ Yes	☐ No
Splash suits/coveralls	☐ Yes	☐ No	Gloves (Type - _____)	☐ Yes	☐ No
Steel toe Work shoes or boots	☒ Yes	☐ No	Work/warming regimen	☐ Yes	☐ No

Modifications/Exceptions: Reflective vests for high traffic areas.

VIII. Procedure review with permit acceptors

	Yes	NA		Yes	NA
Safety shower/eyewash (Location & Use)	☐	☒	Emergency alarms	☐	☐
Daily tail gate meetings	☒	☐	Evacuation routes	☐	☐
Contractor tools/equipment/PPE inspected	☐	☐	Assembly points	☐	☐

IX. Site Preparation

Utility Clearances obtained for areas of subsurface investigation	☐ Yes	☐ No
Physical hazards removed or blockaded	☐ Yes	☐ No
Site control boundaries demarcated/signage	☐ Yes	☐ No

X. Equipment Preparation

	Yes	NA
Equipment drained/depressurized	☐	☒
Equipment purged/cleaned	☐	☒
Isolation checklist completed	☐	☒
Electrical lockout required/field switch tested	☐	☒
Blinds/misalignments/blocks & bleeds in place	☐	☒
Hazardous materials on walls/behind liners considered	☐	☒

XI. Additional Permits required (Hot work, confined space entry). ☐ Yes ☐ No

If yes, complete permit required or contact Health Sciences, Pittsburgh Office

XII. Special instructions, precautions:

_____

Permit Issued by: _____ Permit Accepted by: _____

NON-RADIOLOGICAL
SAMPLE HANDLING
SOP SA-6.1
MARCH 2000

TETRA TECH NUS, INC.	STANDARD OPERATING PROCEDURES	Number SA-6.1	Page 1 of 24
		Effective Date 03/00	Revision 1
		Applicability Tetra Tech NUS, Inc.	
		Prepared Earth Sciences Department	
Subject NON-RADIOLOGICAL SAMPLE HANDLING		Approved D. Senovich	

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

2.0 SCOPE

This procedure:

- Describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped off site for chemical analysis.
- Provides instruction for sample packaging and shipping in accordance with current U.S. Department of Transportation (DOT) and International Air Transportation Association (IATA) regulations. IATA regulates transportation of hazardous materials by air (which is the mode of transportation used for shipping nearly all samples derived during TtNUS projects).

3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173. With slight modifications, IATA has adopted DOT "hazardous materials" as IATA "Dangerous Goods."

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (ɣ261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (ɣ261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

ORM - Other regulated material (see DOT 49 CFR 173.144).

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H_2SO_4
- Nitric Acid - HNO_3
- Sodium Hydroxide - NaOH

Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - $Na_2S_2O_3$

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent.

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

4.0 RESPONSIBILITIES

Field Operations Leader - Directly responsible for the bottling, preservation, labeling, packaging, shipping, and custody of samples up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the shipper.

5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

5.1 Sample Containers

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of sample container orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

Once opened, the container must be used at once for storage of a particular sample. Unused but opened containers are to be considered contaminated and must be discarded. Because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused

containers which appear contaminated upon receipt, or which are found to have loose caps or a missing Teflon liner (if required for the container), shall be discarded.

5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected. Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/ freezing (certain biological samples only).

5.2.1 Overview

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. In general, aqueous samples of low-concentration organics (or soil samples of low- or medium-concentration organics) are cooled to 4°C. Medium-concentration aqueous samples, high-hazard organic samples, and some gas samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO_3, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas high-hazard samples are not cooled.

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

5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H_2SO_4)	1 part concentrated H_2SO_4: 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO_3)	Undiluted concentrated HNO_3	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample. This assumes that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required. Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.

- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).

- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

  If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

  Continue with proper base preservation of the sample as described above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

  The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

  The sample pH is then raised to 9 using the NaOH preservative.

- Sodium thiosulfate must be added to remove residual chlorine from a sample. To test the sample for residual chlorine use a field test kit specially made for this purpose.

  If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

  Continue with proper acidification of the sample as described above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory before sampling begins.

5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).

- To perform filtration, thread the tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration. Run approximately 100 ml of sample through the filter prior to sample collection.

- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

5.4 Sample Packaging and Shipping

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples (if there is any doubt, a sample shall be considered hazardous and shipped accordingly.)

- Protect the health and safety of transport and laboratory personnel receiving the samples (special precautions are used by the shipper and at laboratories when hazardous materials are received.)

Detailed procedures for packaging environmental and hazardous material samples are outlined in the remainder of this section.

5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place properly identified sample container, with lid securely fastened, in a plastic bag (e.g. Ziploc baggie), and seal the bag.

- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic (e.g. "garbage" bag). Drain plugs on coolers must be taped shut.

- Pack with enough noncombustible, absorbent, cushioning materials such as vermiculite (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

- If cooling is required (see Attachments A and B), double-bag ice in Ziploc baggies and place around sample container shoulders, and on top of absorbent packing material (minimum of 8 pounds of ice for a medium-size cooler).

- Seal (i.e., tape or tie top in knot) large liner bag.

- The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment.

- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

5.4.2 Hazardous Material Samples

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

NOTE: Packaging and shipping of hazardous materials can only be performed by personnel who have participated in the TtNUS training course "Shipping Hazardous Materials" (or equivalent training approved by Health Sciences).

5.4.2.1 Known Substances

If the substance in the sample is known or can be identified, package, mark, label, and ship according to the specific instructions for that material (if it is listed) in the DOT Hazardous Materials Table (49 CFR 172.101) or the IATA List of Dangerous Goods Table (IATA Dangerous Goods Regulations). DOT Guide for shippers can be found in Attachment D of this document.

To determine the proper shipping name, use the following steps to help locate the shipping name on the Hazardous Materials Table, DOT 49 CFR 172.101.

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

2. Look for the chemical family name. For example, pentyl alcohol is not listed but the chemical family name is: alcohol, n.o.s. (not otherwise specified). If the chemical family name is not listed, then . . .

3. Look for a generic name based on end use. For example, Paint, n.o.s. If a generic name based on end use is not listed, then . . .

4. Look for a generic family name based on end use, for example, drugs, n.o.s. or cosmetics, n.o.s. Finally, if your material is not listed by a generic family name but you suspect or know the material is hazardous because it meets the definition of one or more hazardous classes, then . . .

5. You will have to use the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s, or Oxidizer, n.o.s.

If you have any doubt regarding the proper shipping name, contact Health Sciences in Pittsburgh, Pennsylvania for assistance.

5.4.2.2 Unknown Substances

For samples of hazardous substances that are not listed on the Hazardous Materials Table, or are of unknown content, the shipper is required to:

1. Determine that the substance is not forbidden for shipment. Items forbidden include explosives (solid and liquid), substances liable to produce a dangerous evolution of heat or gas, and listed "unusual" compounds (which TtNUS fortunately does not typically handle). If the substance is in any way atypical of routine shipments, contact Health Sciences for further information on determining if the substance is forbidden.

2. Classify the substance by assessing whether it is anticipated to exhibit any unusual physical properties as defined by DOT (flammability, explosivity, etc.). If the substance has more than one hazard, follow the hazardous materials classification scheme identified in Attachment C of this SOP.

3. Use the generic or "n.o.s." proper shipping name that most accurately describes the article or substance. There are two types of general proper shipping names:

   - Generic, e.g., Alcohols, n.o.s. *
   - Hazard description, e.g., Flammable liquid, n.o.s.*

   Generic or n.o.s. proper shipping names marked with an "*" require the addition of the technical name in parenthesis () immediately following the proper shipping name. For example, most of our instrument calibration gases are not listed by name and must be declared under the most accurately descriptive name, which is "Compressed Gas, n.o.s. (Mixture Nitrogen and Oxygen)".

The correct shipping classification for an unknown sample is therefore selected through a process of elimination as described above (and detailed in 49 CFR 172.101(c)(11). By using the provisions in this paragraph, the proper shipping name and description will be determined. A step-by-step guide is provided by the DOT and can be found in Attachment D of this SOP. Again, if you have any doubt regarding the proper shipping name, contact Health Sciences for assistance.

5.4.3 Packaging and Shipping of Samples Classified as Flammable Liquid (or Solid)

5.4.3.1 Packaging

Applying the word "flammable" to a sample does not necessarily mean that it is in fact flammable. The word prescribes the class of packaging according to DOT regulations and classification schemes. The DOT defines flammable liquids as substances with a flash point less than 140°F (60°C). For shipping purposes, liquids with a flash point exceeding 95°F (35°C) need not be considered as flammable liquids if they are miscible solutions and have a water content of more than 90% by weight. For solutions classified as flammable liquids:

1. Containerize sample as required (see Attachments A and B). To prevent leakage, fill container no more than 90 percent full. Seal lid with teflon tape or wire.

2. Complete sample label and attach securely to sample container.

3. Seal container and place in 2-mil-thick (or thicker) polyethylene bag (e.g., Ziploc baggie), one sample per bag. Position sample identification label so that it can be read through bag. Seal bag.

4. For soil jars, place sealed bag inside metal can (available from laboratory or laboratory supplier) and cushion it with enough noncombustible, absorbent material (for example, vermiculite or diatomaceous earth) between the bottom and sides of the can and bag to prevent breakage and absorb leakage. Pack one bag per can. Use clips, tape, or other positive means to hold can lid securely, tightly and permanently. Mark can as indicated in Paragraph 1 of Section 5.3.4.2, below. Single 1-gallon bottles do not need to be placed in metal cans.

5. Place one or more metal cans (or a single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans (or bottle) with noncombustible, absorbent cushioning materials for stability during transport. The absorbent material should be able to absorb the entire contents of the container. Mark container as indicated in Paragraph 2 below.

5.4.3.2 Marking/Labeling

1. Use abbreviations only where specified. Place the following information, either hand-printed or in label form, on the metal can (or 1-gallon bottle):

   - Laboratory name and address.
   - Proper shipping name from the hazardous materials table (DOT Regulation CFR 49 172.101). Example: "Flammable Liquid, n.o.s. (with the technical name in parentheses).

2. Determine packing group. The packing group must be included on the shipping papers in the description section. Packaging groups are classified as follows:

   Group I. Most Hazardous
   Group II. Medium Hazard
   Group III. Least Hazardous

   The packing group will be listed in the hazardous materials table, column 5.

3. Place the following information on outside shipping container per the instructions provided in the "Shipping Hazardous Materials" course:

   - Proper shipping name
   - UN or NA number
   - Proper label(s)
   - Addressee and sender

For flammable liquids, the following are the proper labels to be placed on the outside shipping container:

- DOT "Flammable liquid" label
- Package orientation label (arrows pointing upward) on at least two opposite sides of the package
- "Cargo Aircraft Only" label if shipping more than 30L of flammable liquids in the package.

5.4.3.3 Shipping Papers

Principally because of limitations in sample holding times, TtNUS almost exclusively uses air transportation to ship hazardous materials and other environmental samples. The "Dangerous Goods Airbill" is the shipping paper used to document the information associated with the shipment. As identified previously, only personnel who have participated in "Shipping Hazardous Materials" training (or equivalent course) are authorized to prepare hazardous materials for shipment - including preparation of associated shipping papers. Included in this training are instructions on what specific information is to be provided on the Airbill for hazardous materials typically shipped by TtNUS. Refer to the training course Student Manual or contact Health Sciences for this information.

The properly executed Chain-of-Custody Report must be included in the container. Use custody seals.

Using the Airbill of our common carrier (i.e., Federal Express) as an example, the following instructions apply to the information to be provided under "Transport Details", "Nature and Quantity of Dangerous Goods", and other associated fields.

a) Transport Details

- Select "Passenger and Cargo" or "Cargo Aircraft Only" (This is based on the type and quantity of dangerous goods you are shipping). X-out the non-applicable selection.
- Airport of Departure - Enter the full name of the airport or city of departure.
- Airport of Destination - Enter the full name of the airport or city of destination.

b) Shipment Type – Delete the option that does not apply (Non-Radioactive/Radioactive)

c) Nature and Quantity of Dangerous Goods

1. Dangerous Goods Identification

   - Proper Shipping Name - List the proper shipping name (this is the name as it appears on the List of Dangerous Goods Table and NOT the product or trade name), and if applicable, the technical name in parenthesis.
   - Class or Division - List the class or division number and, if applicable, compatibility group.
   - UN or ID No - List the UN or I.D. number, preceded with "UN" or "I.D." This selection may change when shipping in accordance with 49 CFR regulations that permit the shipment under NA (North American Continental Shipments) designations for certain substances.
   - Packing Group – List the appropriate packing group, if applicable. This is the level of anticipated hazard of the shipment. It does not apply for all shipments. When no information is available, leave the space blank.
   - Subsidiary Risk – List the class or division number of the subsidiary risk, if applicable. The subsidiary risk is any additional hazard beyond the most significant (or primary) hazard. This information is obtained from the List of Dangerous Goods Table.

2. Quantity and Type of Packaging – List the number of packages, the type of package, and the net quantity in each package. The type of packaging you are shipping the hazardous material in is presented first, followed by the amount (Kg, L, etc.). For example, "1 fiberboard box X 2 Kg". When no outer packaging is identified, the packaging selected must provide limited protection of the inner packaging by securing and cushioning during shipment. NOTE: Always use the package that the hazardous material was shipped to the site in. If it is not available, contact the Health Sciences Department in Pittsburgh for further instruction.

3. Packing Instructions – Enter the Packing Instruction number. These instructions are provided in Section 5 of the IATA Dangerous Goods Regulations. They provide the exact type of packaging required by the industry for various hazard classes. When no addition packaging considerations are given, the shipper may use their best judgment for the shipment of an identified substance and/or article.

4. Authorization – List the words " Limited Quantity," if applicable; list any special provision(s) or approval(s) if applicable. This section provides for exceptions to this transportation regulation and the conditions for those exceptions.

d) Additional handling Information - Enter any required special handling information.

e) Prepared for Air Transport according to: Check the ICAO/IATA box.

f) Emergency Telephone Number - Enter the 24-hour emergency contact number. This number is required of all US Origin or Destination Shipments. List the number for InfoTRAC (1-800-535-5053). InfoTRAC is a company retained by TtNUS to provide 24-Hour Emergency Hotline service for dangerous goods shipment. This company has MSDSs for the substances routinely shipped by TtNUS. They provide information to FedEx or any other emergency responders, should situations arise with one of our shipments. In addition, they have telephone numbers of certain Tetra Tech NUS Health Science Department personnel in the Pittsburgh Office in the event of an emergency.

g) Name/Title of the Signatory - Enter name and job title (Field Operations Leader, Geologist, Health & Safety Specialist, etc.)

h) Place and date - Enter the city and date of shipment

i) Signature - Sign the form (must be a complete signature). All alterations must be signed with the same signature used to sign the declaration.

5.4.3.4 Transportation

1. The majority of unknown hazardous substance samples will be classified as flammable liquids. The samples will be transported by rented or common carrier truck, railroad, or express overnight package services. Do not transport samples on any passenger-carrying air transport system, even if the system has cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that carry only cargo. If unsure of what mode of transportation to use, consult Health Sciences.1

2. For transport by government-owned vehicle, including aircraft, DOT regulations do not apply. However, procedures described above, with the exception of execution of the bill of lading with certification, shall still be followed.

3. Use the hazardous materials shipping check list (Attachment E) as a guidance to ensure that all sample-handling requirements are satisfied.

4. In some cases, various materials may react if they break during shipment. To determine if you are shipping such materials, refer to the DOT compatibility chart in Attachment F.

5.5 Shipment of Lithium Batteries

Monitoring well data are analyzed using either the Hermit SE 1000 or the Hermit SE 2000 environmental data logger. These instruments are typically powered by lithium batteries in sufficient quantity to make the unit subject to hazardous material shipping requirements. The DOT determined that lithium batteries are to be shipped using the following information:

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1 Note: If you are unsure as how to ship the sample (hazardous or environmental sample), contact Health Sciences so that a decision can be made as to the proper shipping practices. The DOT and IATA penalties for improper shipment of a hazardous material are stringent and may include a prison term for intentional violations.

- Product Designation
  - Hermit SE 1000
  - Hermit SE 2000

- Proper Shipping Name
  - Lithium batteries, contained in equipment, UN3091

- UN No - UN-3091

- Classification or Division
  - Class 9

Shipment of equipment containing lithium batteries must be accompanied by shipping papers completed as indicated in Attachment G. The instrument will be shipped by Federal Express as a Hazardous Material. Place the instrument in the same container in which it was received. This container or case is a DOT-approved shipping container. For Federal Express procedures to ship hazardous materials, call 1-800-238-5355, extension 922-1666. In most cases, the return shipping papers and DOT labels will be shipped to you from the company warehouse or the vendor. An example of the types of labels used for shipment and the wording are shown in Attachment G. These labels will be attached to the outside container and include all the information noted under Section 5.4.3.2. Instead of the Flammable Liquid information, however, the following will be presented with the following wording:

- Lithium Batteries Contained in Equipment
  - UN-3091

- DOT Miscellaneous Hazardous Materials (Class 9) label

- "Cargo Aircraft Only" label

6.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. APHA, Washington, D.C.

International Air Transport Association (latest issue). Dangerous Goods Regulations, Montreal, Quebec, Canada.

U.S. Department of Transportation (latest issue). Hazardous Materials Regulations, 49 CFR 171-177.

U.S. EPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

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

ATTACHMENT A

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration			Container[1]	Sample Size	Preservation[2]	Holding Time[2]
WATER						
Organics (GC&GC/MS)	VOC	Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to ≤ 2	14 days[9]
	Extractables SVOCs and pesticide/PCBs)	(Low	Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticide/PCBs)	(Medium	Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals	Low	High-density polyethylene	1 L	HNO_3 to pH ≤2	6 months (Hg-28 days)
		Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide	Low	High-density polyethylene	1 L	NaOH to pH>12	14 days
	Cyanide	Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	14 days
SOIL						
Organics (GC&GC/MS)	VOC		Wide-mouth glass with teflon liner	2 x 4 oz.	Cool to 4°C	14 days
	Extractables SVOCs and pesticides/PCBs)	(Low	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticides/PCBs)	(Medium	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium		Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All		Wide-mouth glass	4 oz.	None	7 days until extraction; 40 days after extraction
TCLP	All		Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction
AIR						
Volatile Organics	Low/Medium		Charcoal tube – 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended

1 All glass containers should have Teflon cap liners or septa.
2 See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

ATTACHMENT B

ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container[1]	Preservation[2][3]	Maximum Holding Time[4]
INORGANIC TESTS:			
Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C; NaOH to pH 12; 0.6 g ascorbic acid[5]	14 days[6]
Fluoride	P	None required	28 days
Hardness	P, G	HNO_3 to pH 2; H_2SO_4 to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H_2SO_4 to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE TWO

Parameter Number/Name	Container[1]	Preservation[2][3]	Maximum Holding Time[4]
INORGANIC TESTS (Cont'd):			
Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours
METALS:[7]			
Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	P, G	HNO_3 to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO_3 to pH 2	6 months
ORGANIC TESTS:[8]			
Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5] HCl to pH 2 [9]	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5] adjust pH to 4-5 [10]	14 days
Phenols[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
Benzidines[11], [12]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction[13]
Phthalate esters[11]	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitrosamines[11], [14]	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
PCBs[11]	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]; store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs)[11],[14]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]; store in dark	7 days until extraction; 40 days after extraction
Haloethers[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF)[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE THREE

(1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
(2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
(3) When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
(4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer periods, and has received a variance from the Regional Administrator.
(5) Should only be used in the presence of residual chlorine.
(6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments are made to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
(7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
(8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
(9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
(10) The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
(11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
(12) If 1,2-diphenylthydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.
(13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
(14) For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
(15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

ATTACHMENT C

DOT HAZARDOUS MATERIAL CLASSIFICATION (49 CFR 173.2a)

1. Radioactive material (except a limited quantity)
2. Division 2.3, Poisonous Gases
3. Division 2.1, Flammable Gas
4. Division 2.2, Nonflammable gas
5. Division 6.1, Poisonous Liquids, Packing Group 1 (poison by inhalation only)
6. Division 4.2, Pyrophoric Material
7. Division 4.1, Self-Reactive Material
8. Class 3, Flammable Liquids*
9. Class 8, Corrosive Material
10. Division 4.1, Flammable Solid*
11. Division 4.2, Spontaneously Combustible Materials*
12. Division 4.3, Dangerous When Wet Materials*
13. Division 5.1, Oxidizers*
14. Division 6.1, Poisonous Liquids or Solids (other than Packing Group 1)*
15. Combustible liquid
16. Class 9, Miscellaneous Hazardous Materials

* If a material has or meets the criteria for more than one hazard class, use the precedence of hazardous table on the following page for Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1. The following table ranks those materials that meet the definition of Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1.

ATTACHMENT C (Continued)

DOT HAZARDOUS MATERIAL CLASSIFICATION (49 CFR 173.2a)

Class	Packing Group	4.2	4.3	5.1 I[a]	5.1 II[a]	5.1 III[a]	6.1 I (Dermal)	6.1 I (Oral)	6.1 II	6.1 III	8 I (Liquid)	8 I (Solid)	8 II (Liquid)	8 II (Solid)	8 III (Liquid)	8 III (Solid)
3	I						3	3	3	3	3	(c)	3	(c)	3	(c)
3	II						3	3	3	3	8	(c)	3	(c)	3	(c)
3	III						6.1	6.1	6.1	3[d]	8	(c)	8	(c)	3	(c)
4.1	II[b]	4.2	4.3	5.1	4.1	4.1	6.1	6.1	4.1	4.1	(c)	8	(c)	4.1	(c)	4.1
4.1	III[b]	4.2	4.3	5.1	4.1	4.1	6.1	6.1	6.1	4.1	(c)	8	(c)	8	(c)	4.1
4.2	II		4.3	5.1	4.2	4.2	6.1	6.1	4.2	4.2	(c)	8	(c)	4.2	(c)	4.2
4.2	III		4.3	5.1	4.2	4.2	6.1	6.1	6.1	4.2	(c)	8	(c)	8	(c)	4.2
4.3	I			5.1	4.3	4.3	6.1	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
4.3	II			5.1	4.3	4.3	6.1	4.3	4.3	4.3	8	8	8	4.3	4.3	4.3
4.3	III			5.1	4.3	4.3	6.1	6.1	6.1	4.3	8	8	8	8	4.3	4.3
5.1	I[a]						5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
5.1	II[a]						6.1	5.1	5.1	5.1	8	8	8	5.1	5.1	5.1
5.1	III[a]						6.1	6.1	6.1	5.1	8	8	8	8	5.1	5.1
6.1	I, Dermal										8	6.1	6.1	6.1	6.1	6.1
6.1	I, Oral										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Inhalation										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Dermal										8	6.1	8	6.1	6.1	6.1
6.1	II, Oral										8	8	8	6.1	6.1	6.1
6.1	III										8	8	8	8	8	8

(a) There are at present no established criteria for determining Packing Groups for liquids in Division 5.1. At present, the degree of hazard is to be assessed by analogy with listed substances, allocating the substances to Packing Group I, Great; Group II, Medium; or Group III, Minor Danger.

(b) Substances of Division 4.1 other than self-reactive substances.

(c) Denotes an impossible combination.

(d) For pesticides only, where a material has the hazards of Class 3, Packing Group III, and Division 6.1, Packing Group III, the primary hazard is Division 6.1, Packing Group III.

ATTACHMENT D

GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

USE OF GUIDE - This guide is presented as an aid to shippers of hazardous materials. It does not contain or refer to all of the DOT requirements for shipping hazardous materials. For specific details, refer to all of the DOT requirements for shipping hazardous materials, as provided in the Code of Federal Regulations (CFR), Title 49, Transportation, Parts 100-199.

The following is offered as a step-by-step procedure to aid in compliance with the applicable DOT regulations.

STEP 1 - DETERMINE THE PROPER SHIPPING NAME. The shipper must determine the proper shipping name of the materials as listed in the Hazardous Materials Table, 49 CFR 172.101, Column (2).

STEP 2 - DETERMINE THE HAZARD CLASS OR CLASSES.

a. Refer to the Table, 49 CFR 172.101, Column (3), and locate the hazard class of the material.
b. If more than one class is shown for the proper shipping name, determine the proper class by definition.
c. If the materials have more than one hazard, classify the material based on the order of hazards in 49 CFR 173.2.

STEP 3 - SELECT THE PROPER IDENTIFICATION NUMBERS.

a. Refer to the Table, 49 CFR 172.101, Column (3a), and select the Identification Number (ID) that corresponds to the proper shipping name and hazard class.
b. Enter the ID number(s) on the shipping papers and display them, as required, on packagings, placards and/or orange panels.

STEP 4 - DETERMINE THE MODE(S) OF TRANSPORT TO ULTIMATE DESTINATION.

a. As a shipper, you must assure yourself that the shipment complies with various modal requirements.
b. The modal requirements may affect the following: (1) Packaging; (2) Quantity per Package; (3) Marking; (4) Labeling; (5) Shipping Papers; and (6) Certification.

STEP 5 - SELECT THE PROPER LABEL(S) AND APPLY AS REQUIRED.

a. Refer to the Table, 49 CFR 172.101, Column (4) for required labels.
b. For details on labeling refer to (1) Additional Labels, 49 CFR 172.402; (2) Placement of Labels, 49 CFR 172.406; (3) Packagings (Mixed or Consolidated), 49 CFR 172.404(a) and (h); (4) Packages Containing Samples, 49 CFR 172.402(h); (5) Radioactive Materials, 49 CFR 172.403; and (6) Authorized Label Modifications, 49 CFR 172.405.

STEP 6 - DETERMINE AND SELECT THE PROPER PACKAGES.

a. Refer to the Table, 49 CFR 172.101, Column (5a) for exceptions and Column (5b) for specification packagings. Consider the following when selecting an authorized package: Quantity per Package; Cushioning Material, if required; Proper Closure and Reinforcement; Proper Pressure; Outage; etc., as required.
b. If packaged by a prior shipper, make sure the packaging is correct and in proper condition for transportation.

ATTACHMENT D (Continued)
GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

STEP 7 - MARK THE PACKAGING (INCLUDING OVERPACKS).

a. Apply the required markings (49 CFR 172.300); Proper shipping name and ID number, when required (49 CFR 172.301); Name and address of Consignee or Consignor (49 CFR 172.306).
b. For details and other required markings, see 49 CFR 172.300 through 172.338.

STEP 8 - PREPARE THE SHIPPING PAPERS.

a. The basic requirements for preparing shipping papers include Proper Shipping Name; Hazard Class; ID Number; Total Quantity; Shipper's Certification; and Emergency Response Telephone Number.
b. Make all entries on the shipping papers using the information required and in proper sequence (49 CFR 172.202).

STEP 9 - CERTIFICATION.

a. Each shipper must certify by printing (manually or mechanically) on the shipping papers that the materials being offered for shipment are properly classified, described, packaged, marked and labeled, and in proper condition for transportation according to the applicable DOT Regulations (49 CFR 172.202).

STEP 10 - LOADING, BLOCKING, AND BRACING. When hazardous materials are loaded into the transport vehicle or freight container, each package must be loaded, blocked, and braced in accordance with the requirements for mode of transport.

a. If the shipper loads the freight container or transport vehicle, the shipper is responsible for the proper loading, blocking, and bracing of the materials.
b. If the carrier does the loading, the carrier is responsible.

STEP 11 - DETERMINE THE PROPER PLACARD(S). Each person who offers hazardous materials for transportation must determine that the placarding requirements have been met.

a. For Highway, unless the vehicle is already correctly placarded, the shipper must provide the required placard(s) and required ID number(s) (49 CFR 172.506).
b. For Rail, if loaded by the shipper, the shipper must placard the rail car if placards are required (49 CFR 172.508).
c. For Air and Water shipments, the shipper has the responsibility to apply the proper placards.

STEP 12 - HAZARDOUS WASTE/HAZARDOUS SUBSTANCE.

a. If the material is classed as a hazardous waste or hazardous substance, most of the above steps will be applicable.
b. Pertinent Environmental Protection Agency regulations are found in the Code of Federal Regulations, Title 40, Part 262.

As a final check and before offering the shipment for transportation, visually inspect the shipment. The shipper should ensure that emergency response information is on the vehicle for transportation of hazardous materials.

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Revised March 1995.

ATTACHMENT E

HAZARDOUS MATERIALS SHIPPING CHECK LIST

PACKAGING

1. Check DOT 173.24 for appropriate type of package for hazardous substance.
2. Check for container integrity, especially the closure.
3. Check for sufficient absorbent material in package.
4. Check for sample tags and log sheets for each sample and for chain-of-custody record.

SHIPPING PAPERS

1. Check that entries contain only approved DOT abbreviations.
2. Check that entries are in English.
3. Check that hazardous material entries are specially marked to differentiate them from any nonhazardous materials being sent using same shipping paper.
4. Be careful that all hazardous classes are shown for multiclass materials.
5. Check total amounts by weight, quantity, or other measures used.
6. Check that any limited-quantity exemptions are so designated on the shipping paper.
7. Check that certification is signed by shipper.
8. Make certain driver signs for shipment.

RCRA MANIFEST

1. Check that approved state/federal manifests are prepared.
2. Check that transporter has the following: valid EPA identification number, valid driver's license, valid vehicle registration, insurance protection, and proper DOT labels for materials being shipped.
3. Check that destination address is correct.
4. Check that driver knows where shipment is going.
5. Check that the driver is aware of emergency procedures for spills and accidents.
6. Make certain driver signs for shipment.
7. Make certain one copy of executed manifest and shipping document is retained by shipper.

ATTACHMENT F
DOT SEGREGATION AND SEPARATON CHART

Class or Division	Notes	1.1-1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3 gas Zone A*	2.3 gas Zone B*	3	4.1	4.2	4.3	5.1	5.2	6.1 liquids PG-I Zone A*	7	8 liquids only
Explosives... 1.1 and 1.2	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives..... 1.3		*	*	*	*	*	X		X	X	X		X	X	X	X	X		X
Explosives..... 1.4		*	*	*	*	*	O		O	O	O		O				O		O
Very insensitive explosives 1.5	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Extremely insensitive explosives 1.6		*	*	*	*	*													
Flammable gases 2.1		X	X	O	X				X	O							O	O	
Non-toxic, non-flammable gases 2.2		X			X														
Poisonous gas - Zone A** 2.3		X	X	O	X		X				X	X	X	X	X	X			X
Poisonous gas - Zone B** 2.3		X	X	O	X		O				O	O	O	O	O	O			O
Flammable liquids..... 3		X	X	O	X				X	O					O		X		
Flammable solids..... 4.1		X			X				X	O							X		O
Spontaneously combustible materials 4.2		X	X	O	X				X	O							X		X
Dangerous-when-wet materials 4.3		X	X		X				X	O							X		O
Oxidizers 5.1	A	X	X		X				X	O	O						X		O
Organic peroxides.... 5.2		X	X		X				X	O							X		O
Poisonous liquids PG I - Zone A** 6.1		X	X	O	X		O				X	X	X	X	X	X			X
Radioactive materials . 7		X			X		O												
Corrosive liquids 8		X	X	O	X				X	O		O	X	O	O	O	X		

No entry means that the materials are compatible (have no restrictions).

X These materials may not be loaded, transported, or stored together in the same vehicle or facility.
O The materials may not be loaded, transported, or stored together in the same vehicle or facility unless they are separated for 4 feet on all sides.
* Check the explosives compatibility chart in 49 CFR 179.848(f).
A Ammonium nitrate fertilizers may be stored with Division 1.1 materials.
** Denotes inhalation hazardous for poisons; consult field team leader or project manager if you encounter a material in this class
1 before shipment.

ATTACHMENT G
LITHIUM BATTERY SHIPPING PAPERS

3224637861

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non applicable)*

[redacted] | CARGO AIRCRAFT ONLY

Airport of Departure

Airport of Destination: 19CYS

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

Shipment type: *(delete non-applicable)*

NON-RADIOACTIVE | [redacted]

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification						
Proper Shipping Name	Class or Division	UN or ID No.	Subsidiary Risk	Quantity and type of packing	Packing Inst.	Authorization
LITHIUM BATTERIES CONTAINED IN EQUIPMENT	9	UN3091		1 PLASTIC BOX X 55 GRAMS	912 II	PER CA-9206009

FOR SHIPMENTS WITHIN USA, AK, AND HI ONLY

Additional Handling Information

1 HERMIT SERIES DATALOGGER X 55 GRAMS (11 GRAMS/CELL)

I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and are in all respects in the proper condition for transport by air according to the applicable International and National Government Regulations.

Name/Title of Signatory

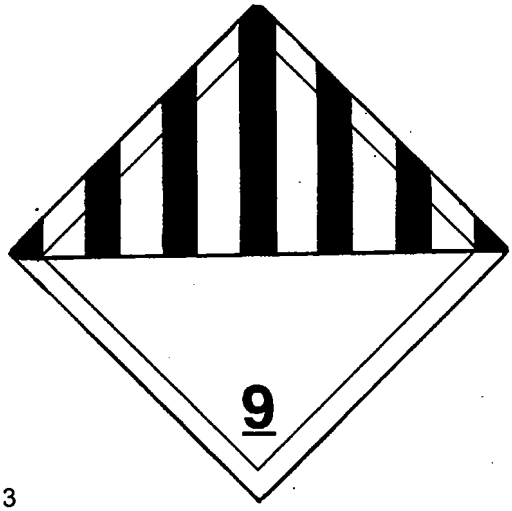
Place and Date

Signature *(see warning above)*

Emergency Telephone Number (Required for US Origin or Destination Shipments)
800-535-5053

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

ATTACHMENT G (CONTINUED)
LITHIUM BATTERY SHIPPING PAPERS



3

LITHIUM BATTERIES CONTAINED IN EQUIPMENT.
UN-3091.
SHIPPED UNDER CA-9206009

FIELD DOCUMENTATION
SOP SA-6.3
JANUARY 2000

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting Tetra Tech NUS field activities.

2.0 SCOPE

Documents presented within this procedure (or equivalents) shall be used for all Tetra Tech NUS field activities, as applicable. Other or additional documents may be required by specific client contracts or project planning documents.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Project Manager (PM) - 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 field documentation used in site activities (i.e., records, field reports, sample data sheets, field notebooks, and the site logbook) in the project's central file upon the completion of field work.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate and current 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 or referenced (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start and/or completion of borehole, trench, monitoring well installation, etc.
- 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 Tetra Tech NUS 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
- Tetra Tech NUS 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 field 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/notebook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be entered in the logbook/notebook 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/notebook. If possible, such techniques shall be avoided, since they can adversely affect the accuracy of photographs. 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. Once processed, the slides of photographic prints shall be consecutively numbered and labeled according to the logbook/notebook descriptions. The site photographs and associated negatives must be docketed into the project's central file.

5.2 Field Notebooks

Key field team personnel may maintain a separate dedicated field 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 field notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a field 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, Request for Analysis, and Field Test Results

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, difficulties, or irregularities 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 electronically generated in-house, 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 carbonless copy of the completed COC form is retained by the field crew, one copy is sent to the Project Manager, while the original is sent to the laboratory. The original (top, signed copy) 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. 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 Tetra Tech NUS Project Manager). The COC form is signed and copied. The laboratory will retain the copy while the original becomes part of the samples' corresponding analytical data package.

5.3.1.4 Chain-of-Custody Seal

Attachment B-7 is an example of a custody seal. The Custody seal is 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 transport 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.

5.3.1.5 Field Analytical Log Sheets for Geochemical Parameters

Field Analytical Log Sheets (Attachment B-8) are used to record geochemical and/or natural attenuation field test results. Attachments B-8 (3-page form) should be used when applicable.

5.3.2 Hydrogeological 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.

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, or Boring Log, (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, cuttings from the borehole, or breathing zone, (using a PID or FID), these results must be entered on the boring log at the appropriate depth. The "Remarks" column can be used to subsequently enter the laboratory sample number, the concentration of key analytical results, or other pertinent information. 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.

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.

5.3.2.7 Miscellaneous Monitoring Well Forms

Monitoring Well Materials Certificate of Conformance (Attachment C-11) should be used as the project directs to document all materials utilized during each monitoring well installation.

The Monitoring Well Development Record (Attachment C-12) should be used as the project directs to document all well development activities.

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 Daily Activities Report

To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

5.4.1.1 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).

5.4.1.2 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.

5.4.1.3 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.

5.4.2 Weekly Status Reports

To facilitate timely review by project management, photocopies of logbook/notebook entries may be made for internal use.

It should be noted that in addition to the summaries described herein, other summary reports may also be contractually required. Attachment F is an example of a Field Trip Summary Report form.

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 B-8	FIELD ANALYTICAL LOG SHEET
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-9	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK (FLUSHMOUNT)
Attachment C-10	EXAMPLE TEST PIT LOG
Attachment C-11	MONITORING WELL MATERIALS CERTIFICATE OF CONFORMANCE
Attachment C-12	MONITORING WELL DEVELOPMENT RECORD
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:

TtNUS	DRILLER	SITE VISITORS
_____	_____	_____
_____	_____	_____
_____	_____	_____

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

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

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

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

SAMPLING DATA:

Date:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Time:								
Method:								

PURGE DATA:

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

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:	Signature(s):

ATTACHMENT B-2

Tetra Tech NUS, Inc.

SURFACE WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

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

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

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

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date:								
Time:								
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

ATTACHMENT B-3

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

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

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

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

GRAB SAMPLE DATA:

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

COMPOSITE SAMPLE DATA:

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

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS/NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

ATTACHMENT B-4

Tetra Tech NUS, Inc.

CONTAINER SAMPLE & INSPECTION SHEET

Page____ of ____

Project Site Name: _____
Project Number: _____
Site Identification: _____
Container Number(s): _____
Sample Type: 0 Grab
0 Composite

Sample ID No. _____
Sampled By: _____
C.O.C. No. _____
Concentration: 0 High
0 Medium
0 Low

CONTAINER SOURCE	CONTAINER DESCRIPTION
DRUM: 0 Bung Top 0 Lever Lock 0 Bolted Ring 0 Other _____	**COLOR:** _____ **CONDITION:** _____
TANK: 0 Plastic 0 Metal 0 Other _____	**MARKINGS:** _____ **VOL OF CONTENTS:** _____
OTHER: _____	**OTHER:** _____

CONTAINER DISPOSITION	CONTENTS DESCRIPTION
SAMPLED: _____ **OPENED BUT NOT SAMPLED:** Reason _____ **NOT OPENED:** Reason _____	**SINGLE PHASED:** _____ **MULTIPHASE :** Layer 1 / Layer 2 / Layer 3 Phase (Sol. or Liq.) _____ _____ _____ Color _____ _____ _____ Viscosity L, M or H L, M or H L, M orH % of Total Volume _____ _____ _____
MONITOR READING:	**SAMPLE and /or INSPECTION DATE & TIME:** _____HRS. **METHOD:** _____
SAMPLER(S) and / or INSPECTOR(S) SIGNATURE:	**ANALYSIS:**

ATTACHMENT B-5

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090	**Project:** **Site:** **Location:**	
Sample No:		**Matrix:**
Date:	**Time:**	**Preserve:**
Analysis:		
Sampled by:	**Laboratory:**	

ATTACHMENT B-6

TETRA TECH NUS, INC. CHAIN OF CUSTODY | NUMBER | PAGE ____ OF _____

PROJECT NO:	SITE NAME:	PROJECT MANAGER AND PHONE NUMBER	LABORATORY NAME AND CONTACT:
SAMPLERS (SIGNATURE)		FIELD OPERATIONS LEADER AND PHONE NUMBER	ADDRESS
		CARRIER/WAYBILL NUMBER	CITY, STATE

STANDARD TAT ☐
RUSH TAT ☐
☐ 24 hr. ☐ 48 hr. ☐ 72 hr. ☐ 7 day ☐ 14 day

CONTAINER TYPE PLASTIC (P) or GLASS (G)
PRESERVATIVE USED
TYPE OF ANALYSIS

DATE YEAR	TIME	SAMPLE ID	MATRIX	GRAB (G) COMP (C)	No. OF CONTAINERS										COMMENTS

1. RELINQUISHED BY	DATE	TIME	1. RECEIVED BY	DATE	TIME
2. RELINQUISHED BY	DATE	TIME	2. RECEIVED BY	DATE	TIME
3. RELINQUISHED BY	DATE	TIME	3. RECEIVED BY	DATE	TIME

COMMENTS

DISTRIBUTION: WHITE (ACCOMPANIES SAMPLE) YELLOW (FIELD COPY) PINK (FILE COPY)

3/99
FORM NO. TtNUS-001

ATTACHMENT B-7

CHAIN-OF-CUSTODY SEAL

CUSTODY SEAL	**CUSTODY SEAL**
Date	**Date**
Signature	**Signature**

ATTACHMENT B-8

Tetra Tech NUS, Inc.

FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

Page __ of __

Project Site Name: _____ Sample ID No.: _____

Project No.: _____ Sample Location: _____

Sampled By: _____ Duplicate: ☐

Field Analyst: _____ Blank: ☐

Field Form Checked as per QA/QC Checklist (initials): ____

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date:								
Time:								
Method:								

SAMPLE COLLECTION/ANALYSIS INFORMATION:

ORP (Eh) (+/- mv): _____ Electrode Make & Model: _____

Reference Electrode (circle one): Silver-Silver Chloride / Calomel / Hydrogen

Dissolved Oxygen:

Equipment: HACH Digital Titrator OX-DT CHEMetrics (Range: _____mg/L) Analysis Time: _____

Range Used:	Range	Sample Vol.	Cartridge	Multiplier
☐	1-5 mg/L	200 ml	0.200 N	0.01
☐	2-10 mg/L	100 ml	0.200 N	0.02

Titration Count	Multiplier		Concentration
_____	x 0.01	=	mg/L
_____	x 0.02	=	mg/L

CHEMetrics: _____mg/L

Notes:

Alkalinity:

Analysis Time: _____

Equipment: HACH Digital Titrator AL-DT CHEMetrics (Range: _____mg/L) Filtered: ☐

Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier		Concentration
☐	10-40 mg/L	100 ml	0.1600 N	0.1	_____ & _____	x 0.1	=	mg/L
☐	40-160 mg/L	25 ml	0.1600 N	0.4	_____ & _____	x 0.4	=	mg/L
☐	100-400 mg/L	100 ml	1.600 N	1.0	_____ & _____	x 1.0	=	mg/L
☐	200-800 mg/L	50 ml	1.600 N	2.0	_____ & _____	x 2.0	=	mg/L
☐	500-2000 mg/L	20 ml	1.600 N	5.0	_____ & _____	x 5.0	=	mg/L
☐	1000-4000 mg/L	10 ml	1.600 N	10.0	_____ & _____	x 10.0	=	mg/L

Parameter:	Hydroxide	Carbonate	Bicarbonate
Relationship:			

CHEMetrics: _____mg/L

Notes:

Standard Additions: ☐ Titrant Molarity: _____ Digits Required: 1st.: _____ 2nd.: _____ 3rd.: _____

Carbon Dioxide:

Equipment: HACH Digital Titrator CA-DT CHEMetrics (Range: _____mg/L) Analysis Time: _____

Range Used:	Range	Sample Vol.	Cartridge	Multiplier
☐	10-50 mg/L	200 ml	0.3636 N	0.1
☐	20-100 mg/L	100 ml	0.3636 N	0.2
☐	100-400 mg/L	200 ml	3.636 N	1.0
☐	200-1000 mg/L	100 ml	3.636 N	2.0

Titration Count			Concentration
_____	x 0.1	=	mg/L
_____	x 0.2	=	mg/L
_____	x 1.0	=	mg/L
_____	x 2.0	=	mg/L

CHEMetrics: _____mg/L

Notes:

Standard Additions: ☐ Titrant Molarity: _____ Digits Required: 1st.: _____ 2nd.: _____ 3rd.: _____

ATTACHMENT B-8 (Continued)

Tetra Tech NUS, Inc.

FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

Page __ of __

Project Site Name: _____ Sample ID No.: _____

Project No.: _____ Sample Location: _____

Sampled By: _____ Duplicate: ☐

Field Analyst: _____ Blank: ☐

Field Form Checked as per QA/QC Checklist (initials): ☐

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Sulfide (S^{2-}):

Equipment: DR-700 DR-8 __ HS-WR Color Wheel Other: _____ Analysis Time: _____

Program/Module: 610nm 93

Concentration: _____ mg/L Filtered: ☐

Notes: _____

Sulfate (SO_4^{2-}):

Equipment: DR-700 DR-8 __ Other: _____ Analysis Time: _____

Program/Module: 91

Concentration: _____ mg/L Filtered: ☐

Standard Solution: ☐ Results: _____

Standard Additions: ☐ Digits Required: 0.1ml:_____ 0.2ml:_____ 0.3ml:_____

Notes: _____

Nitrite (NO_2^--N):

Analysis Time: _____

Equipment: DR-700 DR-8 __ Other: _____ Filtered: ☐

Program/Module: 60

Concentration: _____ mg/L Reagent Blank Correction: ☐

Standard Solution: ☐ Results: ☐

Notes: _____

Nitrate (NO_3^--N):

Analysis Time: _____

Equipment: DR-700 DR-8 __ Other: _____ Filtered: ☐

Program/Module: 55

Concentration: _____ mg/L

Nitrite Interference Treatment: ☐

Standard Solution: ☐ Results: _____ Reagent Blank Correction: ☐

Standard Additions: ☐ Digits Required: 0.1ml:_____ 0.2ml:_____ 0.3ml:_____

Notes: _____

ATTACHMENT B-8 (Continued)

Tetra Tech NUS, Inc.

FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

Page __ of __

Project Site Name: _____ Sample ID No.: _____

Project No.: _____ Sample Location: _____

Sampled By: _____ Duplicate: ☐

Field Analyst: _____ Blank: ☐

Field Form Checked as per QA/QC Checklist (initials): ☐

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Manganese (Mn^{2+}):

Equipment: DR-700 DR-8 __ HACH MN-5 Other: _____ Analysis Time: _____

Program/Module: 525nm 41

Concentration: _____ mg/L Filtered: ☐

Digestion: ☐

Standard Solution: ☐ Results: _____ Reagent Blank Correction: ☐

Standard Additions: ☐ Digits Required: 0.1ml:_____ 0.2ml:_____ 0.3ml:_____

Notes: _____

Ferrous Iron (Fe^{2+}):

Equipment: DR-700 DR-8 __ IR-18C Color Wheel Other: _____ Analysis Time: _____

Program/Module: 500nm 33

Concentration: _____ mg/L Filtered: ☐

Notes: _____

Hydrogen Sulfide (H_2S):

Equipment: HS-C Other: _____ Analysis Time: _____

Concentration: _____ mg/L Exceeded 5.0 mg/L range on color chart: ☐

Notes: _____

QA/QC Checklist:

All data fields have been completed as necessary: ☐

Correct measurement units are cited in the SAMPLING DATA block: ☐

Values cited in the SAMPLING DATA block are consistent with the Groundwater Sample Log Sheet: ☐

Mulitplication is correct for each *Multiplier* table: ☐

Final calulated concentration is within the appropriate *Range Used* block: ☐

Alkalinity *Relationship* is determined appropriatly as per manufacturer (HACH) instructions: ☐

QA/QC sample (e.g., Std. Additions, etc.) frequency is appropriate as per the project planning documents: ☐

Nitrite Interference treatment was used for Nitrate test if Nitrite was detected: ☐

Title block on each page of form is initialized by person who performed this QA/QC Checklist: ☐

ATTACHMENT C-1
EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET

Tetra Tech NUS, Inc.

GROUNDWATER LEVEL MEASUREMENT SHEET

Project Name: _____ **Project No.:** _____
Location: _____ **Personnel:** _____
Weather Conditions: _____ **Measuring Device:** _____
Tidally Influenced: Yes ___ No ___ **Remarks:** _____

Well or Piezometer Number	Date	Time	Elevation of Reference Point (feet)*	Total Well Depth (feet)*	Water Level Indicator Reading (feet)*	Thickness of Free Product (feet)*	Groundwater Elevation (feet)*	Comments

* All measurements to the nearest 0.01 foot

Page ___ of ___

ATTACHMENT C-2
EXAMPLE PUMPING TEST DATA SHEET

Tetra Tech NUS, Inc.

PUMPING TEST DATA SHEET

PROJECT NAME: _____ PUMPING WELL NUMBER: _____
PROJECT NUMBER: _____ MEASURED WELL NUMBER: _____

[ ] PUMPING TEST [ ] STEP DRAW DOWN TEST

DATE(s): MONITORING POINT:
MEASUREMENT METHOD: DEPTH CORRECTION (ft):
TEST NUMBER: PUMP SETTING (Ft. below monitoring point):
STATIC WATER LEVEL (ft): DISTANCE FROM PUMPING WELL (ft):
PERSONNEL:
REMARKS:

MILITARY TIME	ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	CORRECTION (Ft.)	DRAW DOWN OR RECOVERY (Ft.)	PUMPING RATE (GPM)	FLOW METER READING (Gals.)	REMARKS

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

ATTACHMENT C-3

ATTACHMENT C-3

PACKER TEST REPORT FORM

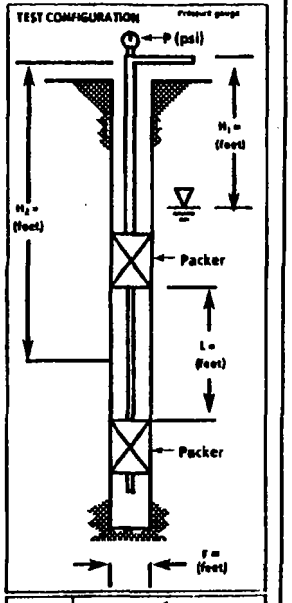
PROJECT: _____ PROJECT NO.: _____ TEST NO: _____ PAGE ____ OF ____

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)

TEST CONFIGURATION



Length of Test Section in feet, L	Cp			
	Drilling Bit Size			
	[illegible] (1.5")	[illegible] (1.875")	[illegible] (2.31")	[illegible] (3")
1	31,000	30,100	29,000	27,900
2	19,400	18,300	16,300	15,900
5	9,800	9,000	8,000	6,800
8	6,800	6,100	5,100	4,300
10	5,700	5,000	4,200	3,500
15	4,100	3,300	2,700	2,100
20	3,200	2,600	2,000	1,600

CP = (1/(2 x L)) ln(L/r) (70.315 5)
7.48 Gallons = 1 Ft³
1 psi = 2.31 ft head

* H_1 is used when the test length is below the water table.
H_2 is used when the test length is above the water table.

Remarks: _____

ATTACHMENT C-4

Tetra Tech NUS, Inc.

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING No.: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

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

* When rock coring, enter rock brokeness.

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

Drilling Area Background (ppm): ____

Remarks: _____

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

ATTACHMENT C4 (Continued)

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"⌀	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"⌀	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)	Identification Procedures on Fraction Smaller than No. 40 Sieve Size: DAY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)	GROUP SYMBOL	TYPICAL NAMES
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

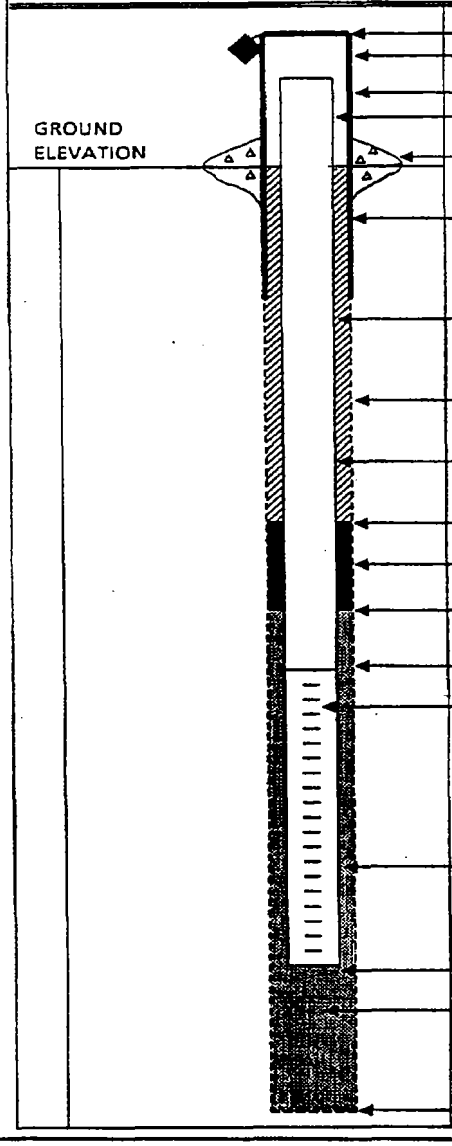
ATTACHMENT C-5
EXAMPLE OVERBURDEN MONITORING WELL SHEET

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: _____ / _____

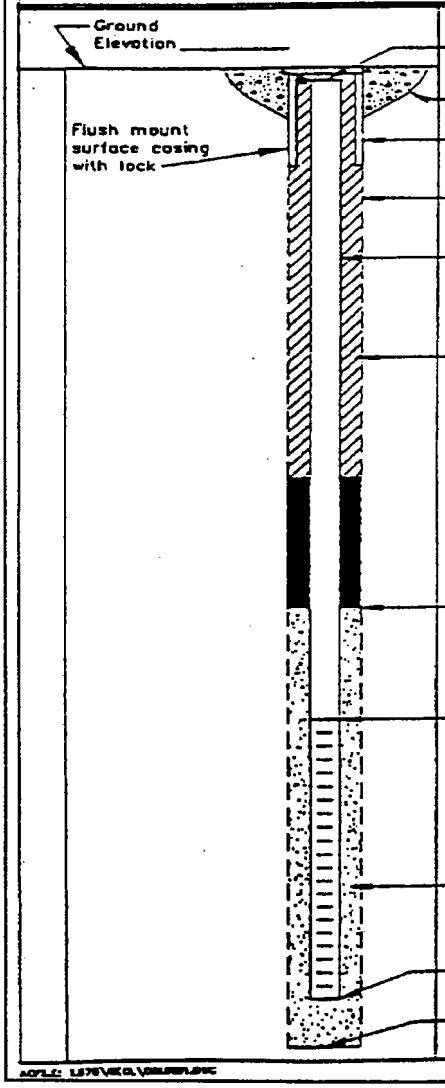
ATTACHMENT C-5A
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)

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: _____ / _____

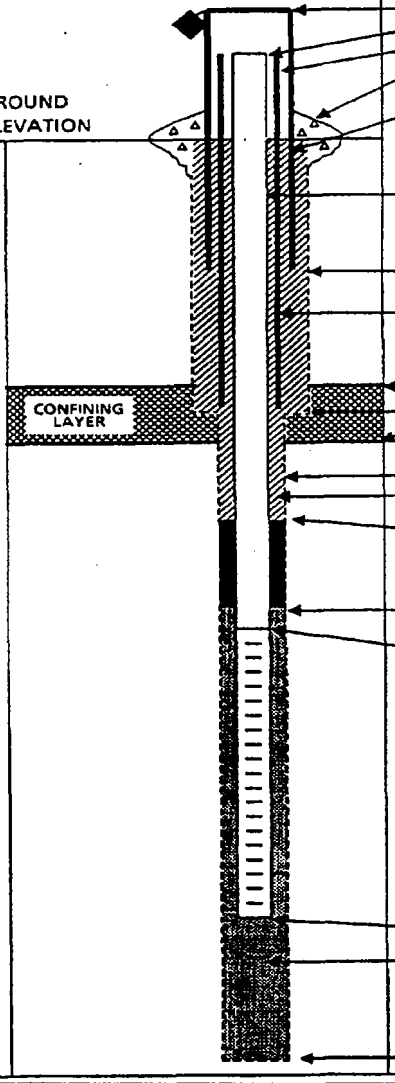
BACKFILL MATERIAL BELOW SAND: _____

ATTACHMENT C-6
EXAMPLE CONFINING LAYER MONITORING WELL SHEET

BORING NO.: _____

CONFINING LAYER
MONITORING WELL SHEET

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



ELEVATION OF TOP OF SURFACE CASING : _____
ELEVATION OF TOP OF RISER PIPE: _____
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: _____

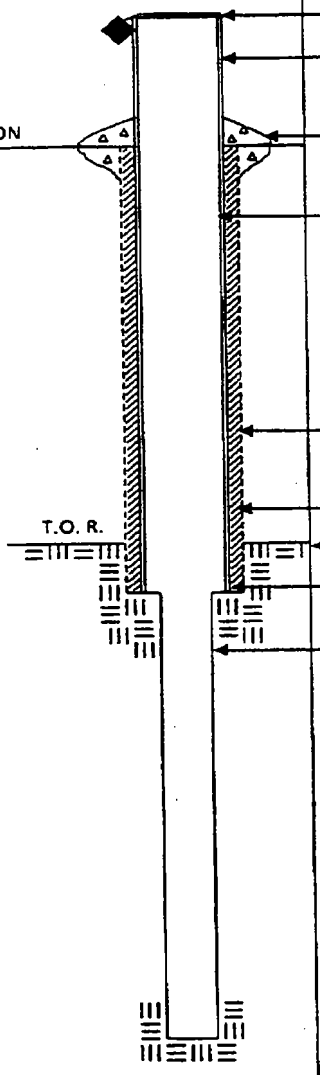
ATTACHMENT C-7
EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL

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: _____ / _____

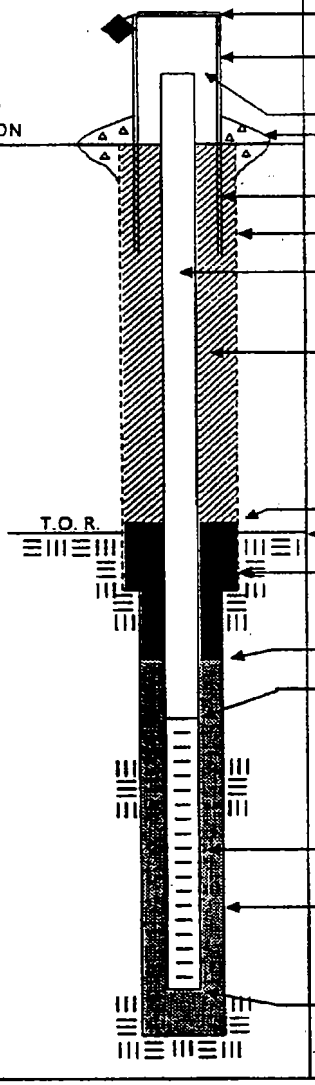
ATTACHMENT C-8
EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK

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: ____/____

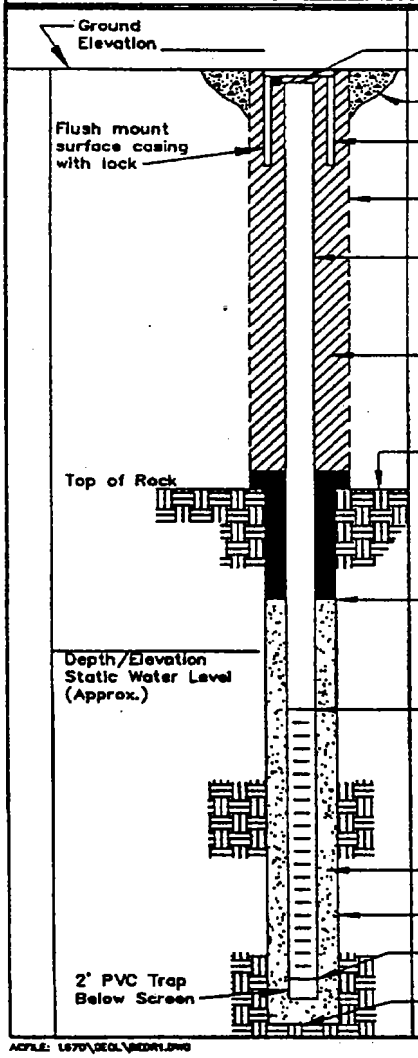
ELEVATION / DEPTH BOTTOM OF HOLE: ____/____

ATTACHMENT C-9
EXAMPLE BEDROCK MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK (FLUSHMOUNT)

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

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



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

_____

DEPTH/ELEVATION TOP OF BEDROCK: _____ / _____

DEPTH/ELEVATION TOP OF SAND: _____ / _____

DEPTH/ELEVATION TOP OF SCREEN: _____ / _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____

DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____

DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____

BACKFILL MATERIAL BELOW SAND: _____

ACFILE: L670\GEOL\BEDR1.DWG

ATTACHMENT C-10
EXAMPLE TEST PIT LOG

TEST PIT LOG

Tetra Tech NUS, Inc.

PROJECT: _____ TEST PIT NO.:
PROJECT NO _____ DATE: _____
LOCATION: _____
FIELD GEOLOGIST: _____

DEPTH (ft.)	LITHOLOGY CHANGES (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 C-11
EXAMPLE CERTIFICATE OF CONFORMANCE

MONITORING WELL MATERIALS
CERTIFICATE OF CONFORMANCE

Well Designation: _____ Site Geologist: _____
Site Name: _____ Drilling Company: _____
Date Installed: _____ Driller: _____
Project Name: _____ Project Number: _____

Material	Brand/Description	Source/Supplier	Sample Collected ?
Well Casing			
Well Screen			
End Cap			
Drilling Fluid			
Drilling Fluid Additives			
Backfill Material			
Annular Filter Pack			
Bentonite Seal			
Annular Grout			
Surface Cement			
Protective Casing			
Paint			
Rod Lubricant			
Compressor Oil			

To the best of my knowledge, I certify that the above described materials were used during installation of this monitoring well.

Signature of Site Geologist: _____

ATTACHMENT C-12
EXAMPLE MONITORING WELL DEVELOPMENT RECORD

Tetra Tech NUS, Inc.

MONITORING WELL DEVELOPMENT RECORD

Page ___ of ____

Site: _____ Depth to Bottom (ft.): _____ Project Name: _____
Well: _____ Static Water Level Before (ft.): _____ Project Number: _____
Date Installed: _____ Static Water Level After (ft.): _____ Site Geologist: _____
Date Developed: _____ Screen Length (ft.): _____ Drilling Co.: _____
Dev. Method: _____ Specific Capacity: _____
Pump Type: _____ Casing ID (in.): _____

Time	Estimated Sediment Thickness (Ft.)	Cumulative Water Volume (Gal.)	Water Level Readings (Ft. below TOC)	Temperature (Degrees C)	pH	Specific Conductance (Units ____)	Turbidity (NTU)	Remarks (odor, color, etc.)

ATTACHMENT D
EXAMPLE EQUIPMENT CALIBRATION LOG

Tetra Tech NUS, Inc.

EQUIPMENT CALIBRATION LOG

PROJECT NAME : _____ INSTRUMENT NAME/MODEL: _____

SITE NAME: _____ MANUFACTURER: _____

PROJECT No.: _____ SERIAL NUMBER: _____

Date of Calibration	Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot No.)	Remarks and Comments
			Pre-calibration	Post-calibration	Pre-calibration	Post-calibration		

ATTACHMENT E

Tetra Tech NUS, Inc.

DAILY ACTIVITIES RECORD

PROJECT NAME: _____ PROJECT NUMBER: _____

CLIENT: _____ LOCATION: _____

DATE: _____ ARRIVAL TIME: _____

Tt NUS PERSONNEL: _____ DEPARTURE TIME: _____

CONTRACTOR: _____ DRILLER: _____

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS: _____

APPROVED BY:

_____ Tt NUS REPRESENTATIVE

_____ DRILLER

DATE: _____

ATTACHMENT F
FIELD TRIP SUMMARY REPORT
PAGE 1 OF 2

SUNDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

MONDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

TUESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

WEDNESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

ATTACHMENT F
PAGE 2 OF 2
FIELD TRIP SUMMARY REPORT

THURSDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

FRIDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

SATURDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

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_____

DECONTAMINATION OF FIELD EQUIPMENT AND WASTE

SOP SA-7.1

MARCH 1998

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1.0 PURPOSE

The purpose of this procedure is to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

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.

Error! Bookmark not defined.**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.

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).

---

* 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.

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

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

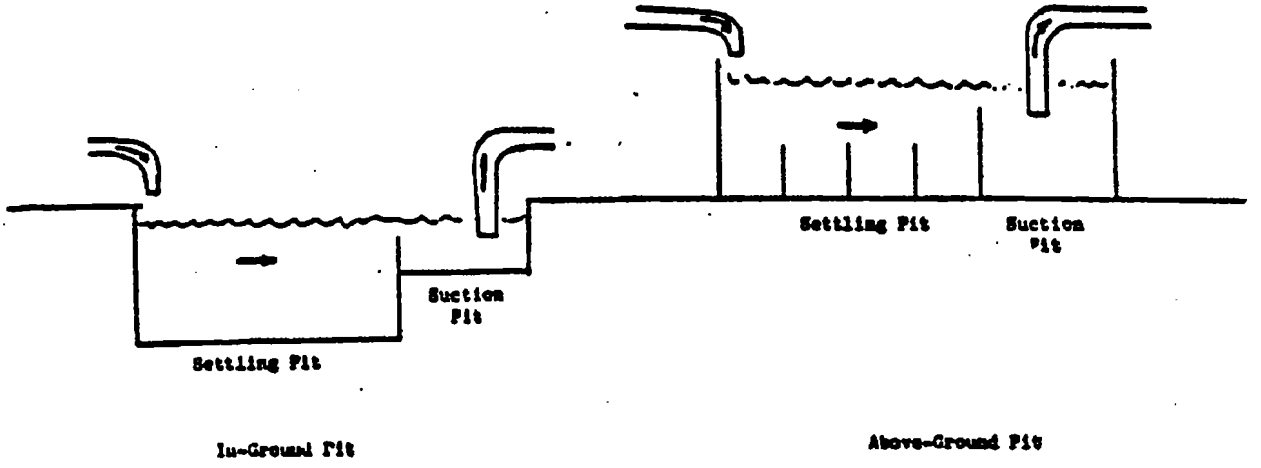
onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions 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



PHOTOVAC 2020 PHOTIONIZATION AIR MONITOR

SOP ME-12

JUNE 1999

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1.0 PURPOSE

To establish procedures for the use, maintenance, and calibration of the Photovac 2020 Photoionization Air Monitor.

2.0 SCOPE

Applies to each usage of the Photovac 2020 Photoionization Air Monitor by TtNUS 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

Office Managers – Office Managers are responsible for ensuring that personnel under their direction who may use this device are first provided with adequate training and information.

Project Managers – Project Managers are responsible for ensuring that appropriate health and safety requirements and resources are addressed for their assigned projects.

Health and Safety Manager (HSM) - The HSM shall ensure that appropriate training is available to users 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. On projects where a dedicated SSO is not assigned, the FOL/FTL is responsible for assuming the duties of that position.

Health and Safety Officer (HSO) - The HSO is responsible for determining air monitoring requirements for the site activities, and providing direction for air monitoring during specific site activities. This identification of types of air monitoring and direction for use are indicated within the Site-Specific Health and Safety Plan (HASP).

Site Safety Officer (SSO) - The SSO shall ensure the instruments identified are employed in the manner directed by the HSO, and that any action levels specified are observed for the application of engineering controls, personal protective equipment (PPE) use, and administrative controls. Additionally, he/she shall ensure the instruments are properly maintained and calibrated prior to use in the field. The SSO, during specific air monitoring applications including STEL and TWA mode measurements, will be responsible for the operation and application of this specialty air monitoring device. The SSO is also responsible for addressing relevant Hazard Communication requirements (e.g., MSDS, chemical inventories, labeling, training, etc.) on each assigned project.

5.0 PROCEDURES

5.1 Principle of Operation

Direct-reading instruments such as a photoionization detector are typically used to monitor for airborne releases that could present an inhalation threat to personnel, and to screen and bias environmental samples. Proper use of these instruments by trained, qualified personnel is essential to the validity of any acquired results. Also essential is that the devices are properly calibrated according to manufacturers instructions (and the specifications of this SOP), and that users of the instrument properly document results.

The Photovac portable photoionizer detects many organic (and a few inorganic) vapors. 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.

The 2020 instrument also performs short-term exposure limit (STEL), time-weighted average (TWA) and PEAK calculations. Any of these results can be viewed, 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 the 2020 instrument. They allow for the manipulation of the data in various ways.

All information entered with the keys and stored in the instrument's memory. This is retained when the instrument is switched off. The clock and calendar continue to operate and do not need to be set each time the instrument is turned on.

5.1.1 Displays

The 2020 instrument has a meter display for reporting detected concentration, and a display used to indicate status information and guide the user through configuration options. All functions of the instrument will be controlled or reported using one of these displays.

5.1.1.1 Meter Display

The meter has a 4-digit display. It will always be used for reporting detected concentrations. When the detector and pump are off, the meter display will be blank.

In order to accommodate the entire range of concentrations the 2020 can detect, the instrument has 2 resolution settings. The 0.1 resolution setting should be used for concentrations below 100 ppm, and the 1 resolution setting should 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 the user 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 both to turn power on to the 2020 as well as to 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 an accidental power off.

The EXIT key provides a way of returning to the default display. In the functional map, the soft keys allow the user to advance and the EXIT key provides a way to go back. At the initial entry of the menu, EXIT will return the user to the default display.

The ENTER key has a context sensitive function. When operating or navigating through the function map, the ENTER key is used to exit the functions and return 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 the 2020 are located directly below the status display. Each key has varying functions for configuring the 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 must be entered, 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 to 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 the EXIT key.

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 8 characters long, which is displayed on the right side of the status display line. The prompt, describing the input, occupies the left side 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 automatically 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 indicate 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 Use and Documentation of Results

As with any direct-reading instrument, understanding not only how – but when to use this instrument is essential to gathering relevant and valid data. This device will only respond to volatile substances in sampled air that have ionization potentials below the UV lamp strength. Inappropriate instrument selection, or use/interpretation of instrument results by an unqualified user not only can yield inaccurate

results, but could place personnel at risk of exposure to hazardous agents. Only personnel who are properly trained and authorized to use this device will be permitted to operate it.

It is essential that instrument operators understand and comply with the requirements to document results. This includes the need to document calibration results as well as operational readings. Calibration results must be recorded using Figure 5-1. Operational results can be recorded in several ways, including:

- Direct-Reading Instrument Response Data (Figure 5-2) – preferred method
- Boring Log Forms (Figure 5-3)
- Test Pit Log Forms (Figure 5-4)
- Log book entries

When using direct-reading instruments, it is important to monitor the air near the source of potential releases (e.g., drilling boreholes, tank entrances, drum openings, etc.) and at worker breathing zone areas. All readings should be recorded, including readings noted where background levels were not exceeded.

5.3.2 Instrument Status

The instrument status is shown on the left side of the first line of the status display and on the Table and Graph outputs. Each status has an assigned 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.

5.3.3 Alarms

While operating the instrument, any one of three audible alarm conditions can occur. To accurately identify the source of the alarm, each type of alarm has been given a unique status.

The 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 alarm conditions, and is named "Ack." If no alarm conditions exist , then the "Ack" key is not shown. To clear an alarm, press the "Ack" key. Once acknowledged, the alarm indicators are cleared. The alarm status will remain until the alarm condition clears.

The 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 the 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.

FIGURE 5-1

DOCUMENTATION OF FIELD CALIBRATION

SITE NAME: _____ PROJECT NO.: _____

Date of Calibration	Instrument Name and Model	Tetra Tech Instrument I.D. Number	Person Performing Calibration	Instrument Settings/Readings		Calibration Standard (Lot Number)	Remarks/ Comments
				Pre-Calibration Setting	Post-Calibration Reading		

FIGURE 5-2

DIRECT-READING INSTRUMENT RESPONSE DATA

SITE NAME: _____

PROJECT NO.: _____

PAGE OF

Date and Time(s)	Instrument Operator Name	Instrument Used	Instrument Reading and Duration	Location (e.g., borehole vs breathing zone)	Operation(s) Being Performed	Personnel in Vicinity at Time of Readings and Level of PPE Worn
Example 12-12-91/14:30	Joe Field	HNU 101	15 ppm/15 min.	breathing zone	sample location no. 12	Jim Technician/Level B George Grunt/Level B

FIGURE 5-2 (Continued)

SITE NAME: _____

PROJECT NO.: _____

PAGE _____ OF ____

Date and Time(s)	Instrument Operator Name	Instrument Used	Instrument Reading and Duration	Location (e.g., borehole vs breathing zone)	Operation(s) Being Performed	Personnel in Vicinity at Time of Readings and Level of PPE Worn

FIGURE 5-3

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: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): 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 5-4

Page ___ of ___

TEST PIT LOG

PROJECT NAME: _____ TEST PIT NUMBER: _____
PROJECT NUMBER: _____ DATE: _____
LOCATION: _____ GEOLOGIST: _____

Depth (Ft.)	Lithology Change (Depth/Ft.)	MATERIAL DESCRIPTION Soil/Waste Characteristics (lithology, density, color, etc.)	USCS	Remarks	PID/FID READING Source (ppm)	BZ (ppm)

TEST PIT CROSS SECTION AND / OR PLAN VIEW

REMARKS: _____

PHOTO LOG: _____

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 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. The 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 the 2020. The results of the calculations can be displayed 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 in the TWA mode, the time on the status display will show the number of minutes and hours of data that TWA data has been accumulated. When the sample time reaches 8 hours, the 2020 stops accumulating data and the TWA is complete.

TWA calculations are always being performed by the 2020. The results of the calculations can be displayed by selecting TWA as the Display mode. When the sampling period is less than 8 hours, record the TWA readout along with the sampling duration displayed on the meter.

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 shown 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 every 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. Typically, the instrument is operated in the PEAK mode. Operation within the other specialized modes are the responsibility of the SSO.

5.5 Set Functions

Pre-set functions are used to setup the 2020. There are three functions which can be used: Calibration, Pump and Clock.

5.5.1 Pump

The Pump function is used to control the pump. After selecting Set Pump, the 2020 responds by displaying the new pump status.

The detector is also turned off when turning 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 the 2020 will only be used for reviewing data or generating reports. Operating the instrument with the pump and detector turned off 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. If the pump is off, pressing the "Pump" key will turn the pump on.

5. A message will be displayed showing the status of the pump. The display 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 to 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 the user to input 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.

5.5.3 Calibration (Cal)

The Cal function allows the user to setup and calibrate the 2020. Three options are available 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 the user 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 for a list of the library entries.

5.6 Preparing for Field Operation of the Photovac 2020

Turning 2020 On

1. Turn the 2020 on by pressing the ON/OFF key.

2. The instrument 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 selections: "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 is for Span determination. Press "Enter" and 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 Documentation of Calibration form as illustrated in Figure 5-1.

This instrument is ready for use.

Calibration is to be performed daily or prior to each use in accordance with Sections 5.6 and 5.7 of this SOP, and with manufacturer's recommendations.

5.7 Maintenance and Calibration Schedule

Function	Frequency
Routine Calibration	Prior to each use. Complete Figure 5-4 for each calibration.
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

5.7.1 Cleaning the UV Light Source Window

1. Turn the FUNCTION switch to the OFF position. Use the instrument's 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. All other lamps - HPLC Grade Methanol

   Observe manufacturer's MSDS requirements when handling these substances.

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 the 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 debris.

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 the multi-tool. (Do not over tighten).

4. Recalibrate as per Sections 5.6 and 5.7.

5.8 Instrument Advantages

The Photovac 2020 is easy to use in comparison to many other types of monitoring instrumentation. Its detection limit is in the low parts-per-million range. Response time quickly reaches 90 percent scale of the indicated concentration (less than 3 seconds for benzene). This instrument's automated performance covers multiple monitoring functions simultaneously, and incorporates 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, 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 compound-specific. Their response to different compounds is relative to the calibration gas used. This is generally referred to as the relative response ratio. Instrument readings may be higher or lower than the true concentration. This can be especially serious 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 environments 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 Pressure - changes in temperature and/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. Significant changes in temperature or pressure from the time of calibration to the time of sample measurement may result in erroneous results.

- 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, the 2020's operation is comprised.

Fault 1: Signal from zero gas is too high.

Cause: If another fault occurred while the 2020 was setting its zero point, then this fault is displayed.

Action: Ensure no faults are occurring and calibrate the 2020 again.

Cause: Contamination of 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 the 2020. If you are using Tedlar bags, mark the calibration and zero gas Tedlar bags clearly.

Cause: Ambient air is contaminated.

Action: If the quality of ambient air is unknown, use a supply of commercial zero grade air.

Fault 2: Signal from span gas is too small.

Cause: Operator may have incorrectly used the span gas for the zero air source.

Action: Ensure clean air is used to zero the 2020. If you are using Tedlar bags, mark the calibration and zero gas Tedlar 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 the 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 the 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: The UV lamp has 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 the 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 the 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 the UV lamp has a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the Equipment Manager.

Cause: The 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 suspected to be present.

Cause: The 2020 has not been calibrated properly.

Action: Ensure the calibration gas is of a reliable concentration and then calibrate the instrument as outlined in 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 the 2020.

Cause: Calibration Memories have not been programmed correctly.

Action: Program all the calibration memories required for the intended 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 the list of response factors. If the compound is not listed or you are measuring gas mixtures, then enter a value of 1.0. See User's Manual.

Cause: Not using the correct Cal Memory.

Action: Select the correct Cal Memory for the intended application.

Note: It does not matter which Cal Memory is selected or which response factor is entered. The 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. 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 the UV lamp has 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 the UV lamp has 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 humidity conditions, there may be a decreased response.

Cause: UV lamp is failing.

Action: Replace UV lamp.

Note: Do not remove or replace the detector lamp in a hazardous location.

Cause: High concentration of non-ionizable compounds suspected.

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 the 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 conduct 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 contains a significant concentration of minerals.

Cause: The 2020 has not been calibrated properly.

Action: Ensure the calibration gas is of a reliable concentration and then calibrate the instrument as outlined in Sections 5.6 and 5.7.

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 required for the intended application. The correct calibration gas and concentration must be used for each Cal Memory. See the User's Manual.

Cause: Not using the correct Cal Memory.

Action: Select the correct Cal Memory for the intended application. See the User's Manual.

Note: It does not matter which Cal Memory is selected or which response factor is entered. The 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 the 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 was removed before the 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 that the 2020 has been turned off before removing the battery pack.

Cause: The 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 the 2020 to the AC adapter and turn the instrument on. Turn the pump off. While the 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 the 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 the 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 the 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 the 2020.

Cause: There is an undetermined problem.

Action: Reset the 2020. Leave the instrument on while disconnecting the battery pack. This will reset the instrument. Reconnect the battery pack and close the battery hatch. Turn on the 2020, set the time and date and program all the calibration memories.

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 the UV lamp has 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 the UV lamp has a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the Equipment Manager.

Cause: The 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: The 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: The 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 the 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 provided that there is no calibration gas cylinder accompanying the kit. When shipping or transporting the calibration gas, a Hazardous Materials (Dangerous Good) Airbill, including the information as stipulated in Figure 5-5 will be prepared. **Only personnel who have been properly trained are permitted to offer a hazardous material for shipment.** The "Shipping Hazardous Materials" course offered by Tetra Tech NUS is considered acceptable training for this purpose. Specific instructions on packaging, labeling, and otherwise preparing a hazardous material shipment are presented in the Student Manual that accompanies the course.

8.0 REFERENCES

Photovac 2020 Photoionization Monitor User's Manual, 1995.

Student Manual from "Shipping Hazardous Materials" course, Tetra Tech NUS, 1999.

FIGURE 5-5

FedEx *Dangerous Goods Airbill* — **Sender's Copy** — *RETAIN FOR 1 YEAR* — RETAIN THIS COPY FOR YOUR RECORDS — *The World On Time*

6/300 7181180

1 From (please print and press hard)

Date _____ Sender's FedEx Account Number _____

Sender's Name _____ Phone ( )

Company _____

Address _____ Dept./Floor/Suite/Room

City _____ State _____ ZIP _____

2 Your Internal Billing Reference Information (Optional) (First 24 characters will appear on invoice)

3 To (please print and press hard)

Recipient's Name: Tom Patton Phone (412) 262-4583

Company: Tetra Tech NUS

Address: Spring Run Road Extension, Suite 140 (We Cannot Deliver to P.O. Boxes or P.O. ZIP Codes) Dept./Floor/Suite/Room

☐ Check here if residence (Extra charge applies for FedEx Express Saver)

City: Coraopolis State: PA ZIP: 15108

For HOLD at FedEx Location check here: ☐ Hold Weekday ☐ Hold Saturday

For WEEKEND Delivery check here: ☐ Saturday Delivery ☐ NEW Sunday Delivery

4a Express Package Service Packages under 150 lbs. Delivery commitments may be later in some areas.

☐ FedEx Priority Overnight ☐ FedEx Standard Overnight ☐ FedEx 2Day ☐ FedEx Express Saver

4b Express Freight Service Packages over 150 lbs. Delivery commitments may be later in some areas.

☐ FedEx Overnight Freight ☐ FedEx 2Day Freight ☐ FedEx Express Saver Freight

(Call for delivery schedule. Some restrictions apply. See back for detailed descriptions of freight services.)

Questions? Call 1•800•Go•FedEx® (800)463-3339

5 Packaging

☒ Other Packaging

Dangerous Goods cannot be shipped in FedEx packaging.

6 Special Handling

☒ Dangerous Goods as per attached Shipper's Declaration ☐ Cargo Aircraft Only

7 Payment

☐ Sender ☐ Recipient ☐ Third Party ☐ Credit Card ☐ Cash/Check

FedEx Account No. _____

Credit Card No. _____ Exp. Date _____

Total Packages _____ Total Weight _____ Total Declared Value* $ .00 Total Charges $ _____

Signature Release Unavailable

FedEx Tracking Number: 807286974806 Form I.D. No.: 0204

355

Page 1 of 1 Pages

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable) PASSENGER AND CARGO AIRCRAFT / ~~CARGO AIRCRAFT ONLY~~

Airport of Departure:

Airport of Destination:

Shipment type: (delete non-applicable) NON-RADIOACTIVE / ~~RADIOACTIVE~~

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification

Proper Shipping Name	Class or Division	UN or I.D. No.	Packing Group	Subsidiary Risk	Quantity and Type of Packaging	Packing Inst.	Authorization
Compressed Gas N.O.S. (mixture Nitrogen and Oxygen)	2.2	UN 1956			1 Plastic box x 0.56 Kg	200	

Additional Handling Information

Prepared for AIR TRANSPORT according to: (Customer MUST check one) ☐ 49 CFR ☒ ICAO / IATA

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

Place and Date

Signature (see warning above)

Emergency Telephone Number (Required for US Origin or Destination Shipments) 1-800-535-5053 InfoTRAC

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

APPENDIX C

FIELD DOCUMENTATION FORMS

Tetra Tech NUS, Inc.

EQUIPMENT CALIBRATION LOG

PROJECT NAME : _____

SITE NAME: _____

PROJECT No.: _____

INSTRUMENT NAME/MODEL: _____

MANUFACTURER: _____

SERIAL NUMBER: _____

Date of Calibration	Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot No.)	Remarks and Comments
			Pre-calibration	Post-calibration	Pre-calibration	Post-calibration		

Tetra Tech NUS, Inc.

GROUNDWATER LEVEL MEASUREMENT SHEET

Project Name: _____ **Project No.:** _____

Location: _____ **Personnel:** _____

Weather Conditions: _____ **Measuring Device:** _____

Tidally Influenced: Yes ___ No ___ **Remarks:** _____

Well or Piezometer Number	Date	Time	Elevation of Reference Point (feet)*	Total Well Depth (feet)*	Water Level Indicator Reading (feet)*	Thickness of Free Product (feet)*	Groundwater Elevation (feet)*	Comments

* All measurements to the nearest 0.01 foot

Tetra Tech NUS, Inc.

TEST PIT LOG

PROJECT NAME: _____ TEST PIT No.: _____
PROJECT NUMBER: _____ DATE: _____
LOCATION: _____ GEOLOGIST: _____

Depth (Ft.)	Lithology Change (Depth/Ft.)	MATERIAL DESCRIPTION Soil/Waste Characteristics (lithology, density, color, etc.)	USCS	Remarks	PID/FID READING Source (ppm)	BZ (ppm)

TEST PIT CROSS SECTION AND / OR PLAN VIEW

REMARKS: _____

PHOTO LOG: _____

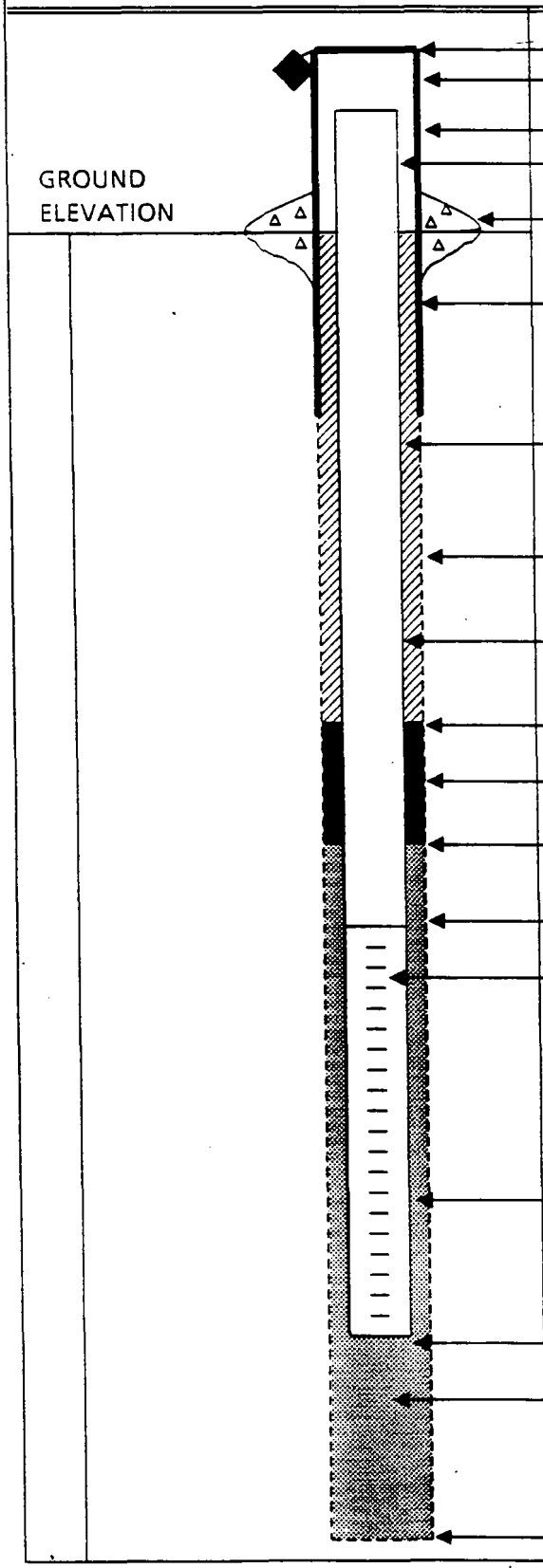
BORING NO.: _____

Tetra Tech NUS, Inc.

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: _____ / _____

Tetra Tech NUS, Inc.

MONITORING WELL DEVELOPMENT RECORD

Page ___ of ____

Well: _____ Depth to Bottom (ft.): _____ Responsible Personnel: _____
Site: _____ Static Water Level Before (ft.): _____ Drilling Co.: _____
Date Installed: _____ Static Water Level After (ft.): _____ Project Name: _____
Date Developed: _____ Screen Length (ft.): _____ Project Number: _____
Dev. Method: _____ Specific Capacity: _____
Pump Type: _____ Casing ID (in.): _____

Time	Estimated Sediment Thickness (Ft.)	Cumulative Water Volume (Gal.)	Water Level Readings (Ft. below TOC)	Temperature (Degrees C)	pH	Specific Conductance (Units _____)	Turbidity (NTU)	Remarks (odor, color, etc.)

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS

1. PROJECT	10. SIZE AND TYPE OF BIT
2. LOCATION *(Coordinates or Station)*	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. *(As shown on drawing title and file number)*	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE	Hole No.
PROJECT	INSTALLATION	SHEET OF SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

DAILY QUALITY CONTROL REPORT

PROJECT: _____

LOCATION: _____

Date: _____

Weather: _____

PERSONNEL:

Name/Position	Company	Hours Worked

EQUIPMENT:

Description	Purpose/Use	Time Used

FIELD INSTALLATIONS:

ID No. _____

Drilled from _____ to _____

Footage: _____

Casing Set: _____

Screen: _____

Riser: _____

Hours Drilling: _____

Hours Installing: _____

Hours Decon: _____

Hours Development: _____

Hours Sampling: _____

Hours Shut Down: _____

# of Samples: _____ Type: _____

Brief Description of Work Performed:

Health and Safety Levels:

Problems encountered:

Any changes from work plan:

Remarks: _____

Signature: _____

APPENDIX D

RESPONSE TO COMMENTS - DRAFT QAPP

RESPONSES TO EPA COMMENTS DATED JUNE 26, 2001 ON DRAFT OU3 PRE-DESIGN INVESTIGATION QAPP PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

General Comments

1. **Comment:** The QAPP was reviewed by EPA's Quality Assurance Unit. The document was reviewed to verify that all required QAPP elements and information, as specified in Table 1 of the Region 1, EPA-New England QAPP Compendium of QAPP Program Requirements and Guidance, October 1999 were present. Also, the document was reviewed to ensure that the project quality objectives, technical activities and related quality assurance/quality control will result in data of known, documented quality that can be used in environmental decision-making. This review showed that the QAPP elements were complete and acceptable.

   Response: Comment noted.

2. **Comment:** This document does not clearly discuss that two items to be evaluated through the pre-design and design phases are the consolidation of certain areas of the landfill, and the evaluation of the feasibility of wetlands as erosion controls. This should be clarified.

   Response: As indicated in the ROD for OU3, consolidation is being considered for the area of the landfill by the former mercury burial vault II and the area of the landfill by Jamaica Cove. The evaluation of consolidation will be a "desktop" study to determine the feasibility of consolidating portions of the landfill. The Feasibility Study for OU3 determined that consolidation of portions of the landfill was not as implementable or cost-effective as capping without consolidation. Data from cone penetration testing, test pitting, and deep borings will provide a more accurate and well defined volume, extent, and depth of the waste in the areas considered for consolidation. The evaluation of consolidation will be conducted based on the data collected during the pre-design investigation; however, it will not be conducted as part of the pre-design investigation and the results will not be included in the data package for the pre-design investigation. The evaluation of erosion protection methods will be provided as part of the design report for the cap system.

   The following text will be added to the QAPP related to the evaluation of consolidation:

   Page ES-2, new bullet after the 3rd bullet to read: "Data from CPT, test pitting, and deep borings will provide a better estimation of the volume and extent of waste in the areas under consideration for consolidation. Consolidation of waste from two areas of the landfill (south western portion by the former mercury burial vault II area and northern portion by Jamaica Cove) into the remaining portion of the landfill is being evaluated as part of the landfill cover design."

   Page 2-5, Section 2.2.2, after list of bullets: "Data from CPT, test pitting, and deep borings will provide a better estimation of the volume and extent of waste in the areas under consideration for consolidation. The evaluation of consolidation will be conducted as part of the landfill cover design."

Page 2-10, Step 3, paragraph (i), add before the last sentence: "CPT and deep borings will provide information on the thickness of the waste layer that will be used in the settlement analysis and in the estimation of the waste volume to consider for consolidation."

Page 2-10, Step 3, paragraph (v), add before last sentence: "Test pitting will also provide information to conduct a better estimation of the volume and extent of wastes in the areas under consideration for consolidation (as part of the landfill cover design)."

Section 3.1, after list of bulleted items: "CPT, test pitting, and deep boring locations within the areas being considered for consolidation (former MBII area and northern portion of landfill near Jamaica Cove) will be used to support the estimation of the volume and extent of waste in these two areas."

3. **Comment:** Provide a brief description of the wetlands function and value assessment, as well as how the information will be used.

   Response: Additional text will be added to applicable sections to present more detail for the wetlands functions and values assessment. Text sections with revisions include additional text to bullet on wetlands on page ES-2, Section 2.3.1 (Steps 2, 3, 4, 5, and 6), and Section 5.2.6.2. Additionally, new sections (Section 3.1.7 and 3.2.7) will be added to discuss the wetlands functions and values assessment. Note that the previous Section 3.2.7 (Other Field Investigation Activities) is now renumbered as 3.2.8.

Specific Comments

4. **Comment:** (was numbered as Specific Comment 3 in EPA comments)

   Section 2.2.2, Field Investigation Activities, page 2-5, bullets 4 and 10 (and throughout the document): As described in item iv on page 2-11, surface soil samples should be evaluated for permeability and moisture-density relationship information. Proposed sand-cone density testing for surface samples (if a Shelby tube cannot be collected for laboratory testing) may only provide density and moisture content information (not permeability information). EPA suggests obtaining block samples by test pits for both permeability and moisture-density relationship.

   Response: Disturbed (bulk) surface soil samples (which will be re-designated SS-1D through SS-4D), will be collected to determine suitability of the existing clay cover over the dredge spoils within the running track area for use in the barrier layer of the proposed cap. This will be done by classifying the material and re-compacting it to determine moisture-density-permeability relationships. The design does not rely on the in situ permeability of these soils but the potential permeability that can be achieved with the material. Furthermore, the in situ permeability of the existing cover material has most likely has been affected by vegetative growth and the lack of cover soil overlying the clay.

   Undisturbed surface soil samples (which will be re-designated SS-1U through SS-4U), will be collected to determine the existing weight-volume relationship, or density, to allow estimation of the volume of material which possibly can be utilized in the barrier or foundation layer. This will be conducted on Shelby tube samples or in place using the sand-cone method.

The 4th bullet will be revised to clarify the surface soil specified is the clay cap material as follows: "Disturbed samples will be used to determine the suitability of the existing clay cover material within the running track of the OU3 area for use in the proposed cap. If suitable the material would be removed from its existing location and placed within the cap as determined by the design. Undisturbed samples, either Shelby tube or sand-cone density, are to determine the density of the soil so volume of suitable material can be determined."

The text in Section 3.1.2, page 3-3 will be edited (last paragraph) to add clarity to the purpose of the surface soil sampling and testing.

Additionally, 2.3.1 Project Quality Objectives, Step 3, p. 2-11, Item iv) will be revised by replacing "existing dredge spoil clay layer" with "existing clay cover material over the dredge spoils".

5. **Comment:** (was numbered as Specific Comment 4 in EPA comments)

Section 3.1.3, Rationale for Test Pit Locations, pages 3-4 and Figure 3-2: Test Pits T-3, T-4 and T-14 do not appear to extend to provide a clear waste boundary. Clarify whether the proposed test pits will extend until the waste boundary is clearly defined or not.

Response: Test pits T-3 and T-4 will extend until the waste boundary is identified. Test pit T-14 (as well as T-15 and T-16) is intended to verify that waste is not present beneath the roadway and to determine the extent of waste adjacent to the roadway to Jamaica Island. Based on aerial photographs the westward extent of the landfill will be taken as the road between building 315 and the landfill.

A new test pit has been added (T-17) to the area adjacent to the east side of Ayeres Circle. Additionally, test pits T-6 and T-7have been extended to begin on the eastern side of Stephenson Road and will continue until the waste limits have been defined.

Appropriate text changes will be made throughout the document to reflect the changes and additional test pit.

6. **Comment:** (was numbered as Specific Comment 5 in EPA comments)

Section 3.2.6, Landfill Gas Survey, page 3-23: The proposed gas sampling depth of approximately 18 inches may not be sufficient to evaluate the potential for the annual methane production rate since the gas probes should penetrate the waste (rather than the top soil layer) or at a minimum should extend to a depth just above the lowest groundwater elevation. EPA suggests installing the gas probes into the waste and along the perimeter of the landfill.

Response: The proposed sampling depth has been revised to 30 inches based on discussions and technical recommendations by the subcontractor – Beacon Environmental Services, Inc. Sampling at this depth has been found in Beacon 's experience to be more than sufficient to detect methane and carbon dioxide that are present within landfills and migrating beyond landfill boundaries.

Beacon routinely performs soil-gas investigations where soil vapors from heavier and less volatile compounds are detected at the near surface when the compounds (present in a dissolved phase) are at depths in excess of 25 feet. An example of the sensitivity and accuracy

of the EMFLUX System was recently demonstrated in a soil-gas investigation of a landfill in the Southwestern United States. In this investigation, chlorinated compounds were found to be migrating off the landfill at a depth of 200 feet bgs, but detected at the surface.

Prior EMFLUX landfill gas investigations have shown that it is not necessary to sample within the waste of a landfill to detect methane that is present. Methane and carbon dioxide are extremely volatile and readily will migrate to the near surface. Typically in EMFLUX Landfill Gas Surveys gas measurements are taken at an 18-inch depth; however, because surface layers at the Jamaica Landfill can range from 6 to 30 inches, gas measurements will be taken at a 30 inch depth at all locations in the subject investigation.

Six additional LFG sampling locations (LGS-26 to LGS-31) will be added to evaluate potential horizontal migration of potential landfill gas (based on the June 21, 2001 RAB discussion/SAPL Comment No. 24 dated July 6, 2001). Figure 3-3 will be revised to show these new locations and Section 3.1.6 will be revised to provide the rationale of the additional samples.

RESPONSES TO MEDEP COMMENTS DATED JULY 3, 2001 ON DRAFT OU3 PRE-DESIGN INVESTIGATION QAPP PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

General Comments

1. **Comment:** Overall the Plan is well organized and clearly written. Clearly, the USEPA Region 1 New England Quality Assurance Project Plan guidance was very useful in the preparation of the Plan. The only criticism regarding document organization is the breakdown of each different type of activity into various activity process category sections. This caused the reviewers a lot of page flipping and searching to find the section with certain activity specific details.

   Response: Comment noted.

2. **Comment:** Intrusive drilling into potential landfilled wastes is proposed at locations for 22 piezometers, 54 cone penetrometers, and 8 deep borings. This represents more chance than any past field programs to rupture a buried drum and not know a breakage has occurred. While the Navy apparently believes that buried drums are somewhat rare in the JILF area, the finding of 41 drums in one test pit last year did not alleviate the DEP's concern that hazardous materials may yet be present at a few localities. It should be assumed that any drilling method has the potential to rupture buried drums.

   The DEP supports the need for intrusion exploration and sample collection. However, the Department expects that the Navy's contractor will be alert and sensitive to the possibility of rupturing a drum during the drilling program, and monitor for vapors with nearly continuous PID/FID readouts during the intrusions. Any significant instrument hit should be immediately reported, and a contingency plan must be activated for an emergency response action. The Navy provides some discussion regarding the potential to encounter buried drums in Section 3.2.3. See our comments on this section below.

   Response: The planning for the pre-design investigation considered previous investigation results. In particular, the MTADS survey was reviewed during the placement of the investigation locations. Areas of significant metallic anomalies were avoided if possible. The Navy will be prepared for the potential for encountering or rupturing buried drums during intrusive work at the JILF. Based on the various investigations conducted to date at the JILF, no drums of hazardous materials have been found. During the test pitting specifically targeted to locating drums, 40 drums in one location and 1 drum in another location were discovered. None of these drums contained hazardous materials. Previous surveys of the site, test pitting, and borings do not support the presence of a large number of drums at the JILF. Therefore, the subcontractor performing intrusive activities will be prepared to handle a few drums if encountered. Drilling work will need to be suspended at any location where more than 5 or 6 drums are present and the Navy will need to implement drum removal action.

   The text in the third paragraph on page 2-3 will be revised by including "of non-hazardous material" in between "Forty-one drums" and "were located".

The text in Section 3.2.3.2 will be revised to discuss procedures when drums may be encountered. Reference to the evaluation of the MTADS information will be added to Section 3.1.

3. **Comment:** The MEDEP would like to observe any of the proposed activities, especially the cone penetration testing, borings, cover sampling, and test pitting.

   Response: The Navy will provide the EPA and MEDEP with the schedule for field activities and any updates to the schedule. The Navy requests the EPA and MEDEP to contact the Shipyard (contact: Marty Raymond, phone 207-438-2536) at least five working days before arriving to observe any activities when possible. All persons on site will be required to have current 29 CFR 1910.120 training, and proper proof of current training certification needs to be brought with each person. All personnel will be under the direction of the TtNUS FOL during site visit activities.

Specific Comments

4. **Comment:** Executive Summary, p. ES-1, para 3

   The following sentence from page 2-3 needs to be added at the end of the paragraph:

   "OU3 FS is being finalized without addressing the separation of source control (OU3) and management of migration (OU6) for the JILF, as agreed to by USEPA and MEDEP."

   Response: The referenced text in ES-1 discusses the ROD and not the FS. The FS was finalized in November 2000. The paragraph will be revised to indicate that the ROD is currently draft final and is dated July 2001.

5. **Comment:** Executive Summary, p. ES-1, para 4, last sentence

   a) This last sentence summarizes the purpose of the entire document. Therefore, it would be helpful to write the items in this sentence as bulleted items. This makes each item stand out and improves the clarity of the document.

   Response: The last sentence will be provided as bulleted items.

   b) Change the phrase, "...the activities to make sure the data are collected appropriately..." to "...the procedures to make sure the data are collected appropriately..."

   Response: The text will be revised by adding "procedures and" before "activities".

6. **Comment:** Executive Summary, p. ES-2, 1st para

   The last sentence should be reformatted as follows for clarity:

   "As part of the pre-design investigation, the USACE will be using the information collected to support the design for the landfill cover."

Response: The USACE will be using the data collected as part of the pre-design investigation to support the design as part of the design activities and not as part of the pre-design investigation. Therefore, the sentence as provided is appropriate and will not be revised.

7. **Comment:** USEPA-NE QAPP Worksheet #2, pp. 1-6 - 1-7

Please clarify the strikeouts in this worksheet.

Response: The clarification of strikeouts is provided on page 1-3 as part of item 9 (which indicates that the information not required for this investigation is indicated by "strikethrough" font). This note will also be added to the bottom of each page of the table for clarity.

8. **Comment:** 2.1.3 Site History and Background, p. 2-3, para 1

"At that time, 332 tons of surrounding contaminated soil [at Site 11] were also excavated and disposed of offsite."

Please clarify that some contaminated soil still remains at Site 11.

Response: The sentence will be revised by adding "; however, residual contamination associated with Site 11 remains" to the end of the sentence.

9. **Comment:** 2.1.3 Site History and Background, p. 2-3, para 4

"The Navy prepared an OU3 FS Clarification Memorandum..."

Please indicate the date of this memorandum within the text and include this document in the References section.

Response: The reference for the clarification memorandum will be added to the text (Navy, November 2000) and the following added to the reference list:

Navy, November 2000. Operable Unit 3 (OU3) Feasibility Study (FS) Clarification Memorandum, Navy correspondence dated November 21, 2000 for Portsmouth Naval Shipyard, Kittery, Maine.

10. **Comment:** 2.2.1 Project Overview, p. 2-4

"The project planning phase determines the project quality objectives, i.e., the type, quantity, and quality of data needed to ensure project data can be used for their intended purpose."

The MEDEP understands that the Navy followed the USEPA guidance for Quality Assurance Project Plans. And as we stated earlier, following that guidance resulted in a very well written document. However, for the Portsmouth Naval Shipyard Superfund Site it has been typical for the Navy, EPA, MEDEP, and the community to participate in at least one Data Quality Objectives meeting to discuss the project quality objectives indicated above. Please explain why such a meeting was not proposed for the pre-design investigation.

Response: To date, the Navy has not generally held DQO meetings with the EPA, MEDEP, and RAB as part of work plan development. Regulator and RAB input on the project objectives and proposed investigation activities is typically provided via comments and comment response on the draft versions of the work plan. While the Navy believes that a technical meeting with the regulators and RAB may be necessary for some projects/investigation planning, the Navy believes that the pre-design investigation scope is sufficiently focused enough that a separate technical meeting is not required to review and discuss the DQOs. The Navy also notes that inclusion of a technical meeting can also extend the schedule for preparation of work plans. However, based on comments on the draft Pre-design Investigation QAPP, the Navy believes that a technical meeting is not required.

If at any time the MEDEP (or EPA or RAB) believe that a technical meetings is required to discuss DQOs, the Navy requests that the MEDEP inform the Navy at the earliest time possible so that the project schedule can be revised appropriately to include the meeting in the project schedule. Early notification helps to ensure schedule impacts are kept to a minimum, whereas late notification in the project can significantly impact the project schedule.

The end of the fourth paragraph (Page ES-1) will be revised by adding "Comments on the draft QAPP were received from the regulators and RAB and revisions to the DQOs and QAPP were made accordingly (Comments and responses are included in Appendix D)."

The following sentence will be added to the end of the second paragraph under Section 2.1.1 to clarify regulator and RAB input into the project planning for this project: "Regulatory and RAB participation in the project planning for this project is through review and comment on the draft QAPP. Comments received on the draft QAPP with the Navy's responses are provided in Appendix D of this QAPP."

Additionally, the following sentence will be added after the second sentence under Step 7 (Section 2.3.1) to clarify the regulatory and RAB input to the field investigation program: "Regulatory and RAB participation in the optimization of the field investigation plan for this project is through review and comment on the draft QAPP. Revisions to the investigation activities and numbers/locations of samples based on comments on the draft QAPP have been made as required. Comments received on the draft QAPP with the Navy's responses are provided in Appendix D of this QAPP. The responses indicate the revisions made based on the comments received."

Table 2-1 will be revised to indicate USEPA and MEDEP participation through comments on the draft QAPP and the note will be revised to indicate comments have been received on the draft QAPP from USEPA, MEDEP, and RAB, revisions made based on these comments, and that the response to comments are provided in Appendix D.

11. **Comment:** 2.2.2 Field Investigation Activities, p. 2-5, 3rd bullet

"Deep boring sampling and analysis of the soil and rock underlying the landfill..."

The "soil" under the landfill is actually sediment. Please correct this.

Response: The text will be revised by replacing "soil" with "underlying mud flats material/sediment".

12. Comment: 2.2.5 Analytical Tasks, p. 2-6

"Soil samples for geotechnical testing will be collected in the field..."

Please clarify if this task refers to soil within the waste, i.e., fill, or sediment beneath the waste.

Response: This refers to the sediment beneath the waste as well as the existing clay soil over the dredge spoil area within the running track. No samples will be taken from the waste layer itself. Cone penetration testing (CPT), standard penetration testing (SPT) at the boring locations, and test pitting will indirectly provide information on the shear strength, compressibility of the waste layer, and visual classification of the waste material. Because of the nature of the waste, rubble, metal, etc, no sampling for geotechnical testing is planned.

Note that the samples collected are outlined in the sampling tasks section (Section 2.2.3). The text is Section 2.2.5 will be edited as follows: "Sediment and surface soil samples for geotechnical testing will be transported from the site to the laboratory..."

The first two bullets in Section 2.2.3 will be modified to read the following:

- Deep borings to gather sediment samples for geotechnical laboratory testing and rock cores for field testing.
- Sampling of the existing clay cover surface soil for geotechnical laboratory testing.

13. Comment: 2.3.1 Project Quality Objectives, Step 2, p. 2-10

"Decisions will be made..." and "The decisions during the design will be made..."

It is important to state who will make the decisions. We suggest the following wording:

"The Navy and regulators, with input from the RAB, will make decisions during the design of the OU3 landfill cover system...These same parties will make decisions during the design concerning the following broad topics:"

Response: The following text will be added to the first paragraph in Section 2.3.1: "The design documents will be primary documents in accordance with the Federal Facility Agreement for PNS; and will be submitted for review and comment by USEPA, MEDEP, and the RAB. As lead agency under CERCLA, the Navy will make the decisions after considering comments raised during the review and comment process."

14. Comment: 2.3.1 Project Quality Objectives, Step 3, p. 2-11

a) Item iv): "...for evaluating the use of the existing dredge spoil clay layer..."

As discussed in Section 3 of the QAPP permeability testing is proposed for laboratory reworked hand auger "disturbed" samples of the clay cap but not for existing condition shelby tube "undisturbed" samples (per table 3-1). This approach is appropriate for determining the suitability of a clay borrow source. However at this site it may be worthwhile to measure existing condition clay cap permeability because it may give some indication of long term performance of the material. If existing condition permeability is to be determined then tests could be run on

the shelby tube samples. Additionally, for this same purpose, SDRI permeability tests could be performed.

Also, please clarify that the Navy is evaluating the use of the clay cover over the dredge spoils, not the spoils themselves.

Response: Please refer to the Navy's responses to EPA Specific Comment No. 4 dated June 26, 2001, relating to the surface soil samples.

b) Item v): Please clarify that the test "pits" are actually trenches.

Response: The term "test pits" has been used throughout the QAPP document as well as previous investigations that used similar techniques to refer to the investigative study of the nature of waste materials and horizontal extent of the landfill. The test pits will be longer than wider – however, the term "pits" was used to describe these activities. The rationale section (Section 3.1.3) in the document will describe the use of the term "test pits" in reference to trenches.

15. Comment: 2.3.1 Project Quality Objectives, Step 4 items ii and iii, p. 2-11

"This item is directly related to the information in the paragraph (i) above."

The phrase "this item" seems to be referring to some wording in the USEPA guidance document. Please clarify.

Response: The text will be rewritten as follows: "The spatial and temporal boundaries as described under paragraph (i) above will be adequate for decision to be made regarding cover system components."

16. Comment: 2.3.1 Project Quality Objectives, Step 7, p. 2-12

"The types of investigative activities and the number of samples has been planned with the OU3 Navy case team (consisting of Navy, TtNUS, and USACE personnel as listed in Table 2-1)."

See Comment 10.

Response: Please refer to the Navy's responses to MEDEP Comment No. 10, relating to project planning.

17. Comment: 3.1 Field Investigation Rationale, p. 3-1, bullet 8

"Wetlands functions and values assessment"

This is the only mention of this task in the document. This topic deserves to be a separate subsection in Section 3, where the Navy describes the area to be addressed and proposes how the task will be accomplished. For instance, why is this task being performed, what field data will be collected, how will it be performed, what party will perform the task, etc.

Response: Please refer to the Navy's response to EPA Comment No. 3 dated June 26, 2001 for text revisions related to wetlands functions and value assessment. The subcontractor who will perform the work (Woodlot Alternatives, Inc.) will be indicated in Section 2.2.9.

18. Comment: 3.1.3 Rationale for Test Pit Locations, p. 3-3, bullet at bottom of page

"...to verify the western extent of the dredge spoils and waste along Clark Cove shoreline."

Should this be "..along the historic Clark Cove shoreline."?

Response: The text in Section 3.1.3 will be revised by adding "the historic" before "Clark Cove shoreline".

19. Comment: 3.1.3 Rationale for Test Pit Locations, p. 3-4, last bullet

Test pit T-16 is labeled as T-15 in Fig. 3-2, i.e., there are two test pits labeled as T-15.

Response: The labeling for the eastern of the two test pits labeled "T-15" should have been labeled "T-16". This error will be corrected.

20. Comment: 3.1.3 Rationale for Test Pit Locations, p. 3-5, para 1

The QAPP states that the depth of excavation of test tips will be determined by the water table depth, meaning that pits will not be excavated below the water table. We repeat, below, our December 13, 2000 Comment 5 on the draft Drum Removal Report for Drum Investigation at PNS by Foster Wheeler, for which the Navy responded "comment noted".

"The Department still has concerns that drums could exist in a central portion of the landfill at depths greater than reached by the test pits. The depth of test pit excavations in a central N-S belt that overlies the deepest fill/overburden (as interpreted from OU3 FS cross sections) ranged from 5 to 10 feet. The water table was encountered in this depth range, and the test pit excavations were terminated just below the groundwater level. Most of this area is approximately 107 feet PNS datum, or 7 feet above mean high tide water. Therefore, the test pits bottomed at 97 to 102 feet PNS datum; again close to mean high tide. The above N-S belt can be drawn as wide as 300 feet without encountering a monitoring well. Using data from JW-12B, JW-13B and JW-17B as guides, a 10 to 15 foot depth interval below mean high tide is not documented as to the thickness of fill versus natural mudflats sediments. It appears that the bedrock surface is at least 10 feet below mean high tide (90 feet PNS datum) in the TP-4 location, where the buried drums were found at a maximum depth of approximately 6 feet. Therefore, some potential yet exists for undiscovered drums at depth, and the results of the test pitting investigation must be applied with caution."

MEDEP understands that to excavate test pits below the water table at the JILF would require more time and logistical planning. However, technically, it should be possible if excessive sloughing does not occur. We observed several pits being dug last year that did not incur significant cave-in. Has the Navy considered dewatering test pits upon accumulation of groundwater in the pits in order to excavate and observe materials to greater depths? Why not direct the pumped water into the nearest recently excavated test pit via a surface hose, prior to

backfilling that pit?

Response: The Navy expects waste to be encountered above the water table. Furthermore, the intent of the cap remedy is to minimize infiltration into the unsaturated waste material. The test pits will not be extended below the groundwater table for this investigation. The purpose of the test pits is to identify the horizontal extent of the landfill for the cap design; and not to provide additional data on the nature of the waste within the landfill or to provide additional information with respect to possible drums within the site.

The Navy will be prepared to go below the groundwater table if site conditions exist that warrant additional investigation below the groundwater table. This additional scope may result in a delay of the investigation and the mobilization of additional equipment or contractors. Tidally influenced groundwater associated with test pits T-9, T-10, T-12, and T-13 will be evaluated during excavation. These pits will be excavated as field activities permit during approximate periods of low tide.

Please refer to the Navy's response to MEDEP Comment No. 2 for further discussion.

21. Comment: 3.1.4 Rationale for Piezometer Locations, p. 3-6, 1st full para

"Groundwater and tide level data will be collected hourly for a month..."

Further in this report, the Navy states that transducers will be used to record the water level and tide fluctuation data at all piezometers to be installed. DEP is pleased to see this level of effort being proposed. We strongly recommend that the recording interval be reduced from hourly to every 15 minutes, to more accurately define tidal pulses through the landfill and mudflat deposit. Large databases are easily handled by today's computer programs.

Also, please explain why two additional piezometers for measuring pore-water pressure in the tidal mudflat/wetland are not planned for Jamaica Cove.

Response: Data will be collected at 15 minute intervals to help refine the peaks and troughs of groundwater levels.

Tidal mudflat pore-water pressure measurements are not considered necessary for the Jamaica Cove area because of the gradual slope that occurs at the shoreline. The steep drop-off in Clark Cove means it will be the critical area for slope stability. If excess pore water pressure within the tidal mudflat at low tide causes a low factor of safety for slope stability in Clark Cove, that data can be included in the slope stability analysis for Jamaica Cove.

22. Comment: 3.1.5 Rationale for CPT Locations, p. 3-6

"Spacing of CPT locations in the northern area adjacent to Jamaica Cove was modified to account for the proposed parking lot development."

Please explain the proposed parking lot development. Is this for the proposed Bachelor Enlistee Quarters?

Response: The BEQ parking facility has been eliminated from future design considerations in the Jamaica Cove area. The CPT locations have been selected for approximate equal spacing throughout the area adjacent to Jamaica Cove. The text throughout the document will be revised to reflect the elimination of the BEQ. In addition, the crane test pad will not be located on the landfill once the cover is in place. The text in the QAPP will be revised accordingly.

23. Comment: 3.2.1.2.3 Digital Terrain Model, p. 3-10, last paragraph

The first sentence of this paragraph is not a complete sentence. We assume that it relates to the preceding mention of DTM coordinates.

Response: The sentence referred to in the comment will be edited and combined with the second sentence to read: "Break lines, such as non-visible break lines, natural breaks or changes in grade of the terrain such as shelves, depressions, ditches, embankment, road centerlines and other slope break lines will be collected as three-dimensional line strings."

24. Comment: 3.2.1.3, Topographic Mapping, p. 3-12, 3rd para

"Monitoring wells within the survey boundary will be located and mapped."

It is unclear whether the monitoring wells (existing) will be resurveyed. If so, DEP recommends that their elevation datum be surveyed, as significant settlement may have occurred since their installation.

Response: The existing monitoring wells located within the boundary of the OU3 survey will be resurveyed. The top of casing will be the surveyed point.

25. Comment: 3.2.1.4 Pre-Work Survey

"...no yellow or magenta on PNS..."

Please explain this.

Response: The Shipyard has restrictions for use of yellow and magenta for marking and labeling as these colors are used to identify specific types of work at the Shipyard.

26. Comment: 3.2.1.6 Hydrographic Survey, p. 3-13

"Hydrographic data will be collected..."

Please state that the hydrographic data were already collected. Also indicate the date of the survey.

Response: The text referring to activities that have now been completed will be edited to the past-tense (throughout the QAPP). The hydrographic survey was conducted before Memorial Day because after Memorial Day many recreational boats are docked/anchored in Clark Cove and these boats would interfere with the hydrographic survey. The text will be revised

accordingly.

27. Comment: 3.2.2.1 Soil Borings, p. 3-14

"A total of 8 soil borings...will be drilled at locations shown on Figure 3-2..."

As discussed at the June 21 RAB meeting, the Navy should consider drilling sediment borings offshore of the landfill in Clarks Cove to determine the likelihood of slope failure resulting from unconsolidated sediment in the cove. It may be possible to delay a decision on borings in the cove pending the results of the bathymetric survey and the soil borings in the landfill.

Response: Information from the 1979 dredging project will be evaluated for Standard Penetration Testing, which was completed on the tidal mudflats underlying the area to be filled and under the area where dike construction was proposed. Additionally, the slope stability analysis will include a sensitivity analysis to determine whether the offshore sediment is a controlling factor at the Jamaica Cove shoreline. The Navy is not planning additional borings in Clark Cove.

28. Comment: 3.2.2.2.1, Disturbed Sampling, p. 3-17, end of page

"These samples will be analyzed for the geotechnical parameters as shown on Table 3-1."

The Department cannot find a heading of geotechnical parameters in this table. Was this information inadvertently left out?

Response: The table has a column for "Testing Method/SOP" which refers to the ASTM geotechnical method to be performed for the various samples. The testing descriptions are outlined and discussed in the text (see Section 4.2.1).

For reference, the ASTM methods are as follows:

ASTM D 2487	USCS soil classification
ASTM D 2216	Water Content
ASTM D 4318	Atterberg Limits (Liquid Limit, Plastic Limit, Plasticity Index)
ASTM D 422	Particle size distribution
ASTM D 854	Specific gravity of soil solids
ASTM D 2850	Unconsolidated-Undrained shear strength
ASTM D 1557	Compaction characteristics of soil, modified effort
ASTM D 5084	Hydraulic Conductivity
ASTM D 2937	Soil Density
ASTM D 2488	Field classification of soil
ASTM D 2435	Time and load deformation characteristics of soil
ASTM D 4767	Consolidated-Undrained shear strength
ASTM D 6032	Rock Quality Density (RQD)

29. Comment: 3.2.3 Test Pits, p. 3-19

"The backhoe operator...will temporarily suspend operation if any of the following conditions are encountered:

1. Groundwater or non-aqueous phase liquid
2. Drums or other potential waste containers...

...Field decisions between the TtNUS FOL and the Navy may also be required during excavation of the test pits."

As we stated in our general comment 2, there is no discussion of what will be done (beyond temporarily suspending operations) should drums be encountered or should the backhoe inadvertently rupture a full drum. The decision as to what to do in such a case should not be left for a "field decision". The Navy must have some sort of response plan in place. Please discuss any such plans.

Response: Please refer to the Navy's response to MEDEP Comment No. 2 regarding the issue of drums and related procedures.

30. Comment: 3.2.3.1 Logging Procedures, p. 3-19

"At a minimum, the test pit log will include the following information..."

This section should also reference SOP SA-6.3, Field Documentation.

Response: The reference to SOP SA-6.3 will be added to the text. Additionally, test pit logs will note items such as any odors, staining, or other evidence of potential environmental contamination encountered (as suggested in SAPL Comment No. 33 dated July 6, 2001).

31. Comment: 3.2.3.2 Sampling Procedures, p. 3-20

"If an intact or a ruptured drum is encountered, then the TtNUS FOL will contact Navy personnel."

Again, there is not enough information regarding the procedures the Navy will take if a ruptured drum is encountered. See General Comment 2 and Comment 29.

Response: Please refer to the Navy's response to MEDEP Comment No. 2 regarding the issue of drums and related procedures.

32. Comment: Table 3-1, p. 3-33

Table 3-1 notes that some of the ASTM D2487 soil classification will be by "field method" only. In general, this soil classification method uses laboratory tests including grain size, liquid limit and plasticity index. The ASTM D2488 procedure is for identifying soils based on visual examination and manual tests. Is the D2487 "field method" the same as the D2488 visual/manual? This is a fairly minor issue but clarification would be helpful. Method summaries are attached.

Response: The table will be edited to refer to ASTM D2488 in the cells that have the "(field test only)".

33. Comment: 5.1 Data Acquisition Requirements, p. 5-1, last para

"Add limitations of other documents used by the USCE..."

This sentence is confusing. Is this language inadvertently copied from the EPA guidance document?

Response: The sentence was inadvertently included in the text and will be deleted.

34. Comment: 5.2.6.1, Geographical Information System..., p.5-4, 2nd para

"The contours will be generated using AutoCADD 2000."

Using computerized contouring software usually is a good first cut at deciphering the elevation data. However, automated contouring seldom generates the best contouring interpretations, because in most settings groundwater flow does not follow simple linear patterns. We strongly recommend that a hydrogeologist familiar with the subsurface of the site closely review the CADD output and make the appropriate manual adjustments.

Response: The text will be edited to read: "The contours will be generated using AutoCADD 2000 with the review of an experienced hydrogeolgist."

35. Comment: 5.2.6.2, Subcontractors Deliverables, p. 5-4

"However, landfill gas survey and CPT data will not be included in GIS."

The MEDEP would like these data included. All data collection points should be entered into GIS. The landfill gas survey and CPT information are considered data worthy of inclusion.

Response: The GIS database will include the landfill gas survey and CPT locations obtained from the field investigation. Section 5.2.6.2 will be edited to reflect the updated deliverables from the subcontractors.

RESPONSES TO SAPL COMMENTS DATED JULY 6, 2001 ON DRAFT OU3 PRE-DESIGN INVESTIGATION QAPP PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

General Comment: This QAPP is much easier to follow and understand than the last QAPP (for the Site 10 investigation) SAPL reviewed. While adhering to the US Environmental Protection Agency's guidance for writing QAPPs results in the reader having to flip back and forth to find related procedure-specific information in different sections, overall this QAPP is an improvement over some previous documents SAPL has commented on. Given the discussions at recent technical and Restoration Advisory Board (RAB) meetings, SAPL appreciates the Navy's efforts to make sure the Executive Summary, in particular, can be understood by the community.

Response: Comment noted.

1. **Comment:** Page ES-1, EXECUTIVE SUMMARY

As noted in the General Comment above, the Executive Summary is easier for the community to understand than summaries in a number of previous documents. One suggestion for further improvement is to delete most the acronyms (such as Navy, EFANE, CLEAN, CTO, and IRP) in the first paragraph. This paragraph is repeated at the beginning of Section 1.0, so the acronyms would be defined within the QAPP, just not in the opening of the Executive Summary.

Response: The Navy believes that inclusion of the acronyms is important for people who are familiar with the activities at PNS who rely on the Executive Summary to understand the report (such as many of the RAB members). While the Navy understands that some people are confused by acronyms, others may be more familiar with the acronym rather than the definition. Although there are various acronyms in the Executive Summary, few acronyms are repeated throughout the summary. Because this concern has not been raised before, the Navy proposes to leave the acronyms in the Executive Summary for the Pre-design Investigation QAPP and discuss the use of acronyms in the Executive Summary further with the RAB members to determine the preference of the RAB.

2. **Comment:** Page ES-1, EXECUTIVE SUMMARY

The second paragraph should be amended to state that no environmental contamination was apparent at Site 9, but that contaminated soil remains at Site 11. We concur with the Maine Department of Environmental Protection's (MEDEP) comment number 4 (dated July 3, 2001) that a statement regarding the Feasibility Study for Operable Unit 3 (OU3) should be added to the third paragraph.

Response: The following sentence will be added to the end of the second paragraph on ES-1 for clarity: "No residual contamination associated with Site 9 remains, whereas, contamination associated with Site 11 (in soil and groundwater) remains." Please see the Navy's response to MEDEP Comment No. 4 dated July 3, 2001 related to the FS.

3. **Comment:** Page ES-2, EXECUTIVE SUMMARY

The first sentence of the second bullet is a bit confusing and should be revised.. As currently written, it appears that the topography of the water's surface will be mapped, rather than the topography of the intertidal and subtidal substrate offshore.

Response: The hydrographic survey is used to provide data that is used to develop topographic mapping of the floor of the offshore areas at Clark Cove and Jamaica Cove. The bullet will be edited to clarify this activity.

4. **Comment:** Page 1-3, USEPA-NE Worksheet #2

The US Army Corps of Engineers should be listed as a data user in item number 8 on the form. The first sentence under item number 9 is confusing. It reads: "All of the elements related to sample collection, analyses, and analytical related activities have been excluded." The statement is at odds with text elsewhere in the QAPP regarding the collection of samples to determine geotechnical properties. The sentence must be revised to clarify that samples will not be collected and analyzed for chemicals of concern and related chemical aspects.

Response: The USACE will use the data as a contractor for the Navy; therefore, the worksheet text is appropriate under number 8. The text under Section 1.2.2 will be clarified by adding "as a contractor to the Navy after "(USACE)".

Geotechnical testing and not analytical (chemical) testing will be conducted. The first sentence under number 9 will be revised to read "All of the elements related to sample collection, analysis, and analytical data for chemical analytical related activities have been excluded as shown in the worksheet."

5. **Comment:** Pages 1-5 - 1-7, USEPA-NE Worksheet #2

Given that samples will be collected for geotechnical properties analysis, it is not clear why entries related to sampling and analysis have been struck through. Please clarify.

Response: The requirements for geotechnical testing differ from chemical analytical activities and requirements. For example, because chemical analysis is not being conducted, sample preservation is not required. Therefore, these have been struck through.

6. **Comment:** Page 2-2, Section 2.1.2 Site Location and Description

Does "ambulatory services" in the last sentence mean a health clinic? If so, please revise.

Response: Suggested response follows: The text will be clarified by including "(health clinic)" after "ambulatory service".

7. **Comment:** Page 2-2, Section 2.1.3 Site History and Background

The industrial wastes that were reportedly disposed at Site 8 should be listed. The wastes

reported included incinerator ash, plating sludges, asbestos, volatile organic compounds, empty acetylene and chlorine gas cylinders, dredge spoils, waste paints and solvents, sandblast grit, reinforcement bars, and chainlink fence.

Response: The information provided is a summary of the history of the sites. As indicated in the last paragraph of Section 2.1.3, Section 1.0 of the Feasibility Study for Operable Unit 3 provides additional detail. No changes to the text in the QAPP with respect to this comment will be made.

8. **Comment:** Page 2-3, Section 2.1.3 Site History and Background

A statement should be added to the end of the first paragraph in page 2-3 that contaminated soil remains at Site 11. The third paragraph contains the statement that test pits were not included in the capped area of the landfill. The "capped" area should be defined in the text and on the appropriate figure (likely Figure 2-3 on page 2-21). The date of the OU3 FS Clarification Memorandum should be added to the fourth paragraph, and the complete citation added to the References section.

Response: Please refer to the Navy's response to MEDEP Comment No. 8 dated July 3, 2001 for text revisions related to Site 11. The text will be revised by replacing "capped area of the landfill" with "clay covered area of the landfill (within the running track)" to be consistent with the description of Site 8 provided on page 2-2. Figure 2-3 shows the running track. Please refer to the Navy's response to MEDEP Comment No. 9 dated July 3, 2001 for text revisions related to the Clarification Memorandum.

9. **Comment:** Page 2-4, Section 2.2.1 Project Overview

SAPL shares MEDEP's concern (MEDEP comment number 10, dated 7/3/01) that the USEPA, MEDEP, and the RAB should participate in at least one of the Data Quality Objectives meetings with the Navy in order to discuss project quality objectives.

Response: Please refer to the Navy's response to MEDEP Comment No. 10 dated July 3, 2001 related to DQO meetings and regulatory and RAB participation. If at any time SAPL believes that a technical meetings is required to discuss DQOs, the Navy requests that SAPL inform the Navy at the earliest time possible so that the project schedule can be revised appropriately to include the meeting in the project schedule. Early notification helps to ensure schedule impacts are kept to a minimum, whereas late notification in the project can significantly impact the project schedule.

10. **Comment:** Page 2-5, Section 2.2.2 Field Investigation Activities

This section lists in bullet form the various activities that will be conducted as part of the pre-design investigation. The OU3 Record of Decision (ROD) states on page 1-3 that the feasibility of consolidation of portions of the landfill will be re-evaluated, and that the evaluation will be conducted as part of the pre-design investigation and cap design for OU3. How do the activities listed on page 2-5 of the QAPP relate to the re-evaluation of the landfill for consolidation? Since the ROD is explicit in identifying the re-evaluation activity, the QAPP should also explicitly identify which tasks will address the landfill consolidation evaluation.

Response: Please refer to the Navy's response to EPA Comment No. 2 dated June 26, 2001 for discussion regarding consolidation and associated text revisions.

11. **Comment:** Page 2-8, Section 2.2.9 Records and Reports

The report of the results of the investigation must also document any major changes in scope from the final approved QAPP.

Response: Any significant changes to the scope of investigation will be documented in the Data Package for the results of the pre-design investigation activities. This is a standard practice for the Navy. The following sentence will be added to the end of Section 2.2.9 to clarify that major changes in scope will be discussed in the data package: "Deviations from the final QAPP will also be discussed in the data package."

12. **Comment:** Page 2-10, Section 2.3.1 Project Quality Objectives

The paragraph under the Step 2 heading (State the Decision to be Made) should spell out who will be involved in making decisions. In addition, how do the wetlands assessment and the evaluation of landfill consolidation (see comment number 10, above) fit in the topics listed for Step 2? Perhaps they need separate headings.

Response: Please refer to the Navy's response to MEDEP Comment Nos. 10 and 13 dated July 3, 2001, related to the decision making. Please refer to the Navy's response to EPA Comment Nos. 2 and 3 dated June 26, 2001 related to landfill consolidation and the wetlands assessment, respectively (and associated text revisions).

Evaluation of landfill consolidation (how much will the underlying sediment and the waste layers settle under the weight of the cap) will determine the design slope and geometry. Initial design slopes must allow for adequate slope after settlement (consolidation). Similarly, the geometry may be tailored to reduce loading in areas of higher estimated settlement. This can be done by locating the peaks and valleys to minimize settlement, for example the peaks would be located in areas of lower settlement potential.

13. **Comment:** Pages 2-10 & 2-11, Section 2.3.1 Project Quality Objectives

Information regarding the wetlands assessment and the evaluation of landfill consolidation must be added to the characteristics listed under Step 3 - Identify Information Needed to Make a Decision. The last sentence in item i) states that the slope of the cover surface and the drainage layer will be determined based on the extent of settlement that can be expected. The investigation includes the collection and laboratory analysis of geotechnical samples from the tidal mudflats underlying the landfill. The data generated will be used to evaluate the consolidation and strength of the deposit. How will the settlement of the landfill material itself be determined? In addition, as was mentioned at the June 21, 2001 RAB meeting, the geotechnical characteristics of materials immediately offshore of the landfill that have not been consolidated by emplacement of waste material should also be determined. Item v) on page 2-11 states that the extent of the landfill will be determined with test pit data. The test pits, as described in the QAPP, will only extend to the water table. Given the nature of waste disposal (waste being dumped out onto a tidal mudflat) it is likely that a significant amount of waste

occurs below the water table. If waste does not extend above the water table at a test pit location, the actual extent and content of the landfill will remain undetected. This limitation should be noted in appropriate passages of the QAPP.

Response: Please refer to the Navy's responses to EPA Comment Nos. 2 and 3 dated June 26, 2001 related to landfill consolidation and wetlands assessment, respectively. Settlement of the waste material will be estimated by traditional geotechnical methods during the design of the cap system. The consolidation coefficient will be estimated based on the results of cone penetration testing and standard penetration tests.

As to test pitting, please refer to the Navy's response to MEDEP Comment No. 20 dated July 3, 2001.

14. Comment: Page 2-11, Section 2.3.1 Project Quality Objectives

The meaning of the sentence in item ii) and of the first sentence in item iii) under Step 4 - Establish Spatial and Temporal Boundaries, is unclear. Both sentences must be revised.

Response: Please refer to the text clarification provided in the Navy's response to MEDEP Comment No. 15 dated July 3, 2001.

15. Comment: Page 3-1, Section 3.1 FIELD INVESTIGATION RATIONALE

The second bullet identifies geotechnical sampling and CPT for landfill/waste thickness and geotechnical characteristics. How and where will geotechnical samples of the landfill/waste materials be collected and how will they be analyzed? The only geotechnical sampling and analysis described in the QAPP is of surface materials in the dredge spoil disposal area and of the tidal mudflat deposit underlying the landfill.

Response: The second bullet will be revised : "Geotechnical testing, Standard Penetration Tests, and CPT for..."

Geotechnical sampling in waste will be split spoon samples collected and visually observed in the field during drilling. No laboratory testing will be performed on these samples.

The third paragraph after the bullets on page 3-1 indicates deep boring and surface soil geotechnical sampling. Section 3.1.2 provides rationale for geotechnical sampling locations and Section 3.2.2 provides sampling information.

16. Comment: Page 3-1, Section 3.1 FIELD INVESTIGATION RATIONALE

The eighth bullet lists wetland functions and values assessment, yet this task is not described further. Other tasks, such as soil and rock boring and test pitting, are described in detail in task-specific sections in Chapter 3. Sections devoted to the wetlands functions and values assessment task, that describe why, where, and how, etc., must be added to this chapter as well.

Response: Please refer to the Navy's response to EPA Comment No. 3 dated June 26, 2001 for text revisions related to the functions and value assessment.

17. **Comment:** Page 3-1, Section 3.1 FIELD INVESTIGATION RATIONALE

The installation of piezometers is described as the first investigation activity to be performed. However, at the June 21st RAB meeting, the Navy stated that the hydrographic survey had already been completed. The text should be updated.

Response: Please refer to the Navy's response to MEDEP Comment No. 26 dated July 3, 2001 for text revisions related to the hydrographic survey.

Note that the installation of the piezometers would be the first "investigative" activity. Surveying (land and hydro) will be started prior to the field investigation. Text throughout various sections of the QAPP will be edited to clarify the actual sequencing of events.

18. **Comment:** Page 3-3, Section 3.1.3 Rationale for Test Pit Locations

The bullet at the bottom of the page states that test pits T-1 and T-2 are planned along the Clark Cove shore. However, Figure 3-2 shows these test pits to be located well inland. Did the Navy mean the "historic" shore of Clark Cove? Please clarify.

Response: The test pits are intended to be along the historic shoreline. Please refer to the Navy's response to MEDEP Comment No. 18 dated July 3, 2001 for the text revisions.

19. **Comment:** Page 3-4, Section 3.1.3 Rationale for Test Pit Locations

The third bullet mentions a road. If this road has a name, it should be added to the text and to the appropriate figure(s).

Response: The road (Ayeres Circle) will be referred to in this section. The road name is shown on Figure 2-3.

20. **Comment:** Page 3-5, Section 3.1.3 Rationale for Test Pit Locations

SAPL concurs with the concerns expressed in MEDEP's comment number 21 (dated 7/3/01) regarding limiting the depth of test pitting to the water table depth, particularly given the concern for buried drums in the landfill. Has the Navy considered extending the test pits to below the water table?

Response: Please refer to the Navy's response to MEDEP Comment No. 20 dated July 3, 2001 related to the test pit depths.

21. **Comment:** Page 3-5, Section 3.1.4 Rationale for Piezometer Locations

What is the rationale for installing the four deeper piezometers in close proximity to the four

shallow piezometers closest to Clark Cove? Are a couple of deeper piezometers needed along the shore of Jamaica Cove?

Response: Please refer to the Navy's response to MEDEP Comment No. 21 dated July 3, 2001.

22. Comment: Page 3-6, Section 3.1.4 Rationale for Piezometer Locations

SAPL concurs with the MEDEP that water level measurements should be collected every quarter hour, rather than hourly.

Response: Please refer to the Navy's response to MEDEP Comment No. 21 dated July 3, 2001 related to water level measurements.

23. Comment: Page 3-6, Section 3.1.5 Rationale for CPT Locations

What and where is the proposed parking lot mentioned near the end of the section? Additional information is needed.

Response: Please refer to the Navy's response to MEDEP Comment No. 22 related to the Rationale for CPT Locations.

24. Comment: Page 3-6, Section 3.1.6 Rationale for LGS Locations

The landfill gas survey (LGS) will measure methane occurrences. Are there other gases to be concerned with at a landfill such as the Jamaica Island landfill? As was discussed at the June 21st RAB meeting, gas survey locations should be added at buildings adjacent to the landfill to ensure gas is not migrating to, accumulating in, or otherwise posing a hazard to nearby buildings and occupants.

Response: Only active generation of gases (i.e., methane generation) is a concern for the landfill cover design; therefore, only methane is a concern for the LGS survey. Please also refer to the Navy's response to EPA Comment No. 6 dated June 26, 2001.

25. Comment: Page 3-7 Section 3.2.1 Surveying

The second sentence in the first paragraph should be revised to reflect that the hydrographic surveying has already occurred. This comment also applies to Section 3.2.1.6 on page 3-13.

Response: Please see the Navy's response to MEDEP Comment No. 26 dated July 3, 2001 for text revisions related to the hydrographic survey.

26. Comment: Page 3-10, Section 3.2.1.2.3 Digital Terrain Model - Ground Survey Points

What is the Digital Terrain Model? What will it be used for? What is the triangulated irregular network mentioned on the next page? Also, the first sentence in the last paragraph on page 3-

10 is incomplete and must be revised.

Response: A digital terrain model is a computer generated topographic surface that is derived from individual surveyed ground coordinates (position and elevation). A triangulated irregular network is the algorithm used to generate the digital terrain model.

Please refer to Navy's response to MEDEP Comment No. 23 dated July 3, 2001 for text revisions to the first sentence of the last paragraph on page 3-10.

27. Comment: Page 3-13, Section 3.2.1.6 Hydrographic Survey

The second paragraph states that X, Y, and Z positions will be collected continuously at 10 foot intervals. This is confusing. If data is collected continuously, why is there an interval specified? Please clarify.

Response: The hydrographic survey data was collected using methods that provided continuous (or very close spacing) data. However, the topographic mapping will use data from approximately 10-foot spacing from this field data set.

28. Comment: Page 3-14, Section 3.2.2.1 Soil Borings

SAPL concurs with MEDEP (comment number 28, dated 7/3/01) that borings should be completed in the unconsolidated sediments immediately offshore in Clark's Cove to better assess the likelihood of slope failure.

Response: Please refer to the Navy's response to MEDEP Comment No. 27 dated July 3, 2001 related to soil borings in the unconsolidated sediments.

29. Comment: Page 3-15, Section 3.2.2.1.2 Undisturbed Samples (Shelby Tubes)

The meaning of the last sentence in the first paragraph in the section is unclear. The sentence should be rewritten.

Response: The last sentence will be revised.

30. Comment: Pages 3-17 & 3-18, Section 3.2.2.2.1 Disturbed Samples

The text states that the samples will be analyzed for the geotechnical parameters listed on Table 3-1. That information appears to be missing from the table.

Response: Please refer to the Navy's response to MEDEP Comment No. 28 dated July 3, 2001 related to Table 3-1.

31. Comment: Page 3-18, Section 3.2.2.2.2 Undisturbed Samples

How will the Shelby tube be driven to collect samples of the soil cover?

Response: The text will be revised by adding "(using the excavator bucket or drill rig)" after "A Shelby Tube will be driven".

32. Comment: Page 3-19, Section 3.2.3 Test Pits

SAPL concurs with MEDEP's comment number 31 (dated 7/3/01) that additional information about procedures and a response plan is needed to deal with the discovery and/or puncturing of a drum. This comment also applies to other similar passages in the QAPP, such as in Section 3.2.3.2 on page 3-20. It is also not clear in the QAPP how the Navy will detect or determine if a drum has been encountered during soil boring, piezomenter installation, or cone penetration testing activities. Additional information is needed in other applicable sections of the QAPP to address this concern.

Response: The planning for the pre-design investigation considered previous investigation results. In particular, the MTADS survey was reviewed during the placement of the investigation locations. Areas of significant metallic anomalies were avoided if possible. No other activities are planned to detect or determine if a drum has been encountered during soil boring, piezometer installation, or cone penetration testing activities. Please refer to the Navy's response to MEDEP Comment No. 2 dated July 3, 2001 related to drums.

33. Comment: Page 3-19, Section 3.2.3.1 Logging Procedures

The SOP for logging should be cited in this section and included in Appendix B. In addition, the test pit logs should also note any odors, staining, or other evidence of potential environmental contamination encountered.

Response: Please refer to the Navy's response to MEDEP Comment No. 30 dated July 3, 2001 for information regarding test pit logging. The SOP is already in Appendix B (SOP SA-6.3).

34. Comment: Page 3-22, Section 3.2.5 Cone Penetration Testing

The third paragraph states that two of the CPT will be located close to traditional soil borings in order to correlate the CPT data with direct observations in borings. How close will the CPT locations be to the borings? Given the presumed heterogenity of the landfill material, how closely can the CPT data be correlated with material observed in the borings? Has the Navy considered continuous split-spoon sampling in the borings to be used for CPT correlation? Neither of the two traditional borings proposed (DB-1 or DB-7) are located in the "general fill" area of the landfill. How will the CPT data from the general fill area be correlated or calibrated?

Response: Map shows the general location of the CPT and boring locations. Three additional correlation points (with DB-2, DB-6, and DB-8) will be made with the CPT locations. These additional correlation locations will be within the general fill areas. The correlation data will be used when determining the soil behavior type in the characterization of the CPT data. Continuous split-spoon sampling will be performed for each deep boring; with a minimum of 2-feet of recovery.

35. Comment: Page 3-25, Section 3.2.7.3 Field Equipment Calibration and Maintenance

The first paragraph is confusing. If a PID is used in the field, why isn't it considered field equipment and its calibration discussed in this section along with the calibration of the infra-red landfill gas analyzer? The reader is referred to Chapter 4.0 for field analytical equipment information. But Chapter 4.0 also addresses water level indicators and pressure transducers, which are described in Section 3.2.7.3 as the only field equipment to be used. Section 3.2.7.3 must be revised. Also, information regarding GPS instrumentation should also be presented.

Response: To clarify the calibration and maintenance discussions, all maintenance and calibration sections will be incorporated into Section 4.1. As a result of this modification, previous Tables 3-3 and 3-4 will become Tables 4-1 and 4-2, respectively. Furthermore, previous Tables 4-1 and 4-2 will become Tables 4-3 and 4-4. Appropriate edits to the Section 1 worksheet and other text sections and tables will be made throughout the QAPP. The GPS or other surveying equipment used during the survey operations is not discussed or covered under this equipment calibration and maintenance section. The surveyor provides industry standard checks and calibration on equipment used under the subcontract.

36. Comment: Page 3-26, Section 3.2.7.5 Management of IDW

What happens to the investigation-derived waste (IDW) soil and water after it is drummed and transported to a central location designated by the Shipyard?

Response: The text will be edited to reflect that any IDW soils or water will be sent to the Shipyard's hazardous waste transfer facility for sampling and analysis. The waste will be properly disposed of based on the results of this analysis. Note that this section is now 3.2.8.4.

37. Comment: Page 3-33, Table 3-1

The information about the Shelby tube sample quantity and container size appear to be in conflict. The sample size is listed as greater than 34 inches recovered from the Shelby tube, but the container size lists the Shelby tube as being only 30 inches long per interval. Please clarify.

Response: The information will be corrected on Table 3-1 to read: "24 inches recovery" instead of "34 inches recovery".

38. Comment: Page 4-1, Section 4.1 FIELD TESTING METHOD REQUIREMENTS

The SOP for the pressure transducers should be cited.

Response: SOP GH-2.3 was listed in Table 3-2 and will be referenced within Section 4.1. This reference will also be added to Appendix B.

39. Comment: Page 4-8, Section 4.3.1 Field Quality Control

How often will the periodic checks of the water level data occur?

Response: Water levels will be checked randomly during the other field activities. Data loggers will be checked to ensure the proper operation and collection of data.

40. **Comment:** Page 5-4, Section 5.2.6.1 Geographical Information System (GIS) and Computer Aided Drafting/Design.

SAPL concurs with the MEDEP's comment number 37 (dated 7/3/01) regarding the automatic contouring of water-level measurements. A hydrogeologist familiar with the site should closely review the computer-generated contouring and make manual adjustments as appropriate. SAPL also agrees with the MEDEP that the landfill gas survey and CPT data (Section 5.2.6.2) should be included in the GIS.

Response: A MEDEP Comment No. 37 is not included in the MEDEP's comments dated July 3, 2001. Please see the Navy's responses to MEDEP Comments No. 34 and 35 dated July 3 relating to GIS.

41. **Comment:** Page 7-2, Section 7.1.2 Assessment Findings and Corrective Action Responses

In addition to consulting the USEPA and MEDEP about any scope changes, the text should also state that the agencies will concur with any major scope changes. In addition, any major changes from the final approved QAPP must be documented in the investigation report.

Response: Please refer to the Navy's response to SAPL Comment No. 11 related to deviations from the final QAPP.

42. **Comment:** Page R-1, REFERENCES

The complete citation for the OU3 FS must be provided.

Response: The complete citation will be provided (TtNUS, November 2000. Feasibility Study (FS) Report for Operable Unit 3, Portsmouth Naval Shipyard, Kittery, Maine, Tetra Tech NUS, Inc., King of Prussia, PA). In addition, the other references will be reviewed to ensure the updated reference is provided (e.g., OU3 ROD and MBII removal action report).