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FINAL SAMPLING AND ANALYSIS PLAN FOR OPERABLE UNIT 8 ( OU 8) REMEDIAL  
INVESTIGATION NSY PORTSMOUTH ME  
05/01/2015  
TETRA TECH INC

**Final  
Sampling and Analysis Plan  
for  
Operable Unit 8  
Remedial Investigation**

**Portsmouth Naval Shipyard  
Kittery, Maine**



**Naval Facilities Engineering Command  
Mid-Atlantic**

**Contract Number N62470-08-D-1001  
Contract Task Order WE32**

May 2015

**SAP WORKSHEET #1A: TITLE AND APPROVAL PAGE**

**FINAL  
SAMPLING AND ANALYSIS PLAN  
MAY 2015**

**OPERABLE UNIT 8 REMEDIAL INVESTIGATION  
PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE**

**Prepared for:  
Department of the Navy  
Naval Facilities Engineering Command  
Mid-Atlantic Division  
9742 Maryland Avenue  
Norfolk, Virginia 23511-3095**

**Prepared by:  
Tetra Tech, Inc.  
234 Mall Boulevard, Suite 260  
King of Prussia, Pennsylvania 19046-1433  
(610) 491-9688**

**Prepared under:  
Contract Number N62470-08-D-1001  
Contract Task Order WE32**

Review Signature:

  
\_\_\_\_\_  
Megan B. Ved  
Project Manager  
Tetra Tech, Inc.

4/30/2015

  
\_\_\_\_\_  
Tom Johnston, Ph.D.  
QA Manager  
Tetra Tech, Inc.

4-30-15

**SAP WORKSHEET #1B: REGULATORY TITLE AND APPROVAL PAGE**

**FINAL  
SAMPLING AND ANALYSIS PLAN  
MAY 2015**

**OPERABLE UNIT 8 REMEDIAL INVESTIGATION  
PORTSMOUTH NAVAL SHIPYARD  
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**Prepared for:  
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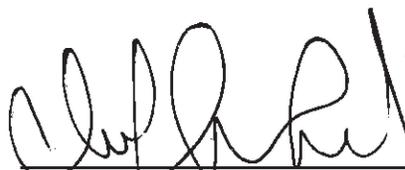
**Prepared by:  
Tetra Tech, Inc.  
234 Mall Boulevard, Suite 260  
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(610) 491-9688**

**Prepared under:  
Contract Number N62470-08-D-1001  
Contract Task Order WE32**

Review Signature:



Matthew Audet  
Remedial Project Manager  
US EPA Region 1



Iver McLeod  
Remedial Project Manager  
MEDEP

**SAP WORKSHEET #1C – DRAFT TITLE AND APPROVAL PAGE**

**Draft  
SAMPLING AND ANALYSIS PLAN  
APRIL 2014**

**OPERABLE UNIT 8 REMEDIAL INVESTIGATION  
PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE**

**Prepared for:  
Department of the Navy  
Naval Facilities Engineering Command  
Mid-Atlantic Division  
9742 Maryland Avenue  
Norfolk, Virginia 23511-3095**

**Prepared by:  
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King of Prussia, Pennsylvania 19406**

**Prepared under:  
Contract Number N62470-08-D-1001  
Contract Task Order WE32**

**APRIL 2014**

**Approval Signatures :**

**NIXON.MONIQUE**  
**E.L.1272150628**

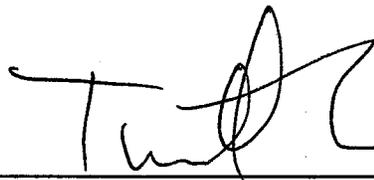
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NIXON.MONIQUE.L1272150628  
DN: c=US, o=U.S. Government, ou=DoD,  
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**Monique Nixon  
NAVFAC QA Officer  
NAVFAC LANT**

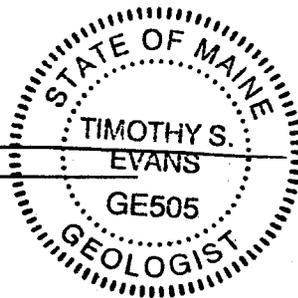
**SAP Worksheet #1D – Maine Certified Geologist Approval Page**  
(UFP-QAPP Manual Section 2.1)

**CERTIFIED MAINE GEOLOGIST  
CERTIFICATION**

By affixing my seal to this report, I certify that the geologic data and interpretations stated in this *Sampling and Analysis Plan for Operable Unit 8 Remedial Investigation, Portsmouth Naval Shipyard, Kittery, Maine*, prepared by Tetra Tech, Inc., and dated May 2015, are true and accurate to the best of my knowledge. I further certify that I am certified to practice geology in the State of Maine and that it is within my professional expertise to verify the correctness of this information.



\_\_\_\_\_  
Timothy S. Evans, C.G.  
Registration Number GE505



5/1/15

\_\_\_\_\_  
Date

## EXECUTIVE SUMMARY

This Operable Unit (OU) 8 Remedial Investigation (RI) Sampling and Analysis Plan (SAP) provides the basis and methods for conducting an RI for OU8 at Portsmouth Naval Shipyard (PNS), Kittery, Maine. Information necessary to complete the RI Report and Feasibility Study for OU8 will be collected during this investigation. This SAP follows the format of the Uniform Federal Policy (UFP) for Quality Assurance Project Plans (QAPPs) (USEPA, March 2005), and was prepared to address a one-time investigation at OU8.

Tetra Tech prepared this QAPP for the United States Department of Navy, Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract Number N62470-08-D-1001, Contract Task Order (CTO) WE32. This investigation is being conducted as part of the RI phase for OU8 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The information collected during this investigation combined with information from the Site Screening Investigation (SSI) is intended to support an evaluation of the nature and extent of contamination, as well as potential current and future risks to human health and the environment.

OU8 is located in the Controlled Industrial Area (CIA), in the western portion of PNS and consists of Site 31 – Former West Timber Basin. Based on the results of past investigations and the conceptual site model (CSM), unacceptable risks to current and/or hypothetical future receptors from exposure to PAHs and metals in soil and groundwater may exist at OU8. Additional soil and groundwater samples are needed to evaluate the nature and extent of contamination and to evaluate risks to human health and the environment. A stratified soil sampling design was selected to determine the number of soil samples required to characterize soil contaminant concentrations at OU8. One surface soil and two subsurface soil samples will be collected from each of the 18 proposed soil sample locations. The soil locations were selected by dividing the sampling area into 100-foot by 100-foot grid cells, and then selecting one location in each cell with consideration of site features and utility locations. Two new monitoring wells will be installed, and groundwater samples will be collected from the five existing monitoring wells and two additional monitoring wells. All samples will be analyzed for PAHs and TAL metals. In addition, soil and groundwater samples will be analyzed for Extractable Petroleum Hydrocarbons (EPH) as requested by Maine Department of Environmental Protection (MEDEP) to provide additional data on petroleum hydrocarbon concentrations at the site. A tidal study will be conducted to further characterize groundwater flow and tidal influence at OU8.

At the conclusion of the investigation, an RI Report of the results will be prepared.

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**Appendices**

Appendix A	Supporting Information
Appendix B	Field Documentation Forms
Appendix C	Field Standard Operating Procedures
Appendix D	Laboratory Certification
Appendix E	Responses to Comments on the Draft SAP

## ACRONYMS AND ABBREVIATIONS

A	Analytical
bgs	below ground surface
CA	Corrective Action
CCC	Calibration Check Compounds
CCV	Continuing Calibration Verification
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CIA	Controlled Industrial Area
CLEAN	Comprehensive Long-Term Environmental Action Navy
CFR	Code of Federal Regulations
CG	Certified Geologist
COPC	Chemical or Potential Concern
COC	Chain of Custody
CSM	Conceptual Site Model
CTO	Contract Task Order
DFTTP	decafluorotriphenylphosphine
DL	Detection Limit
DoD	Department of Defense
DQI	Data Quality Indicator
DQO	Data Quality Objective
DQR	Data quality review
DVM	Data Validation Manager
FOL	Field Operations Leader
EDD	Electronic Data Deliverable
EPH	Extractable Petroleum Hydrocarbons
FID	Flame Ionization Detector
FTRM	Field Task Modification Request
FS	Feasibility Study
FY	Fiscal Year
g	gram
GC	Gas Chromatograph
GC/MS	Gas Chromatograph/Mass Spectrometer
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HI	Hazard Index
HSA	hollow stem auger

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HSM	Health and Safety Manager
ICAL	Initial Calibration
ICS	Interference Check Standards
ICV	Initial Calibration Verification
ICP	Inductively Coupled Plasma
IDW	Investigation-Derived Waste
IEUBK	Integrated Exposure Uptake Biokinetic
ILCR	Incremental Lifetime Cancer Risk
IRP	Installation Restoration Program
L	Liter
LCS	Laboratory Control Sample
LIMS	Laboratory Information Management Systems
LOD	Limit of Detection
LOQ	Limit of Quantitation
MADEP	Massachusetts Department of Environmental Protection
MEDEP	Maine Department of Environmental Protection
MPC	Measurement Performance Criteria
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAVFAC	Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NTU	Nephelometric Turbidity Units
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PCBs	Polychlorinated Biphenyls
PG	Professional Geologist
PID	Photoionization Detector
PM	Project Manager
PNS	Portsmouth Naval Shipyard
ppt	parts per thousand
PQL	Project Quantitation Limit
PQOs	Project Quality Objectives
PSL	Project Screening Level
PVC	polyvinyl chloride
PWD	Public Works Department
QA	Quality Assurance
QAO	Quality Assurance Officer

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QAPP	Quality Assurance Project Plan
QC	Quality Control
QSM	Quality Systems Manual
RI	Remedial Investigation
RF	Response Factor
RME	Reasonable maximum exposure
RPD	Relative Percent Difference
RPM	Remedial Project Manager
RSD	Relative Standard Deviation
RSL	Regional Screening Level
RT	Retention Time
S	Sampling
S&A	Sampling and Analytical
SAP	Sampling and Analysis Plan
SD	Standard Deviation
SDG	Sample Delivery Group
SMP	Site Management Plan
SOP	Standard Operating Procedure
SSI	Site Screening Investigation
SSO	Site Safety Officer
SVOC	Semivolatile Organic Compounds
TAL	Target Analyte List
TCL	Target Compound List
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
UFP	Uniform Federal Policy
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compounds
VSP	Visual Sample Plan

## SAP WORKSHEET #2: SAMPLING AND ANALYSIS PLAN IDENTIFYING INFORMATION

[\(UFP-QAPP Manual Section 2.2.4\)](#)

**Site Name/Number:** Portsmouth Naval Shipyard (PNS)  
Operable Unit: 8  
**Contractor Name:** Tetra Tech  
**Contract Number:** N62470-08-D-1001  
**Contract Title:** Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic Comprehensive Long-Term Environmental Action Navy (CLEAN)  
Work Assignment  
**Number (optional):** Contract Task Order (CTO) WE32

This Sampling and Analysis Plan (SAP) was prepared in accordance with the requirements of the United States Environmental Protection Agency (USEPA) Uniform Federal Policy for Quality Assurance Plans (UFP-QAPP) (USEPA, March 2005) and Guidance for Quality Assurance Project Plans, USEPA QA/G-5 (USEPA, December 2002).

Identify regulatory program: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

This SAP is a project-specific SAP for a Remedial Investigation (RI) for Operable Unit (OU) 8.

List organizational partners (stakeholders) and identify the connection with lead organization:

Organization Partners/Stakeholders	Connection
NAVFAC Mid-Atlantic	Lead Organization
USEPA Region 1	Regulatory Oversight
Maine Department of Environmental Protection (MEDEP)	Regulatory Oversight
PNS Environmental Office	Collaborative Party
Natural Resource Trustees	Collaborative Party
PNS Restoration Advisory Board	Collaborative Party

Lead organization: NAVFAC Mid-Atlantic

If any required SAP elements and required information are not applicable to the project or are provided elsewhere, then note the omitted SAP elements and provide an explanation for their exclusion below:

Not applicable

### SAP WORKSHEET #3: DISTRIBUTION LIST

[\(UFP-QAPP Manual Section 2.3.1\)](#)

SAP Recipients	Title	Organization	Telephone Number (optional)	E-mail Address or Mailing Address
Ms. Linda Cole	NAVFAC Remedial Project Manager (RPM)	NAVFAC Mid-Atlantic	757-341-2011	linda.cole@navy.mil
Mr. Matthew Audet	USEPA RPM	USEPA Region 1	617-918-1449	audet.matthew@epa.gov
Mr. Iver McLeod	MEDEP RPM	MEDEP	207-287-8010	lver.j.mcleod@maine.gov
Mr. Matt Thyng	Public Works Department (PWD) Maine Installation Restoration Program (IRP) Manager	PNS	207-438-6618	frederick.thyng@navy.mil
Ms. Deborah Cohen	Tetra Tech PNS Facility Coordinator	Tetra Tech	Contact Linda Cole	Contact Linda Cole
Ms. Megan Ved	Tetra Tech Project Manager (PM)	Tetra Tech	Contact Linda Cole	Contact Linda Cole
Mr. Tim Evans	Tetra Tech Maine Certified Geologist (CG)	Tetra Tech	Contact Linda Cole	Contact Linda Cole
Dr. Tom Johnston	Tetra Tech Quality Assurance (QA) Manager	Tetra Tech	Contact Linda Cole	Contact Linda Cole
Matthew Kraus	Tetra Tech Project Chemist	Tetra Tech	Contact Linda Cole	Contact Linda Cole
Tim Evans	Tetra Tech Field Operations Leader (FOL)	Tetra Tech	Contact Linda Cole	Contact Linda Cole
Jennifer Obrin	Laboratory PM	Katahdin Analytical Services	Contact Linda Cole	Contact Linda Cole

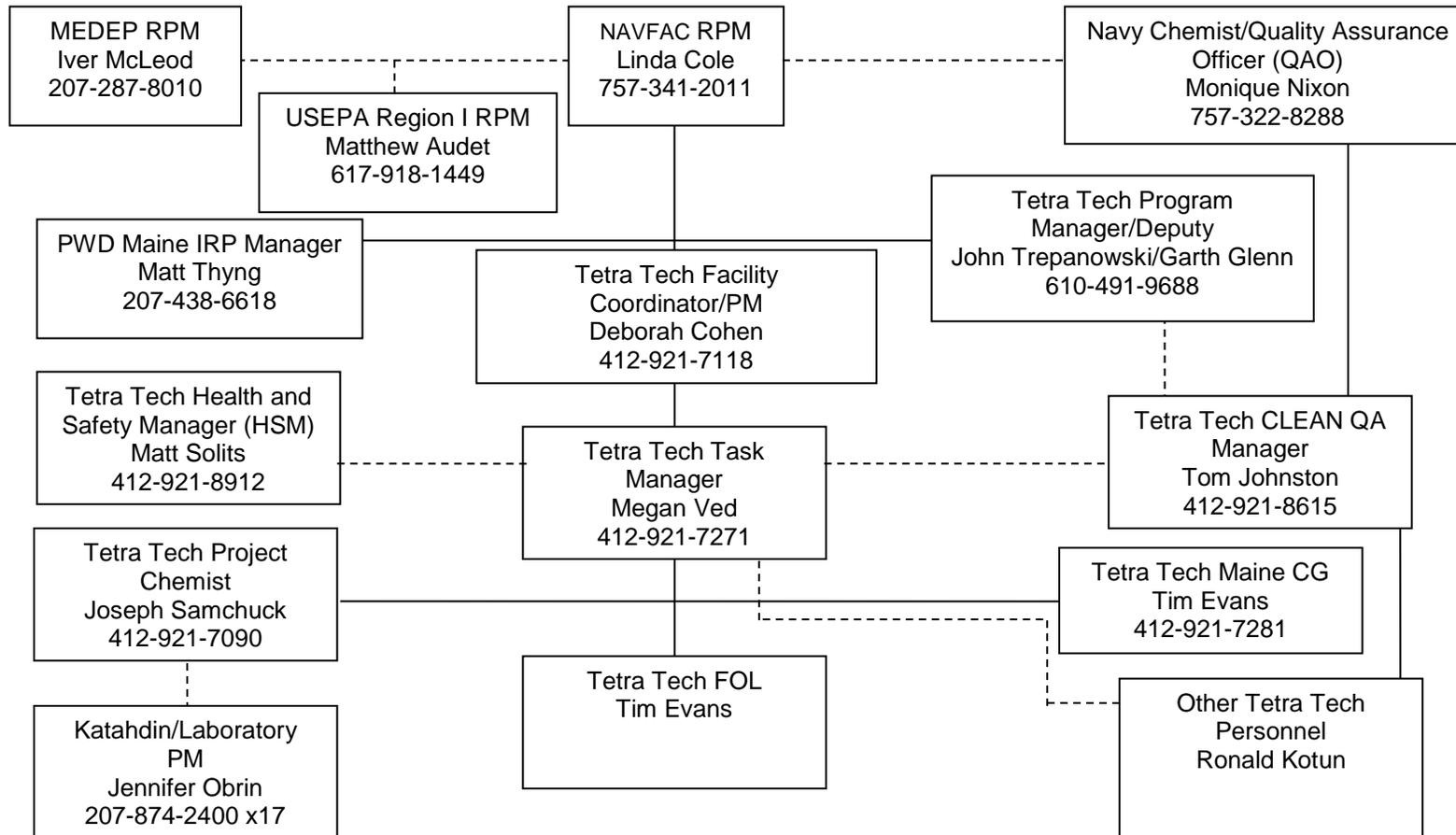
### SAP WORKSHEET #4: PROJECT PERSONNEL SIGN-OFF SHEET

[\(UFP-QAPP Manual Section 2.3.2\)](#)

Name	Organization/Title/Role	Signature/E-Mail Receipt	SAP Section Reviewed	Date SAP Read
Deborah Cohen	Tetra Tech Facility Coordinator		All	
Megan Ved	Tetra Tech PM	See Worksheet #1 Tetra Tech Title and Approval Page	All	
Tom Johnston, PhD.	Tetra Tech QA Manager	See Worksheet #1 Tetra Tech Title and Approval Page	All	
Tim Evans	FOL/Tetra Tech Maine CG	(To be provided as part of Worksheet #1 for the final) Maine CG Approval Page	All	
Joseph Samchuck	Data Validation Manager (DVM)/Project Chemist		Worksheets #s 12, 14, 15, 19, 20, 23-28, 30, 34-37	
Ronald Kotun, PhD.	Human Health Risk Assessor		Worksheets #s 10,11, 15,17, and Appendix A	
Jennifer Obrin	Laboratory PM		Worksheets #s 12, 14, 15, 19, 20, 23-28, 30, 34-37	

### SAP WORKSHEET #5: PROJECT ORGANIZATIONAL CHART

Lines of Authority ————— Lines of Communication - - - - -



\* All Contact with Tetra Tech personnel and subcontractors by non-field personnel should be through Linda Cole.

## SAP WORKSHEET #6: COMMUNICATION PATHWAYS

[\(UFP-QAPP Manual Section 2.4.2\)](#)

The communication pathways for the SAP are shown below.

Communication Drivers	Responsible Affiliation	Name	Phone Number	Procedure
Changes in schedule	Tetra Tech PM NAVFAC RPM  PWD Maine IRP Manager	Megan Ved Linda Cole  Matt Thyng	412-921-7271 757-341-20116  207-438-6618	The Tetra Tech PM will communicate verbally to the NAVFAC RPM incidents that affect schedule changes, and will follow with documentation of changes at the direction of the RPM.
Issues in the field that result in minor modifications of field methodology or sampling protocol	Tetra Tech FOL Tetra Tech PM	Tim Evans Megan Ved	412-921-7281 412-921-7271	The Tetra Tech FOL will inform the Tetra Tech PM verbally the day the issue is realized. Tetra Tech PM will inform NAVFAC RPM of the issue verbally within 1 day of the FOL's notification. Tetra Tech FOL will document the changes in the field logbook and appropriate field forms. The logbook and field forms will be placed in the project file.
Field conditions that require changes to implementation of field work or major modifications in field methodology or sampling protocol	Tetra Tech FOL Tetra Tech PM	Tim Evans Megan Ved	412-921-7281 412-921-7271	The Tetra Tech FOL will inform the Tetra Tech PM the day the issue is realized. The Tetra Tech PM will inform the NAVFAC RPM. The Tetra Tech PM will document the proposed changes via a Field Task Modification Request (FTMR) form within 5 days. The NAVFAC RPM will sign the FTMR within 5 days of receipt, if approved. The Tetra Tech PM will place the FTMR form in the project file, with signatures as determined by the NAVFAC RPM, and will provide the FTMR to the Project Team via e-mail when completed. The Tetra Tech PM will also send a concurrence letter to the NAVFAC RPM within 7 days if the project scope is affected. An example FTMR form is included in Appendix B.

Communication Drivers	Responsible Affiliation	Name	Phone Number	Procedure
Recommendation to stop work and initiate work upon corrective action (e.g., to protect workers from unsafe conditions/situations or to prevent degradation in quality of work)	Tetra Tech FOL Tetra Tech PM Tetra Tech QA Manager Tetra Tech HSM NAVFAC RPM PWD-Maine IR Program Manager	Tim Evans Megan Ved Tom Johnston Matt Soltis Linda Cole Matt Thyng	412-921-7281 412-921-7271 412-921-8615 412-921-8912 757-341-2011 207-438-6618	On the day the problem is identified, the Tetra Tech FOL will inform (verbally or via e-mail) the Tetra Tech PM, inform onsite personnel, subcontractor(s), the NAVFAC RPM, PWD Maine IRP Manager, and other Project Team members as needed. The identified corrective action will be documented via an FTMR.
Field data quality issues	Tetra Tech FOL Tetra Tech PM	Tim Evans Megan Ved	412-921-7281 412-921-7271	The Tetra Tech FOL will inform the Tetra Tech PM verbally or by e-mail on the same day that a field data quality issue is discovered. If the Tetra Tech PM determines that the problem significantly impacts the project, the Tetra Tech PM will inform the NAVFAC RPM of the issue (verbally or via e-mail) within 1 day of the Tetra Tech FOL's notification.
Laboratory analytical data quality issues	Laboratory PM Tetra Tech Project Chemist Tetra Tech Data Validation Manager (DVM) Tetra Tech PM NAVFAC RPM	Jennifer Obrin Matt Kraus Joseph Samchuck Megan Ved Linda Cole	207-874-2400 x 17 412-921-8729  412-921-7271 757-341-2011	The Laboratory PM will notify (verbally or via e-mail) the Tetra Tech Project Chemist within 1 business day of when a quality concern related to laboratory data is discovered. The Tetra Tech Project Chemist will notify (verbally or via e-mail) the DVM and Tetra Tech PM within 1 business day. The Tetra Tech DVM or Project Chemist will notify the Tetra Tech PM verbally or via e-mail within 48 hours of validation completion that a non-routine and significant laboratory quality deficiency has been detected that could affect this project and/or other projects. The Tetra Tech PM will verbally advise the NAVFAC RPM within 24 hours of notification from the Tetra Tech Project Chemist or DVM. The NAVFAC RPM will take corrective action appropriate for the identified deficiency. Examples of significant laboratory deficiencies include data reported that have a corresponding failed tune or initial calibration verification. Corrective actions may include a consult with the Navy Chemist.

## SAP WORKSHEET #7: PERSONNEL RESPONSIBILITIES TABLE

[\(UFP-QAPP Manual Section 2.4.3\)](#)

Name	Title/ Role	Organizational Affiliation	Responsibilities
Linda Cole	NAVFAC RPM	NAVFAC Mid- Atlantic	Functions as primary Navy interface and advisor to the Tetra Tech PM, PNS IRP Manager, and regulatory RPMs.
Matt Thyng	PWD Maine IRP Manager	PNS	Functions as primary Shipyard interface and advisor to the NAVFAC RPM, Tetra Tech PM, and regulatory RPMs.
Matthew Audet/ Iver McLeod	Regulatory RPMs	USEPA Region 1/MEDEP	Functions as primary regulatory interface and advisor to the NAVFAC RPM and PNS IRP Manager.
Megan Ved	PM	Tetra Tech	Oversees project, manages financial, schedule, and technical day-to-day activities of the project.
Tim Evans	FOL/Maine CG	Tetra Tech	Supervises, coordinates, and performs field sampling activities. Directs the planning, collection, reporting, and interpretation of geologic and hydrogeologic data.
Tom Johnston, PhD.	QA Manager	Tetra Tech	Approves SAP and ensures that quality aspects of the Comprehensive Long-Term Environmental Action Navy (CLEAN) program are implemented.
Matt Kraus	Project Chemist	Tetra Tech	Prepares laboratory scopes of work, coordinates analyses with laboratory chemists, ensures that the laboratory scope of work is followed, and communicates with Tetra Tech staff. Performs data quality reviews (DQRs).
Ronald Kotun, PhD.	Human Health Risk Assessor	Tetra Tech	Performs human health risk assessment and oversees preparation of human health risk assessment and risk management decisions for the OU8 RI.
Joseph Samchuck	DVM	Tetra Tech	Provides QA of data validation deliverables.

Name	Title/ Role	Organizational Affiliation	Responsibilities
Tim Evans	Site QA Advisor	Tetra Tech	The FOL (or PM designee) will act as the Site QA/Quality Control (QC) Advisor and will be responsible for ensuring adherence to all QA/QC requirements as defined in this SAP. Strict adherence to these procedures is critical to the collection of acceptable and representative data.
Tim Evans	Site Safety Officer (SSO)	Tetra Tech	Trains and monitors site safety conditions. The SSO reports to the HSM and communicates with the FOL and Tetra Tech PM. Details of the SSO's responsibilities are presented in the Tetra Tech site-specific Health and Safety Plan (HASP).
Matt Soltis	HSM	Tetra Tech	Oversees CLEAN Program Health and Safety Program.
Jennifer Obrin	Laboratory	Katahdin	Responsible for analysis of all samples in accordance with the analytical methods and additional requirements specified in this SAP. Will ensure proper disposal of unused sample aliquots.
Deborah Nadeau	Laboratory Operations Manager	Katahdin	Supports and implements the QA program within the laboratory.
Leslie Dimond	Laboratory QA Officer	Katahdin	Administers the laboratory QA program and is independent of laboratory production management to ensure that laboratory quality performance is assessed without consideration of schedule or budget issues.

## **SAP WORKSHEET #8: SPECIAL PERSONNEL TRAINING REQUIREMENTS TABLE**

[\(UFP-QAPP Manual Section 2.4.4\)](#)

Each site worker will be required to have completed appropriate Hazardous Waste Operations and Emergency Response (HAZWOPER) training specified in Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910.120(e). Project-specific safety requirements are addressed in greater detail in the site-specific HASP.

## SAP WORKSHEET #9: PROJECT SCOPING SESSION PARTICIPANTS SHEET

[\(UFP-QAPP Manual Section 2.5.1\)](#)

<b>Project Name:</b> PNS OU8 RI SAP		<b>Site Name:</b> OU8			
<b>PM:</b> Deborah Cohen		<b>Site Location:</b> PNS, Kittery, Maine			
<b>Date(s) of Session:</b> February 2014					
<b>Scoping Session Purpose:</b> Tetra Tech and NAVFAC internal discussions to determine draft data quality objectives (DQOs).					
Name	Title	Affiliation	Phone #	E-Mail Address	Project Role
Tom Johnston, PhD.	Tetra Tech QA Manager	Tetra Tech	412- 921-8615	tom.johnston@tetrattech.com	QA Manager
Deborah Cohen, P.E.	PM/Process Engineer	Tetra Tech	412- 921-7118	deborah.cohen@tetrattech.com	PM/Engineer
Megan Ved, EIT	Environmental Engineer	Tetra Tech	412-921-7271	megan.ved@tetrattech.com	Task Manager/Engineer
Linda Cole	NAVFAC RPM	NAVFAC	757-341-2011	linda.cole@navy.mil	NAVFAC RPM

Tim Evans, Maine CG, provided geologic input separately.

Comments/Decisions: Discussion was held regarding the status and evaluation of existing data for OU8 to determine the most appropriate path forward. It was decided that the existing soil and groundwater data were insufficient to determine site conditions or risks associated with contamination to support an RI for OU8. The issue of new construction and the significant number of utility lines and corridors on site were discussed as related to associated difficulties in determining soil sampling locations.

Action Items: Prepare Internal Draft SAP for NAVFAC RPM and Chemist review

Consensus Decisions: The SAP will include surface and subsurface soil sampling, groundwater sampling, and analysis of tidal fluctuations, and the data collected will be used to evaluate risks at OU8.

## **SAP WORKSHEET #10: CONCEPTUAL SITE MODEL**

[\(UFP-QAPP Manual Section 2.5.2\)](#)

### **10.1 SITE DESCRIPTION**

PNS is a military facility with restricted access on an island located in the Piscataqua River, as shown on Figure 1. PNS is engaged in the conversion, overhaul, and repair of submarines for the Navy. PNS was established as a government facility in 1800, and served as a repair and building facility for ships during the Civil War. A large number of submarines have been designed, constructed, and repaired at this facility since 1917. PNS continues to service submarines as its primary military focus.

OU8 is located in the Controlled Industrial Area (CIA), in the western portion of PNS. OU8 is also known as Site 31 – Former West Timber Basin. The layout of OU8 is presented on Figure 2. OU8 is an industrial area surrounded by buildings and dry docks. The site is an area that was previously filled with various materials and is bounded on the east, west, and south by historical quay walls. There are two main buildings flanking OU8, Building 92 on the east and Building 174 on the west. An addition to Building 174 was completed in 2013, and intrusive activities underneath and within the building for environmental activities are prohibited. Additional utility corridors were also installed during new building construction, and utility corridors also existed previously on site. The abundance of utilities on site may present obstacles to future construction, potential sampling, and site use. Previous investigations at OU4 (offshore) monitoring stations MS-13 and MS-14 (shown on Figure 1) have shown that contaminants are not migrating to the offshore areas of OU8 at unacceptable levels (Navy, August 2013).

### **10.2 SITE HISTORY**

The OU8 site history information in this section is based on the Industrial History of the West Timber Basin (Dolph and Bolger, May 1996) and review of historical maps for OU8. Naval warships built at PNS throughout the 19th Century were constructed with wood, and the wet storage and seasoning (drying) of the wood was conducted in the West Timber Basin. A new timber basin was constructed on the eastern side of the Shipyard, and by 1913, wet storage of timber in the West Timber Basin had ceased and was conducted in the new timber basin. In 1917, the former West Timber Basin's granite block quay wall was enclosed, the northern portion of the former timber basin was partially filled, and a metal washing plant, Building 110, was constructed to further extract essential scrap. Based on excavations and borings advanced at the site, the fill material appears to consist of bricks, metal debris, cinders, wood, gravel, and other waste materials. Some of the by-products of operations in the metal washing plant, which operated for approximately 3 years, may have been discarded into the former West Timber Basin, including metals, ash, and skimmings. Between 1920 and 1940, cleaning of steel plates and pickling continued in the area of Building 110.

The majority of filling of the former timber basin was completed by 1925, when only a small area in the southwestern corner had not been filled. By 1940, filling of the former timber basin was complete. Fill apparently included soil, rock, cinders, and other industrial debris. By 1940, Building 92 had been extended into the former West Timber Basin fill area. Around 1940, a metal plate yard was also constructed, which included a traveling crane, four pickling tanks, two washing aprons, and a potassium nitrate storage building (Building 157). There is no evidence of plating operations taking place at the site. Also in 1940, the metal washing plant was razed. The plate yard was active for 20 years and was the primary steel storage and pickling location at the Shipyard. The pickling tanks for the plate yard were removed from the site at an unknown time. Filling west of the former timber basin began sometime after 1941, and by 1947, the fill area west of OU8 extended to the current shoreline, and Buildings 174 and 175 had been built.

### **10.3 HISTORY OF ENVIRONMENTAL INVESTIGATIONS AND ACTIONS**

Environmental sampling at OU8 was conducted as part of the Site Screening Investigation (SSI) in 1998 (Tetra Tech, May 2000). The investigation was conducted to determine the presence or absence of contamination remaining from past industrial operations and to determine whether further investigation was needed to assess the extent and potential hazards associated with contamination, if detected. Surface soil, subsurface soil, and groundwater samples were collected in areas with past industrial activities that may have resulted in potential contamination of soil.

Soil samples collected during the SSI were analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and pesticides/polychlorinated biphenyls (PCBs); Target Analyte List (TAL) metals and cyanide; hexavalent chromium; sulfate; total organic carbon (TOC); petroleum hydrocarbons (diesel and gasoline range); and pH. Tables 1 and 2 in Appendix A present analytical results for SSI surface soil and subsurface soil samples, respectively. Consistent with the presence of debris-like materials in the subsurface, the highest levels of polycyclic aromatic hydrocarbons (PAHs) and metals were detected in the subsurface. Only metals (iron, lead, manganese, and mercury) and PAHs were detected in site soils at concentrations exceeding USEPA industrial risk-based screening levels and PNS-specific background concentrations. Risk-based screening levels represent concentrations above which chemical concentrations are potentially threatening to human health, and background levels are concentrations above which a chemical concentration indicates potential site-related contamination.

The mercury exceedance was unexpected considering that the site history did not indicate any reason for high mercury concentrations in soil, and the concentration detected at location WTB-SB05/WTB-MW05 was significantly outside the range of other mercury concentrations at OU8 and other PNS sites that had

been investigated for contamination. Low levels of PAHs detected sparsely throughout the site suggest that these levels may be attributable to ongoing industrial activities at the site. Hexavalent chromium was not detected in soil; therefore, chromium at OU8 can be assumed to be in the trivalent oxidation state. The site history did not indicate a reason to suspect VOC, SVOC, pesticide or PCB contamination, and this was confirmed because there were no risk-based screening level exceedances for these compounds during the SSI.

Groundwater samples collected during the SSI were analyzed for TCL VOCs, SVOCs, and pesticides/PCBs; total TAL metals and cyanide; hexavalent chromium; TOC; petroleum hydrocarbons (diesel and gasoline range); alkalinity; chloride; bromide; sulfate; nitrate; pH, and salinity. Table 3 in Appendix A presents analytical results for SSI groundwater samples. Several metals (aluminum, arsenic, iron, manganese, mercury, and potassium) were detected at concentration in excess of residential screening levels (based on drinking water standards) and site-specific background concentrations in groundwater. No chemicals exceeded industrial screening levels and site-specific background concentrations. No correlation was made between concentrations of metals in soil that exceeded soil screening criteria and those that exceeded groundwater criteria; however, metals contamination was suspected to be present based on the historical use of the site as a metal picking facility and plate yard. The site history did not indicate a reason to suspect the presence of VOC, SVOC, pesticide or PCB contamination, and this was confirmed because there were no risk-based criteria exceedances of these compounds during the SSI. Although PAHs and some metals were not detected in groundwater during the SSI, they are still of interest based on soil concentrations detected, and known previous activities conducted onsite. In addition, detection limits for the SSI groundwater data for many PAHs and some metals were greater than residential screening levels.

Petroleum hydrocarbons (particularly diesel range) were detected in SSI soil and groundwater samples. Although there were no known fuel oil tanks at OU8, there were fuel oil tanks in areas adjacent to OU8. In comments on the draft UFP-SAP, MEDEP requested EPH analysis because of potential petroleum hydrocarbon contamination. Based on resolution of MEDEP's comments, the Navy agreed to include EPH in the list of analyses for OU8 as discussed further in Worksheet 11.

Based on site history and exceedances of screening levels, metals and PAHs are chemicals potentially associated with OU8 sources.

#### **10.4 CONCEPTUAL SITE MODEL**

A summary of the conceptual site model (CSM) based on current site conditions at OU8 is shown on Figure 3. The text below describes the CSM.

#### **10.4.1 Geology**

Boring logs and historical information indicate that OU8 was filled with various materials of natural and anthropogenic origin. The geologic cross-section locations are presented on Figure 4, and Figures 5 and 6 present the geologic cross-sections for OU8 based on information from the SSI and recent geotechnical investigations conducted as part of Shipyard construction projects for Buildings 92 and 174. A layer of silty fine sand to sandy silt mixed with metamorphic rock fragments and trace amounts of brick and other debris underlies the surface of the entire site. This layer varies in thickness from 8.5 to 17.5 feet. A layer of coal, cinders, and ash exists in the shallow subsurface in the northern part of the site. The layer of coal, cinders, and ash is thickest in the area of WTB-SB07 and thins to the south and west. A layer of metamorphic rock fragments (typically up to several feet thick) underlies the silty sand/sandy silt unit in several areas of the site.

Underlying the fill material is a laterally continuous unit of gray organic silt to mottled clayey silt. The clayey silt is interpreted as the Presumpscot Formation, whereas the upper sediments may be recent shallow marine deposits of silt and clay. The silt/clayey silt blankets the former basin, thickening toward the center.

Underlying the silt/clayey silt is a thin unit of fine sand containing varying amounts of metamorphic rock fragments. This unit is interpreted as till and directly overlies the bedrock surface. East of the site the overburden consists of silt with fine sand, presumably till, overlying bedrock.

#### **10.4.2 Hydrogeology**

Potentiometric surface maps for low and high tides at OU8 as determined during the SSI are provided in Appendix A. The groundwater is unconfined in the fill, overburden, and bedrock. Groundwater flow directions were estimated based on SSI data, but further measurements would be required to gain a better understanding of groundwater flow at the site. Groundwater flow during low tide appears to be from the interior of OU8 towards Piscataqua River. During high tide, the flow direction reverses, with groundwater mounding along the river and flowing toward the center of the former West Timber Basin.

Salinity readings measured during the SSI in OU8 wells ranged from 0.23 to 26 parts per thousand (ppt). Groundwater is considered fresh if salinity readings are less than 0.5 ppt, brackish if salinity is between 0.5 and 30 ppt, and saline if salinity is greater than 30 ppt.

Based on the salinity readings, groundwater at WTB-MW03 and WTB-MW04 was in the fresh range, and groundwater from WTB-MW02, WTB-MW05, and upgradient well WTB-MW01 was in the brackish range.

Based on salinity levels in the OU8 wells and the conceptual model of tidal flow flushing the area, groundwater at the site is assumed not to be suitable for drinking.

#### **10.4.3 Potential Sources of Contamination**

Based on site history and the results of environmental investigations at OU8 to date, the potential sources of contamination at OU8 are as follows;

The metal washing plant operated for about 3 years, and reportedly, some to all of the by-product from operation of the plant were discarded into the timber basin. Between 1920 and 1940, the timber basin was completely filled, and the cleaning of steel plates and pickling continued in the area of Building 110. All of these activities could have resulted in metals and other inorganic chemicals being present at OU8. The metal washing activities were conducted in the northern portion of OU8, as shown on Figure 4.

A plate yard with new pickling tanks was constructed around 1940 in the western portion of OU8, as shown on Figure 4. This plate yard was active for 20 years. The former pickling tanks and washing aprons were used for the treatment of metal with acid solution to remove scale, oxides, and dirt. A potassium nitrate storage building was also constructed at the same time as the pickling tanks and washing aprons. The purpose of the potassium nitrate is unknown, but nitrates are reportedly used as bluing agents that passivate metal surfaces to reduce or minimize corrosion.

In addition, various train and crane tracks have traversed the OU8 area since the area was filled.

#### **10.4.4 Potential Contaminant Migration Mechanisms**

Contaminants may have been introduced to the subsurface through direct deposition (e.g., ash or releases) or spills (e.g., pickling liquor or fuel oil). Precipitation-driven migration and tidal flushing were likely past contamination migration mechanisms; however, leaching from soil to groundwater is not expected to be a significant current or future pathway because of the age of the site and tidal flushing at the site. Past leaching/flushing is expected to have already resulted in leaching of the majority of the leachable contaminants at the site.

Precipitation-driven migration of potentially contaminated soil into underlying soil and groundwater is not likely to be a significant current migration mechanism because OU8 is covered with asphalt and buildings that prevent significant soil contact with precipitation. However, if the buildings and asphalt were to be removed, or if their integrity were compromised, migration of contaminants could occur as indicated on Figure 3 as contaminants leach from the soil (illustrated by the future potential migration arrows). The potential for future removal of the pavement is reflected in Figure 3.

Migration of soil contaminants into underlying soil and groundwater may occur through groundwater fluctuations which could cause leaching from the soil. Contaminants in groundwater migrate downgradient with groundwater flow but their migration rates are not as fast as groundwater seepage velocity because most contaminants interact with soil and bedrock in a way that retards migration. Lead is the least mobile of the contaminants of interest and tends to move very slowly if at all whereas the more soluble metals, soluble anions, and organic chemicals are more mobile. The rate of movement of each chemical, because of interactions with the matrix through which it moves in groundwater, is retarded relative to the groundwater flow rate. In addition, tidal effects may limit the net migration of contaminants in groundwater because of semi-diurnal (twice a day) hydraulic gradient changes.

Migration of groundwater to the offshore has been investigated as part of OU4 (offshore) investigations, and no contamination was found to be present in the offshore area associated with OU8. No further action was selected as the remedy for the offshore area of the site (MS-13 and MS-14) as documented in the Record of Decision for OU4 (Navy, August 2013). Because there is no continuing contaminant source on shore, the onshore contaminant concentrations from OU8 cannot increase and contamination cannot migrate offshore at unacceptable levels in the future.

#### **10.4.5 Land Uses and Potential Exposure**

Figure 7 presents the Risk Exposure Model based on land uses and potential exposures described in this section. PNS is a military facility with access restricted to authorized base personnel. OU8 is located in the CIA, which requires additional authorization to gain access. The current land use for OU8 is industrial and is likely to remain the same for the foreseeable future. Therefore, current receptors at OU8 are construction and occupational workers.

Current human health exposure pathways for surface and subsurface soil and groundwater exist for construction workers digging in the soil and exposed to groundwater. These pathways are dermal contact, incidental ingestion, and inhalation of vapors. Occupational workers who visit the site daily for routine office work or similar activities that do not require contact with soil are not likely to be exposed to soil at OU8 under current conditions because of asphalt covering the entire site. Future occupational worker exposure to surface soil would be possible if the asphalt was removed. In this case incidental ingestion from resuspended soil dust is the most likely exposure pathway, but dermal contact and inhalation may also be possible. Recreational and residential uses of the site are not likely as long as the Shipyard is in operation; however, hypothetical future recreational and residential uses could occur if the Shipyard closed or if the site usage changed from an industrial area to either recreational or residential use. These receptors also could be exposed via dermal contact, inhalation, and incidental ingestion, with the resident being more likely to receive exposure than a recreational user.

## **SAP WORKSHEET #11: PROJECT QUALITY OBJECTIVES (PQOS)/SYSTEMATIC PLANNING PROCESS STATEMENTS**

[\(UFP-QAPP Manual Section 2.6.1\)](#)

### **11.1 PROBLEM DEFINITION**

Based on the site history and CSM presented in Worksheet #10, a potential risk to current and future receptors from exposure to PAHs and metals in soil and groundwater exists at OU8. The nature and extent of metals and PAH contamination and risks from exposure to metals and PAHs in soil and groundwater need to be evaluated so that risks can be mitigated if they are found to be unacceptable. For completeness, all soil and groundwater samples will be analyzed for TAL metals and PAHs and the analytical results will be evaluated in the risk assessment.

All soil and groundwater samples will also be analyzed for EPH, and the analytical results will be evaluated in the uncertainty section of the risk assessment.

### **11.2 INFORMATION INPUTS**

To resolve the problem presented in Section 11.1, the following information is needed:

- Nature and extent of soil and groundwater contamination. Concentrations of metals and PAHs in surface and subsurface soil and groundwater must be measured. A list of the target analytes is provided in Worksheet #15 and is based on the CSM presented in Worksheet #10, site history, and SSI results. The sampling and analysis methods are presented in Worksheet #19.
- Concentrations of EPH in soil and groundwater. Detections of EPH in surface and subsurface soil and groundwater must be measured to provide data on petroleum hydrocarbons at the site as requested by MEDEP. A list of the target analytes is provided in Worksheet #15 the sampling and analysis methods are presented in Worksheet #19.
- Groundwater well stabilization parameters and level measurements. The stabilization parameters are dissolved oxygen, oxidation-reduction potential, pH, salinity, specific conductivity, temperature, and turbidity. Measurement of these parameters is necessary to establish the groundwater to be sampled is representative of site groundwater prior to collecting samples.
- Tidal information, including the magnitude of tidal influence and tidal lag on groundwater levels. This information will be used to establish representative groundwater sample collection times that factor in potential tidal lag times.

- Aquifer characteristics. Groundwater flow direction, groundwater elevations, potentiometric surface gradient, and hydraulic conductivity must be determined to estimate the seepage velocity of groundwater at the site.
- Salinity. The salinity of the groundwater must also be determined to establish the likelihood that groundwater from OU8 could be used in the future for drinking water purposes.
- Project Action Limits – For human health risk assessment of soil and groundwater, the project action limits (PALs) for determining whether risks are acceptable are an Incremental Lifetime Cancer Risk (ILCR) of greater than  $10^{-4}$  for carcinogens and a hazard index (HI) greater than 1 for non-carcinogens. PALs for lead will be determined using the mean lead concentration as the exposure point concentration (EPC) and incorporating it into the lead exposure models [Integrated Exposure Uptake Biokinetic (IEUBK) for children and Adult Lead Model for adults (USEPA 2003 and 2009)]. If any of these limits are exceeded, the risks will be considered unacceptable. Chemicals of potential concern (COPCs) for the human health risk assessment will include chemicals with maximum concentrations exceeding risk-based screening values, which are called project screening levels (PSLs), and that are shown to exceed facility background concentrations. For groundwater, chemical concentrations must be compared to PSLs based on drinking water exposure only if groundwater across the majority of the site is determined to be fresh water. If the majority of groundwater is saline or brackish, the groundwater data will be compared to construction worker PSLs only. For determining the adequacy of the analytical methods, risk-based screening values for both cases are presented on Worksheet #15. PALs for EPH were determined based on **the risk based criteria developed for MEDEP**.
- QC sample data - QC samples for estimating precision, bias, and contamination potential must be collected at the frequencies established in Worksheet #12.
- Sampling location coordinates. Survey coordinate data are needed to document the locations of the new monitoring well, tidal gauge, and soil sampling locations, both horizontally and vertically. The survey will be based on North American Datum (NAD) 83 and PNS 2002 Vertical Datum.
- Background concentrations. A full list of available facility background data specific to PNS must be used to evaluate whether soil and groundwater concentration data represent contamination. Detections that are within the range of background concentrations or less than background concentrations will not be considered in the risk assessment, because this contamination is likely pre-existing and not attributable to the site.

- Results reported between the Limit of Quantitation (LOQ) and Detection Limit (DL) will be flagged "J" and considered usable for project decisions.

### **11.3 STUDY AREA BOUNDARIES**

The geographical/physical boundary of OU8 is illustrated on Figure 2. Horizontally, the risk exposure unit for occupational workers, construction workers, hypothetical future recreational users, and hypothetical future residents is considered to be the entire area within the OU8 boundary. The exposure unit includes the soil to a depth of 10 feet below ground surface (bgs) (to the approximate groundwater elevation) and groundwater within the boundary of OU8. Surface soil is defined as soil from 0 to 2 feet bgs, and subsurface soil is defined as soil from 2 to 10 feet bgs or bedrock, whichever is shallower. Groundwater in unconsolidated materials at the site must be evaluated.

Target analyte concentrations are anticipated to be relatively unchanged (stable) over the course of time needed to conduct the environmental investigations and into the foreseeable future; therefore, no temporal constraints exist except for groundwater sampling. Groundwater samples must be collected during low tide periods, as determined by tidal lags. There is no surface water or sediment at OU8, so surface water and sediment are not included in the risk exposure unit.

Because of the tidal flow patterns at the site, with the area being influenced by semi-diurnal tidal cycles twice daily, and given the current understanding of groundwater flow direction, it is expected that downgradient concentrations will be approximately the same at any location. Soil at the site is physically contained by the quay walls to the east, south, and west and by being covered by asphalt and buildings, so all soil outside of the physical site boundaries is considered unaffected by any site soil contamination.

### **11.4 ANALYTIC APPROACH**

The decision rules below govern the use of data collected during this RI. The 95-percent upper confidence limits (UCLs) on the means of soil target analyte concentrations will be used as estimates of the EPCs within the exposure unit for all COPC except for lead. The exposure unit is the area defined in Section 11.3. An ILCR or non-cancer HI will be computed for all carcinogenic and non-carcinogenic COPCs, respectively, except lead. For lead, the mean lead concentration will be used as the EPC and will be incorporated into the IEUBK exposure model and Adult Lead Model. Chemical-specific UCLs for data collected from OU8 will be calculated using the most current version of USEPA's ProUCL software. If the 95-percent UCL is greater than the maximum detected concentration or if there are less than three detected concentrations, the maximum detected concentration will be used to represent the EPC.

There is no decision rule for the EPH data collected, as the data is being collected for informational purposes and no decisions for remedial action will be made based on the results.

The appropriate EPCs for groundwater will be chosen in accordance with the Navy Human Health Risk Assessment Guidance (Navy, December 2008) by a risk assessor based on evaluation of the data (i.e., number of samples and distribution of the data).

**Decision Rule #1:** If the project team agrees that the nature and extent of metals or PAH contamination within OU8 has been determined sufficient to support a risk assessment (see Decision Rule #2), stop delineating contamination; otherwise, convene the team to develop a plan for an additional investigation, as needed. This evaluation would include an evaluation of contaminant patterns, magnitudes of target analyte concentrations compared to screening values (see Worksheet #15), and other factors that combine to indicate whether contamination is well bounded, even if some locations exhibit slight exceedances of screening values. For this determination, background values greater than risk-based screening values will be considered to be the PSLs.

**Decision Rule #2:** If the majority of groundwater across OU8 is found to be brackish (i.e., salinity is greater than 0.5 ppt) and therefore not usable for drinking water, conduct risk assessment for construction worker contact only. Otherwise, the likelihood of a pocket of fresh water at OU8 being encountered by receptors will be considered in the risk assessment.

**Decision Rule #3:** If the total ILCR for a receptor for reasonable maximum exposure (RME) to metals (except lead) and PAHs in soil or groundwater at OU8 is greater than  $1 \times 10^{-4}$  for carcinogens, or if the HI is greater than 1 for non-carcinogens (with a common target organ/effect), or if either of the lead models (as applicable) indicate that greater than 5 percent of a population's blood-lead concentrations are greater than 10 micrograms per deciliter ( $\mu\text{g}/\text{dL}$ ), then conduct a Feasibility Study (FS) to evaluate actions that can be taken to mitigate the unacceptable risks; otherwise recommend no further action.

## 11.5 DECISION PERFORMANCE CRITERIA

The sampling design (see Worksheet #17) for obtaining data needed to make the decisions identified in Section 11.4 is a combination of statistically based and judgmental designs for reasons described below. The elements of the statistical performance criteria that serve as the basis for this design are presented below. These criteria were developed in accordance with the USEPA Guidance on the Data Quality Objectives Process (USEPA, February 2006). Details of the statistical calculations, that were used to estimate a reasonably defensible number of samples to be collected at OU8, are provided in Appendix A. Based on the calculations, it was determined that a minimum of 18 soil sampling locations are required to characterize the exposure unit.

For groundwater, a statistical calculation of this nature is not appropriate because the EPCs are computed from a limited number of wells exhibiting the greatest target analyte concentrations. The expectation is that a receptor may be exposed by accessing the same well repeatedly, which is different than exposure to soil, which assumes random exposure to soil throughout the exposure unit. Hence, the number of wells and well locations were selected based on knowledge of site conditions to represent the most likely exposures for the identified receptors.

After completing the calculations described in Appendix A, which assume that sampling locations are randomly positioned within the area to be sampled, consideration was given to the presence of underground utilities and other objects that could impede or prevent the collection of soil samples. There are many utilities and buried vaults in the area to be sampled; therefore, sampling points were hand selected with the intent of maximizing coverage of the site while avoiding buried obstacles.

Data quality will be evaluated through the data verification, validation, and usability assessment processes (see Worksheets #34 through #37). If the specified numbers of soil and groundwater samples are obtained and all analyses are completed with no significant data quality deficiencies, and if the specifications in Appendix A that were used to compute the minimum number of soil samples are satisfied, the project team will conclude that enough data have been collected to attain project objectives. If data deficiencies are identified, the project team will evaluate them to determine whether project objectives can be attained in light of the deficiencies. The tendency will be to recommend additional data collection unless data quality deficiencies are minor or the project team considers the number of additional samples required to meet the Visual Sample Plan (VSP) input specifications of alpha and beta to be small.

## **11.6 PLAN FOR OBTAINING DATA**

The plans for obtaining the data at OU8 are described in detail on Worksheet #17 along with the sampling design and rationales.

## SAP WORKSHEET #12: FIELD QUALITY CONTROL SAMPLES

[\(UFP-QAPP Manual Section 2.6.2\)](#)

Measurement Performance Criteria (MPCs) Table – Field QC Samples

QC Sample	Analytical Group	Frequency	Data Quality Indicators (DQIs)	MPCs	QC Sample Assesses Error for Sampling, Analytical or both
Field duplicates	Inorganics	One per 10 samples per soil and groundwater matrices	Precision/Comparability	Values $\geq 5x$ LOQ: relative percent difference (RPD) $\leq 50$ percent Values $< 5x$ LOQ: absolute difference $\leq 4x$ QL	S & A
	PAHs	One per 10 samples per soil and groundwater matrices	Precision/Comparability	RPD $\leq 50$ percent If sample results are $< 2x$ LOQ, professional judgment is used.	S & A
	EPH	One per 10 samples per soil and groundwater matrices	Precision/Comparability	RPD $\leq 50$ percent If sample results are $< 2x$ LOQ, professional judgment is used.	S & A
Equipment rinsate blanks	Inorganics, PAHs, EPH	One for soil sampling event	Bias/Contamination	No target analytes $>$ LOQ for organic compounds or MDLs for inorganic analytes	S
Cooler Temperature Indicator	Inorganics, PAHs, EPH	One per cooler	Accuracy/Representativeness	Between 2 and 6 degrees Celsius ( $^{\circ}C$ ).	S
All samples	Inorganics, PAHs, EPH	All samples	Sensitivity	QL $<$ project action limits listed in Worksheet #15	A
Data Completeness Check	Inorganics, PAHs, EPH	All samples	Data Completeness	95 percent overall	S & A

### SAP WORKSHEET #13: SECONDARY DATA CRITERIA AND LIMITATIONS TABLE

[\(UFP-QAPP Manual Section 2.7\)](#)

Secondary Data	Data Source (originating organization, report title, and date)	Data Generator(s) (originating organization, data types, data generation/collection dates)	How Data Will Be Used	Limitations on Data Use
SSI Report for Site 30 (Building 184), Site 31 (West Timber Basin), and Site 32 (Topeka Pier)	Tetra Tech, May 2000	The SSI was conducted in 1998 by Tetra Tech. Soil and groundwater samples were collected and analyzed, geological information was collected from borings, and hydrogeology information was collected from newly installed monitoring wells.	The soil and groundwater data support identification of risk drivers (metals and PAHs,) and provide characterization information for likely past sources.	None.
Environmental Soil Testing Report, P268 Waterfront Support Facility – Portsmouth Naval Shipyard	R.W. Gillespie & Associates, Inc., February 2010	A subsurface investigation was conducted as part of the Shipyard construction project for Building 174. Some borings were installed in and adjacent to OU8.	Boring logs provide information on subsurface conditions in and to the west of OU8. Samples were analyzed for limited analytes, and analytical data from this investigation will not be used quantitatively for the risk assessment.	Boring logs may not be detailed enough to distinguish ash/cinders.
Report of Geotechnical Evaluation for Waterfront Support Facility – Portsmouth Naval Shipyard	R.W. Gillespie & Associates, Inc., January 2010	A subsurface investigation was conducted as part of the Shipyard construction project for Building 174. Some borings were installed in and adjacent to OU8.	Boring logs provide information on subsurface conditions in and to the west of OU8. The western historic quay wall at OU8 was located during this investigation.	Boring logs may not be detailed enough to distinguish ash/cinders.
Subsurface Investigation Report for P-266/P-326 Consolidation of Structural Shops – Portsmouth Naval Shipyard	Pennoni Associates, Inc., January 2011	A subsurface investigation was conducted as part of the Shipyard construction project for Building 92. Some borings were installed in or adjacent to OU8.	Boring logs provide information on subsurface conditions in and to the east of OU8. Samples were analyzed for limited analytes, and analytical data from this investigation will not be used quantitatively for the risk assessment.	Boring logs may not be detailed enough to distinguish ash/cinders.

<b>Secondary Data</b>	<b>Data Source</b> (originating organization, report title, and date)	<b>Data Generator(s)</b> (originating organization, data types, data generation/collection dates)	<b>How Data Will Be Used</b>	<b>Limitations on Data Use</b>
Geotechnical Engineering Services, Structural Shops Addition – Portsmouth Naval Shipyard	Pennoni Associates, Inc., May 2011	A geotechnical evaluation of the subsurface was conducted to support a construction project for Building 92.	Boring logs provide information on subsurface conditions in and to the east of OU8.	Boring logs may not be detailed enough to distinguish ash/cinders.

## **SAP WORKSHEET #14: SUMMARY OF PROJECT TASKS**

[\(UFP-QAPP Manual Section 2.8.1\)](#)

### **SUMMARY OF PROJECT TASKS**

#### **Field Tasks:**

- Mobilization/demobilization
- Site-specific health and safety training
- Utility clearance
- Collection of sampling coordinates. For borings, monitoring wells, and staff gauges, a survey will be conducted to record sampling locations and obtain sampling coordinates.
- Monitoring equipment calibration
- Monitoring well installation and well development, including installation of two additional groundwater wells to total depths of approximately 14 to 17 feet bgs.
- Soil and groundwater sampling (see Figure 8) including direct push technology (DPT) soil sample collection of surface and subsurface samples and groundwater sampling conducted using low-flow methods.
- Equipment decontamination
- Investigation-derived waste (IDW) will be drummed by Tetra Tech. PNS will provide the appropriate IDW containers, and PNS is responsible for sampling, analyzing, and disposing of IDW in accordance with state and federal guidelines.
- Field QA/QC management
- Field documentation QA/QC and review
- Sample custody and shipment
- Synoptic groundwater level measurements
- Tidal study
- In-situ hydraulic conductivity testing (slug tests)

#### **Analysis Tasks:**

- The fixed-base laboratory will analyze soil and groundwater samples for PAHs, EPH and metals as outlined in Worksheet #15.

#### **Quality Control Tasks:**

- Implement Standard Operating Procedures (SOPs) for sampling activities, sample preservation/shipping methods, and sample preparation/analysis methods.

- Collect and analyze QA/QC field samples including duplicates, equipment rinsate blanks, and temperature blanks (for coolers) in accordance with Worksheet #s 12, 18, 19, 20, 21, 23, 27, and 30.
- Field duplicate samples will be collected following the same sampling procedures as for environmental samples.
- Laboratory analysis of matrix spike (MS)/matrix spike duplicate (MS/MSD) samples in accordance with Worksheet #28.
- Calibration and other QC checks as specified in Worksheet #s 24 and #28.
- Assessments in accordance with Worksheet #s 32 and 33.

**Secondary Data:**

- See Worksheet #13.

**Data Management Tasks (see Worksheet #s 29, 34 through 37):**

- Data receipt and Electronic Data Deliverable (EDD) upload (Sample Management Coordinator).
- Data verification and validation (Data Validation Chemist or Environmental Scientist and DVM).
- Upload of validated data to the project database (Project Database Manager).

**Documentation and Records:**

- Documentation of sample location coordinates, borings logs, chain-of-custody forms, samples logs, and shipping documents for all samples.
- The EDDs and corresponding databases will be formatted in both Navy and MEDEP formats.
- Preparation of electronic and hardcopies of this finalized OU8 RI SAP.

**Data Packages:**

- Receipt of analytical data packages from the fixed-base laboratory.
- Generation of Tetra Tech data validation reports.

**Data Review Tasks:**

- The fixed-base laboratory will verify that all samples listed on the chain-of-custody are analyzed in accordance with the methods specified on the chain-of-custody form and laboratory scope of work, and in this SAP. Data verification and validation will be performed by Tetra Tech as provided in Worksheet #s 34 through 36. A data validation report will be produced for each Sample Delivery Group (SDG).
- All field data records and validated data will be reviewed by Tetra Tech to determine the usability of the data. The outcome of this assessment will be conveyed to the project team for agreement before the

project report is finalized. Data limitations pertaining to PQOs and Action Limits will be identified, and corrective actions will be taken as necessary.

- A data usability assessment will be conducted in accordance with Worksheet #37.

## SAP WORKSHEET #15: REFERENCE LIMITS AND EVALUATION TABLES

[\(UFP-QAPP Manual Section 2.8.1\)](#)

Matrix: Soil

Analytical Group: TAL Metals **SW-846 Method 6010 limits with the exception of arsenic, cobalt, thallium (SW-846 Method 6020 limits presented), and mercury by SW-846 Method 7471B**

Analyte	CAS No.	PSLs (mg/kg) <sup>1</sup>	PSL Reference <sup>1</sup>	Project QL Goal (mg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ(mg/kg)	LOD (mg/kg)	DL (mg/kg)
Aluminum	7429-90-5	7700 N	USEPA RSL	2600	30	10	0.71
Antimony	7440-36-0	3.1 N	USEPA RSL	1.0	0.8	0.5	0.07
Arsenic	7440-38-2	0.67 C	USEPA RSL	0.22	0.5	0.4	0.15
Barium	7440-39-3	1500 N	USEPA RSL	500	0.5	0.3	0.03
Beryllium	7440-41-7	16 N	USEPA RSL	5.3	0.5	0.05	0.007
Cadmium	7440-43-9	7 N	USEPA RSL	2.3	1.0	0.3	0.008
Calcium	7440-70-2	NA	USEPA RSL	NA	10	8.0	1.78
Chromium	7440-47-3	12000 N	USEPA RSL	4000	1.5	0.4	0.03
Cobalt	7440-48-4	2.3 N	USEPA RSL	0.77	0.1	0.03	0.0054
Copper	7440-50-8	310 N	USEPA RSL	100	2.5	1.0	0.16
Iron	7439-89-6	5500 N	USEPA RSL	1800	10	8.0	1.4
Lead	7439-92-1	400	USEPA RSL	130	0.5	0.4	0.09
Magnesium	7439-95-4	NA	USEPA RSL	NA	10	8.0	0.68
Manganese	7439-96-5	180 N	USEPA RSL	60	0.5	0.4	0.16
Mercury	7439-97-6	0.94 N (elemental)	USEPA RSL	0.31	0.033	0.017	0.0052

Matrix: Soil

Analytical Group: TAL Metals **SW-846 Method 6010 limits with the exception of arsenic, cobalt, thallium (SW-846 Method 6020 limits presented), and mercury by SW-846 Method 7471B**

Analyte	CAS No.	PSLs (mg/kg) <sup>1</sup>	PSL Reference <sup>1</sup>	Project QL Goal (mg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ(mg/kg)	LOD (mg/kg)	DL (mg/kg)
Nickel	7440-02-0	150 N	USEPA RSL	50	4	0.4	0.044
Potassium	7440-09-7	NA	USEPA RSL	NA	100	50	2.9
Selenium	7782-49-2	39 N	USEPA RSL	13	1.0	0.7	0.17
Silver	7440-22-4	39 N	USEPA RSL	13	1.5	0.4	0.03
Sodium	7440-23-5	NA	USEPA RSL	NA	100	50	1.48
<b>Thallium <sup>3</sup></b>	<b>7440-28-0</b>	<b>0.078 N</b>	<b>USEPA RSL</b>	<b>0.026</b>	<b>0.1</b>	<b>0.04</b>	<b>0.0094</b>
Vanadium	7440-62-2	39 N	USEPA RSL	13	2.5	0.4	0.04
Zinc	7440-66-6	2300 N	USEPA RSL	770	2.5	1.0	0.17

Notes:

- 1 The PSLs are for use as part of COPC screening in the risk assessment. Chemicals with concentrations that exceed PSLs and facility background levels (based on a statistical comparison of the site data set to the facility background data set) will be selected as COPCs. The PSLs are the USEPA residential Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C). PSLs are NA for chemicals that do not have screening levels.
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data.
- 3 Thallium toxicity criterion is only suitable for screening and is not used for quantifying risks.

Matrix: Soil

Analytical Group: PAHs  
 Selected Ion Monitoring (SIM) Analysis  
**SW-846 Method 8270D SIM**

Analyte	CAS No.	PSL (µg/kg)	PSL Reference <sup>1</sup>	Project QL Goal (µg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ (µg/kg)	LOD (µg/kg)	DL (µg/kg)
Acenaphthene	83-32-9	350000 N	USEPA RSL	120000	20	10	1.5
Acenaphthylene	208-96-8	350000 N (based on acenaphthene)	USEPA RSL	120000	20	10	1.2
Anthracene	120-12-7	1700000 N	USEPA RSL	570000	20	10	1.2
Benzo(a)anthracene	56-55-3	150 C	USEPA RSL	50	20	10	1.9
<b>Benzo(a)pyrene</b>	<b>50-32-8</b>	<b>15 C</b>	<b>USEPA RSL</b>	<b>5</b>	<b>20</b>	<b>10</b>	<b>3.3</b>
Benzo(b)fluoranthene	205-99-2	150 C	USEPA RSL	50	20	10	2.4
Benzo(g,h,i)perylene	191-24-2	170000 N (based on pyrene)	USEPA RSL	57000	20	10	2.0
Benzo(k)fluoranthene	207-08-9	1500 C	USEPA RSL	500	20	10	3.1
Chrysene	218-01-9	15000 C	USEPA RSL	5000	20	10	1.7
<b>Dibenzo(a,h)anthracene</b>	<b>189-64-0</b>	<b>15 C</b>	<b>USEPA RSL</b>	<b>5</b>	<b>20</b>	<b>10</b>	<b>1.8</b>
Fluoranthene	206-44-0	230000 N	USEPA RSL	77000	20	10	1.8
Fluorene	86-73-7	230000 N	USEPA RSL	77000	20	10	3.2
Indeno(1,2,3-CD)pyrene	193-39-5	150 C	USEPA RSL	50	20	10	1.9
Naphthalene	91-20-3	3800 C	USEPA RSL	1300	20	10	2.6

**Matrix:** Soil

**Analytical Group:** PAHs  
 Selected Ion Monitoring (SIM) **SW-846 Method 8270D SIM**  
 Analysis

Analyte	CAS No.	PSL (µg/kg)	PSL Reference <sup>1</sup>	Project QL Goal (µg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ (µg/kg)	LOD (µg/kg)	DL (µg/kg)
Phenanthrene	85-01-8	170000 N (based on pyrene)	USEPA RSL	57000	20	10	1.8
Pyrene	129-00-0	170000 N	USEPA RSL	57000	20	10	2.1

**Notes:**

- 1 The PSLs are for use as part of COPC screening in the risk assessment. Chemicals with concentrations that exceed the PSLs and facility background levels (based on a statistical comparison of the site data set to the facility background data set) will be selected as COPCs. The PSLs are the USEPA residential RSLs for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C).
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data.

**Matrix:** Soil

**Analytical Group:** EPH  
 Selected Ion Monitoring (SIM) **MADEP/EPH**  
 Analysis

Analyte	MEDEP No.	PSL (mg/kg)	PSL Reference <sup>1</sup>	Project QL Goal (mg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ (µg/kg)	LOD (µg/kg)	DL (µg/kg)
Total EPH C9-C18 Aliphatics	DEP2043	2700	MEDEP	900	20	15	10
Total EPH C19-C36 Aliphatics	DEP2042	10000	MEDEP	3333	20	15	10
Total EPH C11-C22 Aliphatics	DEP2041	750	MEDEP	250	20	15	10

**Notes:**

- 1 The PSLs are for use as part of screening to provide an evaluation in the uncertainty section of the risk assessment, but COPCs will not be selected based on this screening. Chemicals with concentrations that exceed the PSLs and facility background levels (based on a statistical comparison of the site data set to the facility background data set) will be discussed in the RI. The PSLs are based on the MEDEP Remedial Action Guidelines for Sites Contaminated with Hazardous Substances (MEDEP, May 2013) and Remediation Guidelines for Petroleum Contaminated Sites in Maine (MEDEP, December 2009) . The values shown are based on a target hazard quotient of 1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-5}$  for carcinogens (C).
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data.

Matrix: Groundwater

Analytical Group: TAL  
 Metals (Total and  
 Dissolved)

SW-846 Method 6010 limits with the exception of antimony, arsenic, beryllium, cadmium, cobalt, selenium, silver, thallium and vanadium (SW-846 Method 6020 limits presented). Mercury by SW-846 Method 7470A.

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Aluminum	7429-90-5	2000 N	1150000 N	USEPA RSL/ PNS CW SL	670	300	100	14.8
<b>Antimony</b>	<b>7440-36-0</b>	<b>0.78 N</b>	<b>138 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.26</b>	<b>1.0</b>	<b>0.5</b>	<b>0.054</b>
<b>Arsenic</b>	<b>7440-38-2</b>	<b>0.052 C</b>	<b>345 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.017</b>	<b>5.0</b>	<b>4.0</b>	<b>2.25</b>
Barium	7440-39-3	380 N	35700 N	USEPA RSL/ PNS CW SL	130	5.0	3.0	0.23
Beryllium	7440-41-7	2.5 N	97.2 N	PNS CW SL	0.83	1.0	0.2	0.034
<b>Cadmium</b>	<b>7440-43-9</b>	<b>0.92 N</b>	<b>65.4 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.31</b>	<b>1.0</b>	<b>0.2</b>	<b>0.03</b>
Calcium	7440-70-2	NA	NA	USEPA RSL/ PNS CW SL	NA	100	80	11.2
Chromium	7440-47-3	2200 N	27100 N	USEPA RSL/ PNS CW SL	730	10	4.0	0.36
<b>Cobalt</b>	<b>7440-48-4</b>	<b>0.6 N</b>	<b>4570 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.20</b>	<b>1.0</b>	<b>0.3</b>	<b>0.06</b>
Copper	7440-50-8	80 N	46000 N	USEPA RSL/ PNS CW SL	27	25	10	0.63
Iron	7439-89-6	1400 N	804000 N	USEPA RSL/ PNS CW SL	470	100	80	5.42
Lead	7439-92-1	15	1340	USEPA RSL/ PNS CW SL	5	5.0	4.0	1.07

Matrix: Groundwater

Analytical Group: TAL  
 Metals (Total and  
 Dissolved)

SW-846 Method 6010 limits with the exception of antimony, arsenic, beryllium, cadmium, cobalt, selenium, silver, thallium and vanadium (SW-846 Method 6020 limits presented). Mercury by SW-846 Method 7470A.

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Magnesium	7439-95-4	NA	NA	USEPA RSL/ PNS CW SL	NA	100	80	7.8
Manganese	7439-96-5	43 N	2550 N	USEPA RSL/ PNS CW SL	14	5.0	4.0	1.06
Mercury	7439-97-6	0.57 (mercuric chloride)	357 (mercuric chloride)	USEPA RSL/ PNS CW SL	0.19	0.2	0.1	0.013
Nickel	7440-02-0	39 N	8710 N	USEPA RSL/ PNS CW SL	13	10	4.0	0.28
Potassium	7440-09-7	NA	NA	USEPA RSL/ PNS CW SL	NA	1000	500	41
Selenium	7782-49-2	10 N	5750 N	USEPA RSL/ PNS CW SL	3.3	5.0	3.0	0.19
Silver	7440-22-4	9.4 N	853 N	PNS CW SL	3.1	1.0	0.4	0.05
Sodium	7440-23-5	NA	NA	USEPA RSL/ PNS CW SL	NA	1000	500	23.7
<b>Thallium <sup>3</sup></b>	<b>7440-28-0</b>	<b>0.020 N</b>	<b>46.0 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.0067</b>	<b>1.0</b>	<b>0.4</b>	<b>0.06</b>
Vanadium	7440-62-2	8.6 N	703 N	USEPA RSL/ PNS CW SL	2.9	5.0	4.0	0.51
Zinc	7440-66-6	600 N	412000 N	USEPA RSL/ PNS CW SL	200	20	10	0.73

Notes:

1 If the majority of groundwater at the site is fresh water, the PSLs for fresh water will be used as part of COPC selection. Otherwise, the PSLs for brackish or saline water will be used as part of COPC selection. The PSLs for fresh water are the USEPA Tap water RSLs for Chemical

Contaminants at Superfund Sites, RSL Table, May 2014. The PSLs for brackish or saline water are PNS-specific screening levels for construction worker contact (dermal) with groundwater (PNS CW SL) that were calculated using the methodology provided in Appendix A.4. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C). PSLs are NA for chemicals that do not have screening levels.

- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data. If the LOQ and LOD exceed the PSL, bold text and shading are used for the entire row of data.
- 3 Thallium toxicity criterion is only suitable for screening and is not used for quantifying risks.

Matrix: Groundwater

Analytical Group: PAHs SIM **SW-846 Method 8270D SIM**  
 Analysis

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Acenaphthene	83-32-9	53 N	3760 N	USEPA RSL/ PNS CW SL	18	0.2	0.1	0.064
Acenaphthylene	208-96-8	53 N (based on acenaphthene)	1080 N	USEPA RSL/ PNS CW SL	18	0.2	0.1	0.054
Anthracene	120-12-7	180 N	10100 N	USEPA RSL/ PNS CW SL	60	0.2	0.1	0.044
<b>Benzo(a)anthracene</b>	<b>56-55-3</b>	<b>0.034 C</b>	<b>1870 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.046</b>
<b>Benzo(a)pyrene</b>	<b>50-32-8</b>	<b>0.0034 C</b>	<b>187 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.0011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.066</b>
<b>Benzo(b)fluoranthene</b>	<b>205-99-2</b>	<b>0.034 C</b>	<b>1870 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.089</b>
Benzo(g,h,i)perylene	191-24-2	12 N (based on pyrene)	21.0 N	USEPA RSL/ PNS CW SL	4.0	0.2	0.1	0.065
Benzo(k)fluoranthene	207-08-9	0.34 C	18700 C	USEPA RSL/ PNS CW SL	0.11	0.2	0.1	0.049
Chrysene	218-01-9	3.4 C	187000 C	USEPA RSL/ PNS CW SL	1.1	0.2	0.1	0.036
<b>Dibenzo(a,h)anthracene</b>	<b>189-64-0</b>	<b>0.0034 C</b>	<b>187 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.0011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.070</b>
Fluoranthene	206-44-0	80 N	779000 N	USEPA RSL/ PNS CW SL	27	0.2	0.1	0.073
Fluorene	86-73-7	29 N	5650 N	USEPA RSL/ PNS CW SL	9.7	0.2	0.1	0.061

Matrix: Groundwater

Analytical Group: PAHs SIM **SW-846 Method 8270D SIM**  
 Analysis

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Indeno(1,2,3-CD)pyrene	193-39-5	0.034 C	1870 C	USEPA RSL/ PNS CW SL	0.011	0.2	0.1	0.052
Naphthalene	91-20-3	0.17 C	23600 N	USEPA RSL/ PNS CW SL	0.057	0.2	0.1	0.064
Phenanthrene	85-01-8	12 N (based on pyrene)	58400 N	USEPA RSL/ PNS CW SL	4.0	0.2	0.1	0.051
Pyrene	129-00-0	12 N	1850 N	USEPA RSL/ PNS CW SL	4.0	0.2	0.1	0.059

Notes:

- 1 If the majority of groundwater at the site is fresh water, the PSLs for fresh water will be used as part of COPC selection. Otherwise, the PSLs for brackish or saline water will be used as part of COPC selection. The PSLs for fresh water are the USEPA Tap water RSLs for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The PSLs for brackish or saline water are PNS-specific screening levels for construction worker contact (ingestion and dermal) with groundwater (PNS CW SL) that were calculated using the methodology provided in Appendix A.4. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C). PSLs are NA for chemicals that do not have screening levels.
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data. If the LOQ and LOD exceed the PSL, bold text and shading are used for the entire row of data.

Matrix: Groundwater

Analytical Group: EPH  
 SIM Analysis

Analyte	MEDEP No.	PSL Residential (µg/L) <sup>1</sup>	PSL Construction Worker (µg/L) <sup>1</sup>	PSL Reference <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Total EPH C9-C18 Aliphatics	DEP2043	700	1900	MEDEP	233	100	75	50
Total EPH C19-C36 Aliphatics	DEP2042	10000	59000000	MEDEP	3333	100	75	50
Total EPH C11-C22 Aliphatics	DEP2041	200	1600	MEDEP	67	100	75	50

Notes:

- 1 The PSLs are for use as part of screening to provide an evaluation in the uncertainty section of the risk assessment, but COPCs will not be selected based on this screening. Chemicals with concentrations that exceed the PSLs and facility background levels (based on a statistical comparison of the site data set to the facility background data set) will be discussed in the RI. The PSLs are based on the MEDEP Remedial Action Guidelines for Sites Contaminated with Hazardous Substances (MEDEP, May 2013). The values shown are based on a target hazard quotient of 1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-5}$  for carcinogens (C).
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data.

## **SAP WORKSHEET #16: PROJECT SCHEDULE/TIMELINE TABLE (OPTIONAL FORMAT)**

[\(UFP-QAPP Manual Section 2.8.2\)](#)

The schedule for this RI will be handled outside of the UFP-SAP, and based on the PNS Site Management Plan for Fiscal Year (FY) 15.

## **SAP WORKSHEET #17: SAMPLING DESIGN AND RATIONALE**

[\(UFP-QAPP Manual Section 3.1.1\)](#)

Figure 8 presents the proposed locations additional soil samples, monitoring wells, and tidal staff gauges.

### **Soil**

A stratified random soil sampling design was used to determine the number of samples appropriate to refine the conceptual site model for the site, but because of physical limits include buildings and utility corridors, the sampling locations had to be selected preferentially at OU8. The goal is to collect enough samples to calculate mean concentrations for comparison to the appropriate risk-based action levels (see Worksheet #11) with the decision error rates specified in Appendix A. It was determined in Section 11.5 that a minimum of 18 soil sample locations are needed. Three soil samples will be collected from 18 locations (WTB-SS/SB08 through WTB-SS/SB25) at OU8. The soil sample locations were selected by dividing the site into 100-foot by 100-foot grid cells and then selecting one location in each cell that would not disrupt site infrastructure or activities. This method was used to ensure comprehensive spatial representation of the exposure unit while avoiding biases to the extent possible. Because of the new addition to Building 174, access around the area and in the building will be limited and therefore soil samples will not be collected in this area. One surface and two subsurface soil samples will be collected from each location at the targeted depths (see Worksheet #18).

### **Groundwater**

The two additional monitoring wells (WTB-MW06 and WTB-MW07) will provide data between existing wells, and will help to ensure that groundwater contamination is detected and quantified. The wells will be installed to total depths between approximately 14 to 17 feet bgs. Groundwater samples will be collected from the existing upgradient well (WTB-MW01) and the six wells within or downgradient of the exposure unit (WTB-MW02 through WTB-MW07) using low-flow methods during low tidal periods, based on tidal lags (see the following discussion), and analyzed by the fixed-base laboratory for PAHs, EPH, and TAL metals.

To estimate tidal influence, a tidal study will be conducted. The tidal study will provide data on the magnitude of tidal influence and the tidal lag at each well location. The tidal study will be performed in the upgradient (WTB-MW01) and OU8 wells (WTB-MW02 through MW07) and the two staff gauges over at least two tidal cycles (2 to 3 days).

To estimate the hydraulic conductivity of the shallow aquifer zone at the site, slug tests will be conducted in at least three monitoring wells. The slug tests will be conducted immediately following the tidal study because transducers will be on site and already installed in wells. The proposed wells to be tested

include WTB-MW02 or WTB-MW07 (depending on the lithology encountered during drilling of WTB-MW07) in the northern portion of the site, WTB-MW03 in the east-central portion of the site, and WTB-MW06 south of the site. These wells will provide spatial distribution as well as provide information about differing lithologies throughout the site.

### **Soil Boring Advancement and Soil Sampling**

Surface and subsurface soil samples will be collected from soil borings advanced in accordance with Tetra Tech SOP SA-2.5 [Direct Push Technology (Geoprobe®/Hydropunch™), included in Appendix C. Soil samples will be collected continuously in 4-foot-long samplers with disposable acetate sleeves during soil boring advancement. The soil collected from the borings will be described by field personnel in accordance with Tetra Tech SOP GH-1.5 (Borehole and Sample Logging) (Appendix C) and recorded on a soil boring log (Appendix B). The descriptions will include color, material [as classified by the Unified Soil Classification System (USCS)], Flame Ionization Detector (FID)/Photoionization Detector (PID) readings (if required), moisture, and any other pertinent observations (e.g., depth to water, odors, staining, etc.). To minimize any depressions in pavement, the soil borings will be backfilled with bentonite chips to above the mean high water table, then filled with bentonite grout to approximately 2 feet bgs, and filled with concrete to ground surface.

Surface and subsurface soil samples for laboratory analyses will be collected in accordance with Tetra Tech SOP SA-1.3 (Soil Sampling) included in Appendix C. A soil sample log sheet will be prepared for each soil sample collected and submitted to the laboratory. A copy of the soil sample log sheet is included in Appendix B.

### **Monitoring Well Installation and Development**

Two new groundwater monitoring wells will be installed at OU8 and developed in accordance with Tetra Tech SOP GH-2.8 (Groundwater Monitoring Well Installation). Monitoring well borings will be installed using hollow-stem auger (HSA) drilling techniques. The well borings will be advanced using 4-1/4-inch inside diameter (nominal 8-inch outside diameter) HSAs in accordance with Tetra Tech GH-1.3 (Soil and Rock Drilling Methods) (Appendix C). Soil will be collected continuously using split-barrel samplers during drilling to provide lithology information. The soil will be described in accordance with Tetra Tech SOP GH-1.5, and the information, including other pertinent information (e.g., depth to water, odors, staining, etc.), will be recorded on soil boring logs (Appendix B).

The monitoring wells will be installed such that the majority (approximately 6 to 8 feet) of the screened interval will be submerged below the water table during the low tide periods. It is anticipated that the wells will be screened with the bottoms of the well screens at 14 to 17 feet bgs.

The monitoring wells will be constructed of 2-inch-diameter, Schedule 40, flush-joint, polyvinyl chloride (PVC) riser pipe and slotted screen. The well screens will be 10 feet long and have a slot size of 0.010-inch (factory slotted). A sand filter pack will be placed in the annular space around the well screen to approximately 1 to 2 feet above the top of the well screen. A 2-foot-thick bentonite seal will be installed above the sand filter pack, and the wells will be completed at the surface with steel, flush-to-grade, protective casings set in a concrete well pad. If 3 feet or more of annular space remains above the bentonite seal, cement-bentonite grout will be placed above the seal to approximately 1 foot bgs; otherwise, the remaining annular space will be filled with concrete used for the well pad. Well construction details will be recorded on monitoring well construction sheets (Appendix B).

The wells will be developed no sooner than 48 hours after well completion to remove any fine-grained sediments that may have been introduced into the well during advancement and completion efforts and to enhance the hydraulic connection between the sand pack and the surrounding formation. The wells will be developed during high tide conditions by surging and pumping until the discharge water is visibly clear of sediment and turbidity measurements are less than 10 Nephelometric Turbidity Units (NTUs); however, development time will not exceed 2 hours per well. Well development information will be recorded on well development logs (Appendix B). Development water will be containerized in 55-gallon drums and managed as IDW.

### **Groundwater Purging and Sampling**

Groundwater samples will be collected using low-flow groundwater purging and sampling techniques, in accordance with USEPA Region 1 Low-Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells (Appendix C). Groundwater will be purged using a bladder pump or peristaltic pump. The intake of the pump or tubing will be placed such that it is in the middle of the saturated well screen.

Water quality parameters (pH, conductivity, temperature, dissolved oxygen, and oxidation-reduction potential) will be measured during purging using a water-quality instrument equipped with a flow-through cell. Turbidity will be measured using a Lamotte 2020 (or equivalent) from a sample collected from a "T" connector before the flow-through cell. Water quality measurements along with depths to water will be recorded on the well purging log sheet every 3 to 5 minutes, depending on the volume of the low-flow cell. Purging will continue until water quality parameter readings have stabilized to within the criteria in the USEPA Region 1 SOP. Purge water will be containerized in 55-gallon drums and managed as IDW.

Groundwater samples will be collected directly from the tubing discharge following disconnection from the flow-through cell. Purging and sample information will be collected on groundwater sample log sheets, provided in Appendix B.

### **Tidal Study**

The tidal study will be performed by installing pressure transducers in the upgradient (WTB-MW01) and OU8 wells (WTB-MW02 through MW07) and the two staff gauges and measuring water levels electronically over at least two tidal cycles (2 to 3 days). The transducers will collect data linearly at 5-minute intervals. Tidal lags will be estimated by comparisons of hydraulic head responses in individual wells to the tidal staff gauges. The hydraulic head responses in the wells and at the staff gauges will be graphed, and the tidal lag will be determined from the difference between the nearest wave crests. If no observable change (less than 0.1-foot change) is identified in the graphs for a well, the well will be considered not to be tidally influenced, and groundwater samples may be collected independent of the tidal cycle.

Manual water level measurements will be collected during the tidal study at predicted consecutive high and low tides each day. Water levels will be obtained from upgradient monitoring well WTB-MW01, the OU8 monitoring wells (WTB-MW02 through WTB-MW07), and the two staff gauges (WTB-SG01 and WTB-SG02) at the predicted low tide and predicted high tide each day of the study. Each set of water level measurements will be obtained within a 1-hour period and no sooner than 24 hours after a significant precipitation event to minimize the effects of the tide and precipitation on the data sets. The water level measurements will be taken with an electrical water level indicator using the top of the inner well casings in the monitoring wells and the reference points (marking on stilling well, if installed, or pier) for the staff gauge as the reference points for determining depths to water. Water level measurements will be recorded to the nearest 0.01 foot in the field logbook and on a groundwater level measurement form (Appendix B).

### **In-Situ Hydraulic Conductivity Testing**

In-situ hydraulic conductivity testing (i.e., slug tests) will be performed in accordance with Tetra Tech SOP GH-2.4 (In-Situ Hydraulic Conductivity Testing). The slug tests will be conducted immediately following completion of the tidal study. Solid PVC slugs will be used to induce water level changes in the wells, and the transducers will record the changes in the water levels at logarithmic intervals. Falling and rising head tests will be conducted in each well tested, unless the water level is below the top of the well screen. In such a case, only a rising head test will be performed. Slug test information will be recorded on Hydraulic Conductivity Testing Sheets (Appendix B), and slug test data will be analyzed using the Bouwer and Rice method (Bouwer, 1989) to estimate hydraulic conductivity values.

## **Equipment Decontamination**

Non-dedicated and non-disposable equipment items that come in contact with site media (soil and groundwater) will be decontaminated in accordance with Tetra Tech SOP 7.1 (Decontamination of Field Equipment).

New, disposable, sampling materials (e.g., DPT acetate sleeves or tubing or bladders for pumps) will not require decontamination before use. Disposable items will be handle as residual waste by double-bagging and placing them in a dumpster at PNS.

### SAP WORKSHEET #18: LOCATION-SPECIFIC SAMPLING METHODS/SOP REQUIREMENTS TABLE

[\(UFP-QAPP Manual Section 3.1.1\)](#)

Sampling Location/ID Number	Matrix	Depth	Analytical Group	Number of Samples (identify field duplicates)	Sampling SOP Reference <sup>(1)</sup>
WTB-SS08 to WTB-SS25/WTB-SS-08-0002 to WTB-SS-25-0002	Surface soil	0 to 2 feet bgs	PAHs (SIM), EPH and TAL metals	18 plus 2 duplicates	CT-04, HS-1.0, GH-1.3, GH-1.5, SA-1.3, SA-2.5, SA-6.1, SA-6.3, SA-7.1
WTB-SB08 to WTB-SB25/ WTB-SB-08-0205 to WTB-SB-25-0205	Shallow subsurface soil	2 to 6 feet bgs		18 plus 2 duplicates	
WTB-SB08 to WTB-SB25/WTB-SB-08-0508 to WTB-SB-25-0508	Deeper subsurface soil	6 to 10 feet bgs (or to refusal if shallower than 10 feet bgs)		18 plus 2 duplicates	
WTB-MW01 to WTB-MW07/WTB-GW-MW01 to WTB-GW-MW07	Groundwater		PAHs (SIM), EPH and TAL metals	7 plus 1 duplicate	CT-04, SA-6.1, SA-6.3, SA-7.1, SA-1.1

1 SOP or worksheet that describes the sample collection procedures.

## SAP WORKSHEET #19: FIELD SAMPLING REQUIREMENTS TABLE

[\(UFP-QAPP Manual Section 3.1.1\)](#)

Matrix	Analytical Group	Analytical and Preparation Method/SOP Reference	Containers (number, size, and type)	Sample Volume (units)	Preservation Requirements (chemical, temperature, light protected)	Maximum Holding Time <sup>(1)</sup> (preparation/analysis)
Groundwater and Aqueous QC Samples	PAHs	SW-846 3510C or 3520C, 8270D SIM/CA-213, CA-502	Two 1 - liter (L) glass amber bottles	1,000 milliliters (mL)	Cool to < 6 °C	7 days until extraction, 40 days to analysis
	Metals	SW-846 3010A, 6010C, 7470A/ CA-604, CA-608, CA-615, CA-627	One 500-mL polyethylene bottle	50 mL / 25 mL mercury	Nitric acid to pH <2; Cool to < 6 °C	6 months to analysis, except mercury, which is 28 days to analysis
	EPH	MADEP/EPH	Two 1 - liter (L) glass amber bottles	1,000 milliliters (mL)	Cool to < 4 °C	14 days until extraction, 40 days to analysis
Soil	PAHs	SW-846 3540C or 3550C, 8270D SIM/CA-213, CA-512, CA-526	8-oz glass wide-mouth jar with a Teflon-lined lid	30 grams (g)	Cool to < 6 °C	14 days from sampled date to extract/40 days from extraction to analysis
	Metals	SW-846 3050B, 6010C, 7471B/CA-605, CA-608, CA-611, CA-627	4-oz glass wide-mouth jar with a Teflon-lined lid	2 g/1 g mercury	Cool to < 6 °C	6 months to analysis, except mercury, which is 28 days to analysis
	EPH	MADEP/EPH	4-oz glass wide-mouth jar with a Teflon-lined lid	10 g	Cool to < 4 °C, add HCl to pH<2	14 days until extraction, 40 days to analysis

1 Maximum holding time is calculated from the time the sample is collected to the time the sample is prepared/extracted.

### SAP WORKSHEET #20: FIELD QUALITY CONTROL SAMPLE SUMMARY TABLE

[\(UFP-QAPP Manual Section 3.1.1\)](#)

Matrix	Analytical Group	No. of Sampling Locations	No. of Field Duplicates	No. of MS/MSDs	No. of Field Blanks	No. of Equip. Blanks	No. of VOA Trip Blanks	No. of PT Samples	Total No. of Samples to Lab
Surface Soil	TAL metals	18	2	1	0	1	0	0	22
	PAHs	18	2	1	0	1	0	0	22
	EPH	18	2	1	0	1	0	0	22
Shallow Subsurface Soil	TAL metals	18	2	1	0	0	0	0	21
	PAHs	18	2	1	0	0	0	0	21
	EPH	18	2	1	0	0	0	0	21
Deeper Subsurface Soil	TAL metals	18	2	1	0	0	0	0	21
	PAHs	18	2	1	0	0	0	0	21
	EPH	18	2	1	0	0	0	0	21
Groundwater	TAL metals	7	1	1	0	0	0	0	9
	PAHs	7	1	1	0	0	0	0	9
	EPH	7	1	1	0	0	0	0	9

VOA Volatile organic analysis.

PT Proficiency test.

## SAP WORKSHEET #21: PROJECT SAMPLING SOP REFERENCES TABLE

[\(UFP-QAPP Manual Section 3.1.2\)](#)

Reference Number	Title, Revision Date and/or Number	Originating Organization of Sampling SOP	Equipment or Method Type	Modified for Project Work? (Y/N)	Comments
CT-04	Sample Nomenclature	Tetra Tech	NA	N	None.
GH-1.2	Evaluation of Existing Monitoring Wells and Water Level Measurement	Tetra Tech	Water level indicator	Y	None.
GH-1.3	Soil and Rock Drilling Methods	Tetra Tech	Drilling rig and accessories	Y	None.
GH-1.5	Borehole and Sample Logging	Tetra Tech	Geological logging	Y	None.
GH-2.4	In-Situ Hydraulic Conductivity Testing	Tetra Tech	Pressure transducers, water level indicator	Y	None.
GH-2.8	Groundwater Monitoring Well Installation	Tetra Tech	Drilling rig and accessories	Y	None.
HS-1.0	Utility Locating and Excavation Clearance	Tetra Tech	Remote subsurface sensing, magnetometer, ground-penetrating radar	Y	None.
SA-1.1	Groundwater Sample Acquisition and Onsite Water Quality Testing	Tetra Tech	Multi-parameter water quality meter, water level indicator, pH paper, all necessary pumps, stop watch, pails, buckets, towels, sampling equipment, and decontamination solutions.	Y	None.
SA-1.3	Soil Sampling	Tetra Tech	DPT methods	Y	None.
SA-2.5	Direct Push Technology (Geoprobe®/Hydropunch™)	Tetra Tech	Macrocore sampler, probe sampling adaptors, Roto-hammer with bit, disposable acetate liners, cast aluminum or steel drive points, and Geoprobe® Sampler	Y	None.
SA-6.1	Non-Radiological Sample Handling	Tetra Tech	Sample bottleware, packaging materials, and shipping materials	Y	None.
SA-6.3	Field Documentation	Tetra Tech	Field logbook, field sample forms, boring logs, and soil sample log sheets	Y	None.
SA-7.1	Decontamination of Field Equipment	Tetra Tech	Decontamination equipment, scrub brushes, phosphate-free detergent, and deionized water	Y	None.
USEPA SOP-GW 0001	Low-Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells	USEPA, Region 1	Peristaltic pump or bladder pump, Water-quality meter, and water-level indicator	N	None.

## SAP WORKSHEET #22: FIELD EQUIPMENT CALIBRATION, MAINTENANCE, TESTING, AND INSPECTION TABLE

[\(UFP-QAPP Manual Section 3.1.2.4\)](#)

Field Equipment	Activity	Frequency	Acceptance Criteria	Corrective Action	Resp. Person	SOP Reference	Comments
Water Quality Meter (YSI 600 Series or Equivalent)	Visual Inspection Calibration/ Verification	Daily  Beginning and end of day	Manufacturer's guidance	Operator correction or replacement	Tetra Tech FOL or designee	SA-1.1, Manufacturer's Guidance Manual	None.
Turbidimeter (LaMotte 2020 or Equivalent)	Visual Inspection Calibration/ Verification	Daily  Beginning and end of day	Manufacturer's guidance; calibrations must bracket expected values; Initial Calibration Verification (ICV) must be <5 NTUs.	Operator correction or replacement	Tetra Tech FOL or designee	SA-1.1, Manufacturer's Guidance Manual	None.
Electric Water Level Indicator	Visual Inspection Field checks as per manufacturer	Daily  Once upon receiving from vendor	0.01-foot accuracy	Operator correction or replacement	Tetra Tech FOL or designee	GH-1.2, Manufacturer's Guidance Manual	None.
Pressure Transducer	Visual Inspection Field checks as per manufacturer	Daily  Once upon receiving from vendor	Manufacturer's Specifications	Replacement	Tetra Tech FOL or designee	GH-2.4, Manufacturer's Guidance Manual	None.

## SAP WORKSHEET #23: ANALYTICAL SOP REFERENCES TABLE

[\(UFP-QAPP Manual Section 3.2.1\)](#)

Lab SOP Number	Title, Revision Date, and/or Number	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work? (Y/N)
CA-213	Analysis of Semivolatile Organic Compounds By: SW 846 Method 8270 – Modified for Selected Ion Monitoring (SIM), 04/10, Revision 8.	Definitive	Soil, groundwater, and aqueous QC samples/PAH	GC/MS	Katahdin	N
CA-502	Preparation of Aqueous Samples for Extractable Semivolatile Analysis, 10/09, Revision 6.	Definitive	Groundwater and aqueous QC samples /PAH extraction	Not applicable (extraction)	Katahdin	N
CA-512	Preparation of Sediment/Soil Samples By Sonication Using Method 3550 for Subsequent Extractable Semivolatiles Analysis, 08/10, Revision 8.	Definitive	Soil/PAH extraction	Not applicable (extraction)	Katahdin	N
CA-526	Preparation of Sediment/Soil Samples by Soxhlet Extraction Using Method 3540 for Subsequent Extractable Semivolatile Analysis, 08/10, Revision 7.	Definitive	Soil/PAH extraction	Not applicable (extraction)	Katahdin	N
CA-604	Acid Digestion of Aqueous Samples by USEPA Method 3010 for ICP and ICP-MS Analysis of Total or Dissolved Metals, 04/10, Revision 5.	Definitive	Groundwater and aqueous QC samples /metals digestion	Not applicable (digestion)	Katahdin	N
CA-605	Acid Digestion of Solid Samples by USEPA Method 3050 for Metals by ICP-AES and GFAA, 09/10, Revision 5.	Definitive	Soil/metals digestion	Not applicable (digestion)	Katahdin	N
CA-608	Trace Metals Analysis by ICP-AES Using USEPA Method 6010, 06/10, Revision 11.	Definitive	Soil, groundwater, and aqueous QC samples /metals	Inductively Coupled Plasma (ICP) - Atomic Emission Spectroscopy (AES)	Katahdin	N
CA-611	Digestion and Analysis of Solid Samples for Mercury by USEPA Method 7471, 12/10, Revision 8.	Definitive	Soil/mercury	Mercury Analyzer	Katahdin	N
CA-615	Digestion and Analysis of Aqueous Samples for Mercury by USEPA Method 7470, 04/10, Revision 5.	Definitive	Groundwater and aqueous QC samples/mercury	Mercury Analyzer	Katahdin	N
MADEP-EPH-04	Method of the Determination of Extractable Petroleum Hydrocarbons, 05/04 Revision 1.1	Definitive	Soil and aqueous/EPH	GC/MS	Katahdin	N

GFAA Graphite Furnace Atomic Absorption  
 ICP-MS Inductively Coupled Plasma-Mass Spectroscopy  
 GC/MS Gas Chromatograph/Mass Spectrometer

### SAP WORKSHEET #24: ANALYTICAL INSTRUMENT CALIBRATION TABLE

[\(UFP-QAPP Manual Section 3.2.2\)](#)

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action <sup>(2)</sup>	SOP Reference
GC/MS (SIM) PAHs	Decafluorotriphenylphosphine (DFTPP) Tune	Prior to each initial calibration and at the beginning of every 12-hour analytical sequence.	Criteria listed in Section 7.4, current revision of SOP CA-213	Retune and/or clean source.	Analyst, Supervisor	CA-213
	Initial calibration (ICAL) - A minimum five-point calibration is required	Instrument receipt, instrument change (new column, source cleaning, etc.), when continuing calibration verification (CCV) is out of criteria. Five-point initial calibration for all analytes.	Project-specific criteria: The average response factor (RF) for all target compounds must be $\geq 0.050$ .  The percent relative standard deviation (%RSD) for RFs for calibration check compounds (CCCs) must be $\leq 30\%$ , and one option below must be met: Option 1) %RSD < 15% for all other compounds. If not met: Option 2) Linear least squares regression: $r \geq 0.995$ Option 3) Non-linear regression: $r^2 \geq 0.99$ (six points for second order).	Recalibrate and/or perform the necessary equipment maintenance. Check the calibration standards. Reanalyze the affected data.	Analyst, Supervisor	
	Retention Time (RT) Window Position Establishment	Once per ICAL for each analyte and surrogate.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA	Analyst, Supervisor	

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action <sup>(2)</sup>	SOP Reference
	Evaluation of Relative Retention Times (RRTs)  ICV - Second Source	With each sample.  Once after each ICAL.	RRT of each target analyte must be within $\pm 0.06$ RRT units.  The percent recovery (%R) must be within 80-120% for all target compounds.	Correct problem, then rerun ICAL.  Correct problem and verify second source standard. Rerun second source verification. If that fails, correct problem and repeat ICAL.	Analyst, Supervisor  Analyst, Supervisor	
	CCV	Analyze a standard at the beginning of each 12-hour shift after a DFTPP tune.	The RF for all target compounds must be $\geq 0.050$ .  The percent difference or drift (%D) for all target compounds and surrogates must be $\leq 20\%$ .	Department of Defense (DoD) project-level approval must be obtained for each of the failed analytes, or corrective action must be taken. Correct problem then rerun calibration verification. If that fails, then repeat ICAL. Reanalyze all samples since last acceptable CCV.	Analyst, Supervisor	

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action <sup>(2)</sup>	SOP Reference
ICP-AES - Metals	ICAL - a one-point calibration per manufacturer's guidelines is prepared for all target analytes	At the beginning of each day or if QC is out of criteria prior to sample analysis.	None; only one high standard and a calibration blank must be analyzed. If more than one calibration standard is used, r must be $\geq 0.995$ .	Recalibrate and/or perform the necessary equipment maintenance. Check the calibration standards. Reanalyze the affected data.	Analyst, Supervisor	CA-608
	ICV (second source)	Once after each ICAL, prior to beginning a sample run.	The %R must be within 90-110% of true value for all analytes.	Investigate reasons for failure, and reanalyze once. If still unacceptable, correct problem and repeat ICAL.	Analyst, Supervisor	
	Calibration Blank (initial and continuing)	Before beginning a sample sequence, after every 10 samples, and at end of the analysis sequence.	No analytes detected > LOD. For negative blanks, absolute value < LOD.	Correct problem. Reprep and reanalyze calibration blank. All samples following the last acceptable calibration blank must be reanalyzed.	Analyst, Supervisor	
	CCV	After every 10 samples and at the end of each run sequence.	The %R must be within 90-110% of true value for all analytes.	Correct problem, and rerun calibration verification. If that fails, then repeat ICAL. Reanalyze all samples since the last successful calibration verification.	Analyst, Supervisor	

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action <sup>(2)</sup>	SOP Reference
ICP-AES - Metals	Low-level Calibration Check Standard (if using one-point ICAL)	Daily after one-point ICAL and before samples.	The %R must be within 80-120% of true value for all analytes.	Do not use results for failing elements, unless low-level standard recovery > upper limit and sample results are non-detect. Investigate and correct the problem.	Analyst, Supervisor	
	Interference Check Standards (ICSs – ICS A and ICS B)	At the beginning of an analytical run.	ICS A recoveries must be within the absolute value of the LOD, and ICS B recoveries must be within 80-120 %R of true value.	Terminate analysis; locate and correct problem; reanalyze ICS.	Analyst/Supervisor	
Mercury Analyzer	ICAL	Upon instrument receipt, after a major instrument change, and at the start of each day.	Initial Calibration, five points plus a calibration blank - $r \geq 0.995$ .	Recalibrate and/or perform necessary equipment maintenance. Check calibration standards.	Analyst, Supervisor	CA-611, CA-615
	ICV (second source)	Once after each ICAL, prior to beginning a sample run.	The %R must be within 90-110% of true value for mercury.	Correct problem and verify second source standard. Rerun ICV. If that fails, correct problem and repeat ICAL.	Analyst, Supervisor	
	Calibration Blank (initial and continuing)	Before beginning a sample sequence, after every 10 samples, and at end of the analysis sequence.	No analytes detected > LOD. For negative blanks, absolute value < LOD.	Correct problem. Reprep and reanalyze calibration blank. All samples following the last acceptable calibration blank must be reanalyzed.	Analyst, Supervisor	

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible for Corrective Action <sup>(2)</sup>	SOP Reference
Mercury Analyzer	CCV	Beginning and end of each run sequence and after every 10 samples.	The %R must be within 80-120% of true value for mercury.	Correct problem, and rerun calibration verification. If that fails, then repeat ICAL. Reanalyze all samples since the last successful calibration verification.	Analyst, Supervisor	

## SAP WORKSHEET #25: ANALYTICAL INSTRUMENT AND EQUIPMENT MAINTENANCE, TESTING, AND INSPECTION TABLE

[\(UFP-QAPP Manual Section 3.2.3\)](#)

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference
ICP-AES	Clean torch assembly and spray chamber when discolored or when degradation in data quality is observed. Clean nebulizer, check argon, and replace peristaltic pump tubing as needed. Other maintenance specified in lab Equipment Maintenance SOP.	Metals	Torch, nebulizer chamber, pump, pump tubing	Prior to ICAL and as necessary	Acceptable ICAL or CCV	Correct the problem and repeat ICAL or CCV	Analyst, Supervisor	CA-608
GC/MS	Check pressure and gas supply daily. Manual tune if DFTPP not in criteria, change septa as needed, change liner as needed, and cut column as needed. Other maintenance specified in lab Equipment Maintenance SOP	PAHs, EPH	Ion source, injector liner, column, column flow	Prior to ICAL and/or as necessary	Acceptable ICAL or CCV	Correct the problem and repeat ICAL or CCV	Analyst, Supervisor	CA-12

<b>Instrument/ Equipment</b>	<b>Maintenance Activity</b>	<b>Testing Activity</b>	<b>Inspection Activity</b>	<b>Frequency</b>	<b>Acceptance Criteria</b>	<b>Corrective Action</b>	<b>Responsible Person</b>	<b>SOP Reference</b>
Mercury Analyzer	Replace peristaltic pump tubing, replace mercury lamp, replace drying tube, clean optical cell, and/or clean liquid/gas separator as needed. Other maintenance specified in lab Equipment Maintenance SOP.	Mercury	Tubing, sample probe, optical cell	Prior to ICAL and as necessary	Acceptable ICAL or CCV	Correct the problem and repeat ICAL or CCV	Analyst, Supervisor	CA-611, CA-615

## SAP WORKSHEET #26: SAMPLE HANDLING SYSTEM

[\(UFP-QAPP Manual Appendix A\)](#)

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### SAMPLE COLLECTION, PACKAGING, AND SHIPMENT

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Sample Collection (Personnel/Organization): FOL, Tetra Tech

Sample Packaging (Personnel/Organization): FOL, Tetra Tech

Coordination of Shipment (Personnel/Organization): FOL, Tetra Tech

Type of Shipment/Carrier: Overnight courier service (Federal Express)

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### SAMPLE RECEIPT AND ANALYSIS

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Sample Receipt (Personnel/Organization): Sample Custodians/Katahdin

Sample Custody and Storage (Personnel/Organization): Sample Custodians/Katahdin

Sample Preparation (Personnel/Organization): Extraction Lab, Metals Preparation Lab/Katahdin

Sample Determinative Analysis (Personnel/Organization): Gas Chromatography/Mass Spectrometry Lab, Metals Lab/Katahdin

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### SAMPLE ARCHIVING

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Field Sample Storage (No. of days from sample collection): 60 days from receipt

Sample Extract/Digestate Storage (No. of days from extraction/digestion): 3 months from sample digestion/extraction

Biological Sample Storage (No. of days from sample collection): Not Applicable

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### SAMPLE DISPOSAL

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Personnel/Organization: Sample Custodians/Katahdin

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## **SAP WORKSHEET #27: SAMPLE CUSTODY REQUIREMENTS**

[\(UFP-QAPP Manual Section 3.3.3\)](#)

### **SAMPLE CUSTODY REQUIREMENTS**

#### **Field Chain of Custody**

To ensure the integrity of a sample from collection through analysis, an accurate written record that traces the possession and handling of the sample is necessary. This documentation is referred to as the chain-of-custody form. Chain-of-custody begins at the time of sample collection. A sample is under custody if any of the following conditions apply:

- It is in the owner's actual possession.
- It is in the owner's view, after being in his/her physical possession.
- It was in the owner's possession and was locked or sealed to prevent tampering.
- It is in a secure area.

Custody documentation is designed to provide documentation of preparation, handling, storage, and shipping of all samples collected. A multi-part chain-of-custody form is used, and each page of the form is signed and dated by the recipient of a sample or portion of a sample. The person releasing the sample and the person receiving the sample will each retain a copy of the chain-of-custody form each time a sample transfer occurs.

Preservation of the integrity of the samples collected during the RI will be the responsibility of identified persons from the time the samples are collected until the samples, or their derived data, are incorporated into the final report.

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. When transferring samples, the individuals relinquishing and receiving them will sign, date, and note the time on the chain-of-custody form. This form 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 Katahdin SOPs.

### **Laboratory Chain of Custody**

The laboratory sample custody procedures (receipt of samples, archiving, and disposal) documented in Katahdin SOPs SD-902 and SD-903 will be followed. An SDG number will be created in the Laboratory Information Management System (LIMS) based on the project and chain-of-custody form, with each sample container (jar, bottle, drilling core, etc.) received being assigned a unique ID number. Durable, waterproof, laboratory identification labels will be affixed to each bottle, and samples will be stored in a secure and temperature controlled area. Samples will be stored in accordance with Method requirements and DoD Quality Systems Manual (QSM) 4.1 Section 5.8. Sample status and location throughout the laboratory will be maintained through LIMS as samples are taken from the controlled storage area to the preparation laboratories and when the extracts/digestates are transferred to the instrumentation labs. All related forms are included in SOP SD-902.

## SAP WORKSHEET #28A: LABORATORY QC SAMPLES TABLE

[\(UFP-QAPP Manual Section 3.4\)](#)

**Matrix:** Groundwater, aqueous field QC samples, and soil  
**Analytical Group:** PAHs  
**Analytical Method/SOP Reference:** SW-846 8270D SIM/CA-213

QC Sample	Frequency and Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	DQI	MPC
Method Blank	One per preparation batch of 20 or fewer samples of similar matrix.	No target compounds > ½ LOQ.	(1) Investigate source of contamination. (2) Evaluate the samples and associated QC, i.e., if the blank results are above the LOQ, then report samples that are <LOQ or > 10X the blank result. Reprepare a blank and the remaining samples.	Analyst, Supervisor, and Data Validator	Bias/Contamination	Same as Method/SOP QC Acceptance Limits.
Surrogate	Six per sample- 2-Fluorophenol Phenol-d6 Nitrobenzene-d5 2-Fluorobiphenyl 2,4,6-Tribromophenol Terphenyl-d14	%Rs must be within Katahdin Analytical Services statistically derived limits, which are provided in Appendix D	(1) Check chromatogram for interference; if found, then flag data. (2) If not found, then check instrument performance; if problem is found, then correct and reanalyze. (3) If still out, then re-extract and analyze sample. (4) If reanalysis is out, then flag data.	Analyst, Supervisor, and Data Validator	Accuracy/Bias	Same as Method/SOP QC Acceptance Limits.
Laboratory Control Sample (LCS)	One per preparation batch of 20 or fewer samples of similar matrix.	%Rs must be within Katahdin Analytical Services statistically derived limits, which are provided in Appendix D.	Evaluate and reanalyze if possible. If an MS/MSD was performed in the same 12-hour period and is acceptable, then narrate. If the LCS recoveries are high, but the sample results are <LOQ, then narrate. Otherwise reprepare and reanalyze.	Analyst, Supervisor, and Data Validator	Accuracy/Bias	Same as Method/SOP QC Acceptance Limits.
MS/MSD (not applicable for rinsate blanks)	One per SDG or every 20 samples.	%Rs should be within Katahdin's statistically derived QC limits. Water and soil precision RPD ≤ 30%	Corrective Action will not be taken for samples when recoveries are outside limits and surrogate and LCS criteria are met. If both the LCS and MS/MSD are unacceptable, reprepare the samples and QC.	Analyst, Supervisor, and Data Validator	Precision/Accuracy/Bias	Same as Method/SOP QC Acceptance Limits.
Internal Standard	Six per sample – 1,4-Dichlorobenzene-d4 Naphthalene-d8 Acenaphthene-d10 Phenanthrene-d10 Chrysene-d12 Perylene-d12	RTs for internal standards must be ± 30 seconds and the responses within -50% to +100% of the ICAL midpoint.	Inspect mass spectrometer or gas chromatograph for malfunctions. Mandatory reanalysis of samples analyzed while system was malfunctioning.	Analyst, Supervisor, and Data Validator	Accuracy/Bias	Same as Method/SOP QC Acceptance Limits.
Results between DL and LOQ	NA	Apply "J" qualifier to results between DL and LOQ.	NA	Analyst, Supervisor, Data Validator	Accuracy	Same as QC Acceptance Limits.

Please note that laboratory-derived limits are updated periodically and may change from the issuance of the final SAP to the time data validation is performed. The limits used for validation will be the limits that are current at the time of analysis.

## SAP WORKSHEET #28B: LABORATORY QC SAMPLES TABLE

[\(UFP-QAPP Manual Section 3.4\)](#)

**Matrix:** Groundwater, aqueous field QC samples, and soil  
**Analytical Group:** Metals and mercury  
**Analytical Method/SOP Reference:** SW-846 3010A, 6010C/7470A/7471B CA-604, CA-608, CA-615

QC Sample	Frequency and Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	DQI	MPC
Method Blank	One per digestion batch of 20 or fewer samples.	No analytes detected > ½ the LOQ.	Correct the problem. If method blank is >½ the LOQ, then: 1) Report sample results that are <LOD or sample results >10x the blank concentration without corrective action. 2) For samples with results > LOD and < 10x the contaminated blank result, reprepare/redigest, and reanalyze the method blank and associated samples.	Analyst, Supervisor, Data Validator	Bias/Contamination	Same as QC Acceptance Limits.
LCS	One per digestion batch of 20 or fewer samples.	Water and soil sample %Rs must be between 80 and 120%.	Redigest and reanalyze all associated samples for affected analyte.	Analyst, Supervisor, Data Validator	Accuracy/Bias/Contamination	Same as QC Acceptance Limits.
Duplicate Sample	One per preparation batch of 20 or fewer samples of similar matrix.	The RPD should be ≤20% for duplicate samples for both water and soil.	Narrate any results that are outside control limits.	Analyst, Supervisor, Data Validator	Precision	Same as QC Acceptance Limits.
MS	One per digestion batch of 20 or fewer samples.	Recovery should be ± 25% of the true value if sample < 4x spike added.	Flag results for affected analytes for all associated samples with "N".	Analyst, Supervisor, Data Validator	Accuracy/Bias	Same as QC Acceptance Limits.
ICP Serial Dilution	One per preparation batch of 20 or fewer samples of similar matrix.	If original sample result is at least 50x the instrument detection limit, five-fold dilution must agree within ± 10% of the original result.	Flag results for affected analytes for all associated samples with "E".	Analyst, Supervisor, Data Validator	Accuracy/Bias	Same as QC Acceptance Limits.
Post-Digestion Spike (does not apply to mercury)	One is performed when serial dilution fails or target analyte concentration(s) in all samples are < 50x LOD.	The %R must be within 75-125% of expected value to verify the absence of an interference. Spike addition should produce a concentration of 10-100x LOQ.	Flag results of samples of same matrix as estimates in SDG narrative.	Analyst, Department Manager, Data Validator	Precision	Same as QC Acceptance Limits.
Results between DL and LOQ	NA	Apply "J" qualifier to results between DL and LOQ.	NA	Analyst, Supervisor, Data Validator	Accuracy	Same as QC Acceptance Limits.

## SAP WORKSHEET #28C: LABORATORY QC SAMPLES TABLE

[\(UFP-QAPP Manual Section 3.4\)](#)

**Matrix:** Groundwater, aqueous field QC samples, and soil

**Analytical Group:** Metals (Mercury)

**Analytical Method/ SOP Reference:** SW-846 7470A, 7471B / CA-11, CA-615

QC Sample	Frequency and Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	DQI	MPC
Method Blank	One per digestion batch of 20 or fewer samples of similar matrix.	No mercury > 1/2 LOQ. For negative blanks, absolute value < LOD.	Correct the problem. Report sample results that are <LOD or >10x the blank concentration. Reprepare and reanalyze the method blank and all associated samples with results > LOD and < 10x the contaminated blank result. Contact client if samples cannot be reprepared within hold time.	Analyst, Laboratory Department Manager, Data Validator	Bias/contamination	Same as Method/SOP QC Acceptance Limits.
LCS	One per digestion batch of 20 or fewer samples of similar matrix.	Water: Recovery must be within ± 20% of the true value Soil: Recovery must be within vendor supplied limits (varies by lot).	Redigest and reanalyze all associated samples for affected analyte.	Analyst, Laboratory Department Manager, Data Validator	Accuracy/Bias/Contamination	Same as Method/SOP QC Acceptance Limits.
MS (not applicable for rinsate blanks)	One per SDG or every 20 samples.	Recovery should be ± 20% of the true value if sample < 4x spike added. RPD ≤ 20%	Flag results for affected analytes for all associated samples with "N".	Analyst, Laboratory Department Manager, Data Validator	Accuracy/Bias	Same as Method/SOP QC Acceptance Limits.
Laboratory Duplicate (not applicable for rinsate blanks)	One per SDG or every 20 samples.	Project-specific criteria: If values are ≥ 5x LOQ, RPD should be ≤ 20%. If values are < 5x LOQ, absolute difference should be ≤ LOQ.	Flag results for affected analytes for all associated samples.	Analyst, Laboratory Department Manager, Data Validator	Precision	Same as Method/SOP QC Acceptance Limits.

Please note that laboratory-derived limits are updated periodically and may change from the issuance of the final SAP to the time data validation is performed. The limits used for validation will be the limits that are current at the time of analysis

## SAP WORKSHEET #29: PROJECT DOCUMENTS AND RECORDS TABLE

[\(UFP-QAPP Manual Section 3.5.1\)](#)

Document/Record	Where Maintained
<p><u>Sample Collection Documents and Records</u>                      Field logbook (and sampling notes)                      Field forms (e.g., boring logs, sample log sheets, drilling logs, etc.)                      Chain-of-custody records                      Equipment calibration logs                      Photographs                      FTMR forms                      Field Sampling SOPs</p>	<p>Tetra Tech Project File. Field forms, chain-of-custody records, FTMR forms, and photographs will also be included in the RI data package.</p>
<p><u>Laboratory Documents and Records</u>                      Sample receipt/login forms, custody, and tracking records                      Sample storage records                      Sample preparation logs                      Standard traceability logs                      Equipment calibration logs                      Sample analysis run logs                      Equipment maintenance, testing, and inspection logs                      Corrective action forms                      Reported field sample results                      Reported results for standards, QC checks, and QC samples                      Data completeness checklists                      Sample storage and disposal records                      Telephone logs                      Extraction/clean-up records                      Raw data                      EDD</p>	<p>Tetra Tech Project File, long-term data package storage at third-party professional document storage firm. The EDDs and corresponding databases will be formatted in both Navy and MEDEP formats.</p>
<p><u>Data Assessment Documents and Records</u>                      Field Sampling Audit Checklist (if an audit is conducted)                      Analytical Audit Checklist (if an audit is conducted)                      Data validation memoranda</p>	<p>Tetra Tech Project File. Data validation reports will also be included in the RI data package.</p>
<p><u>Other Documents</u>                      HASP                      All versions of SAP                      RI data package                      All versions of project reports (e.g., RI, FS)</p>	<p>Tetra Tech Project File</p>

### SAP WORKSHEET #30: ANALYTICAL SERVICES TABLE

[\(UFP-QAPP Manual Section 3.5.2.3\)](#)

Matrix	Analytical Group	Sample Locations/ID Number	Analytical Method	Data Package Turnaround Time	Laboratory/Organization <sup>(1)</sup>	Backup Laboratory/Organization
Soil	Metals	See Worksheet #18	SW-846 6010B	21 calendar days	Katahdin	Not applicable
	Mercury	See Worksheet #18	SW-846 7471B	21 calendar days	Katahdin	Not applicable
	PAHs	See Worksheet #18	SW-846 8270D SIM	21 calendar days	Katahdin	Not applicable
	EPH	See Worksheet #18	MADEP/EPH	21 calendar days	Katahdin	Not applicable
Groundwater	Metals	See Worksheet #18	SW-846 6010B	21 calendar days	Katahdin	Not applicable
	Mercury	See Worksheet #18	SW-846 7470A	21 calendar days	Katahdin	Not applicable
	PAHs	See Worksheet #18	SW-846 8270D SIM	21 calendar days	Katahdin	Not applicable
	EPH	See Worksheet #18	MADEP/EPH	21 calendar days	Katahdin	Not applicable

1 Laboratory meets accreditation requirements to support project needs.

### SAP WORKSHEET #31: PLANNED PROJECT ASSESSMENTS TABLE

[\(UFP-QAPP Manual Section 4.1.1\)](#)

<b>Assessment Type</b>	<b>Frequency</b>	<b>Internal or External</b>	<b>Organization Performing Assessment</b>	<b>Person(s) Responsible for Performing Assessment (title and organizational affiliation)</b>	<b>Person(s) Responsible for Responding to Assessment Findings (title and organizational affiliation)</b>	<b>Person(s) Responsible for Identifying and Implementing Corrective Action (CA) (title and organizational affiliation)</b>	<b>Person(s) Responsible for Monitoring Effectiveness of CA (title and organizational affiliation)</b>
Laboratory Systems Audit	Every 18 months	External	Naval Facilities Engineering Service Center (NFESC)	NFESC Representative	Laboratory QA Officer, Katahdin	Laboratory QA Officer, Katahdin	Laboratory QA Officer, Katahdin

**SAP WORKSHEET #32: ASSESSMENT FINDINGS AND CORRECTIVE ACTION RESPONSES TABLE**

[\(UFP-QAPP Manual Section 4.1.2\)](#)

<b>Assessment Type</b>	<b>Nature of Deficiencies Documentation</b>	<b>Individual(s) Notified of Findings</b> (name, title, organization)	<b>Time Frame of Notification</b>	<b>Nature of Corrective Action Response Documentation</b>	<b>Individual(s) Receiving Corrective Action Response</b> (name, title, organization)	<b>Time Frame for Response</b>
Laboratory Systems Audit	Written audit report	Laboratory QA Officer, Katahdin	Not specified by NFESC	Letter	NFESC	Specified by NFESC

### SAP WORKSHEET #33: QUALITY ASSURANCE MANAGEMENT REPORTS TABLE

[\(UFP QAPP Manual Section 4.2\)](#)

Type of Report	Frequency	Projected Delivery Date(s)	Person(s) Responsible for Report Preparation <small>(title and organizational affiliation)</small>	Report Recipient(s) <small>(title and organizational affiliation)</small>
Data validation report	Per SDG	After validation is complete	Tetra Tech DVM or designee	Tetra Tech PM, project file
Major analysis problem identification (internal memorandum)	When persistent analysis problems are detected	Immediately	Tetra Tech QA Manager	Tetra Tech PM, Tetra Tech QA Manager, Tetra Tech Program Manger, project file
Project monthly progress report	Project monthly progress report	Monthly	Tetra Tech PM	Tetra Tech PM
Field progress reports	Daily, oral, during the course of sampling	Every day that field sampling occurs	Tetra Tech FOL	Tetra Tech PM
Laboratory QA report	When significant plan deviations result from unanticipated circumstances	Immediately	Subcontracted laboratory	Tetra Tech, project file

**SAP WORKSHEET #34: DATA VERIFICATION AND VALIDATION (STEPS I AND IIA/IIB) PROCESS TABLE**

[\(UFP-QAPP Manual Section 5.2.1\)](#), [\(UFP-QAPP Manual Section 5.2.2\)](#), [\(Figure 37 UFP-QAPP Manual\)](#), [\(Table 9 UFP-QAPP Manual\)](#)

Verification Input	Description	Internal/ External	Responsible for Verification (name, organization)
Sample tables	Verify that proposed samples have been collected	Internal	Tetra Tech FOL or designee
Chain-of-custody forms	Review of chain-of-custody records by the PM or designee and compare to sample tables listing the proposed samples to verify that all planned samples have been collected and that all analytical results have been received.	Internal	Tetra Tech PM or designee
Sample coordinates	Verify that sample locations are correct and in accordance with the SAP.	Internal	Tetra Tech FOL, PM, or designee
Laboratory data packages	Verify that the data package contains all of the elements required by the scope of work. This occurs as part of the data validation process.	Internal	Tetra Tech Data Validator, or PM
Sample log sheets	Verify that log sheets were completed as samples were collected in the field and are compiled for inclusion in the data package.	Internal	Tetra Tech FOL, PM, or designee

## SAP WORKSHEET #35 -- VALIDATION (STEPS IIA AND IIB) PROCESS TABLE

[\(UFP-QAPP Manual Section 5.2.2\)](#) [\(Figure 37 UFP-QAPP Manual\)](#) [\(Table 9 UFP-QAPP Manual\)](#)

Step Iia/Iib <sup>(1)</sup>	Validation Input	Description	Responsible for Validation (position, organization)
Iia	Data Deliverables and SAP	Verify that all the required sampling and analysis documents (listed in Worksheet #34) were provided.	Internal. Tetra Tech PM or designee
Iib	Field Logs/Sample Coordinates	Verify that the sampling plan was implemented and carried out as written and that any deviations are documented.	Internal. Tetra Tech PM
Iia	Field Transcription	Verify that the transcription of sampling data from field notebooks to reports is accurate.	Internal. Tetra Tech PM or designee
Iia	Laboratory Data Package	Verify that elements of the data package that are required for validation are present, and if not, the laboratory will be contacted and the missing information will be requested. Validation will be performed per Worksheet #36 and will include summary reports including qualified data, reasons for qualification of data, and deviations from methods, procedures, or contracts.	External. Tetra Tech Data Validator
Iib	MPCs and Project Action Limits	Apply project-specific MPCs per Worksheet #s 12 and 28 and evaluate project QLs and project action limits and their affect on data.	External. Tetra Tech Data Validator
Iia	Electronic Data	Verify that all data were transferred correctly and completely to the validation database, that deviations were documented, and that MPCs were achieved.	Internal. Tetra Tech PM or designee
Iia	Communications	Verify that all of the required communication procedures were followed by field and/or laboratory personnel.	Internal/External. Tetra Tech PM
Iib	Sampling Plan and Procedures	Verify that the sampling plan was executed as specified by the SAP and that all sampling procedures were followed in compliance with relevant SOPs. Document deviations from sampling plans or procedures.	Internal/External. Tetra Tech PM and FOL or designee
Iib	Data Deliverables and SAP	Verify that summary data validation reports are complete and determine the affects that data deviations from the SAP will have on achieving MPCs.	Internal. Tetra Tech PM or designee

Step IIa/IIb <sup>(1)</sup>	Validation Input	Description	Responsible for Validation (position, organization)
IIa	Analytical Method QC Documentation	Verify that QC samples and standards prescribed in analytical SOPs were analyzed and that results are within the prescribed control limits. If any significant QC deviations occur, the laboratory shall have contacted the Tetra Tech PM.	External. Tetra Tech PM or designee
IIa, IIb	SAP QC Sample Documentation	Verify that all QC samples specified in the SAP were collected and analyzed and that the associated results were within prescribed SAP acceptance limits.	Internal/External. Tetra Tech PM or designee

- 1 IIa = Compliance with methods, procedures, and contracts (see Table 10, page 117, UFP-QAPP Manual, V.1, March 2005).  
 IIb = Comparison with MPCs in the SAP (see Table 11, page 118, UFP-QAPP Manual, V.1, March 2005).

## SAP WORKSHEET #36 –ANALYTICAL DATA VALIDATION (STEPS IIA AND IIB) SUMMARY TABLE

[\(UFP-QAPP Manual Section 5.2.2.1\)](#)

Step IIA/IIB	Matrix	Analytical Group	Validation Criteria	Data Validator (title and organizational affiliation)
Ila and Iib	Soil	PAHs	Tier III data validation. Criteria for SW-846 8270D SIM listed in Worksheet #s 12 and 28. If not included in Worksheet #s 12 or 28, default to USEPA-NE Environmental Data Review Supplement for Regional Data Review Elements and Superfund Specific Guidance/Procedures, April 2013 and USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. If not included in the worksheets or Region 1 guidelines listed above, default to DoD QSM for Environmental Laboratories, July 2013.	External. DVM or designee, Tetra Tech
Ila and Iib	Soil	EPH	Tier III data validation. Criteria for MADEP/EPH listed in Worksheet #s 12 and 28. If not included in Worksheet #s 12 or 28, default to USEPA-NE Environmental Data Review Supplement for Regional Data Review Elements and Superfund Specific Guidance/Procedures, April 2013 and USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. If not included in the worksheets or Region 1 guidelines listed above, default to DoD QSM for Environmental Laboratories, July 2013.	External. DVM or designee, Tetra Tech
Ila and Iib	Soil	TAL metals	Tier III data validation. Criteria for SW-846 6010B/6020/7471B listed in Worksheet #s 12 and 28. If not included in Worksheets # 12 or #28, default to USEPA-NE Environmental Data Review Supplement for Regional Data Review Elements and Superfund Specific Guidance/Procedures, April 2013 and USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Methods Data Review, January 2010. If not included in the worksheets or Region 1 guidelines listed above, default to DoD QSM for Environmental Laboratories, July 2013.	External. DVM or designee, Tetra Tech
Ila and Iib	Groundwater	PAHs	Tier III data validation. Criteria for SW-846 8270D/8270D SIM listed in Worksheets #12 and #28. If not included in Worksheet #s 12 or 28, default to USEPA-NE Environmental Data Review Supplement for Regional Data Review Elements and Superfund Specific Guidance/Procedures, April 2013 and USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. If not included in the worksheets or Region 1 guidelines listed above, default to DoD QSM for Environmental Laboratories, July 2013.	External. DVM or designee, Tetra Tech

Step IIa/IIb	Matrix	Analytical Group	Validation Criteria	Data Validator (title and organizational affiliation)
IIa and IIb	Groundwater	EPH	Tier III data validation. Criteria for MADEP/EPH listed in Worksheets #12 and #28. If not included in Worksheet #s 12 or 28, default to USEPA-NE Environmental Data Review Supplement for Regional Data Review Elements and Superfund Specific Guidance/Procedures, April 2013 and USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. If not included in the worksheets or Region 1 guidelines listed above, default to DoD QSM for Environmental Laboratories, July 2013.	External. DVM or designee, Tetra Tech
IIa and IIb	Groundwater	TAL Metals	Tier III data validation. Criteria for SW-846 6010B/6020/7471B listed in Worksheet #s 12 and 28. If not included in Worksheet #s 12 or 28, default to Region 1 USEPA-NE Environmental Data Review Supplement for Regional Data Review Elements and Superfund Specific Guidance/Procedures, April 2013 and USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Methods Data Review, January 2010. If not included in the worksheets or Region 1 guidelines listed above, default to DoD QSM for Environmental Laboratories, July 2013.	External. DVM or designee, Tetra Tech

## SAP WORKSHEET #37: USABILITY ASSESSMENT

[\(UFP-QAPP Manual Section 5.2.3\)](#)

**Summarize the usability assessment process and all procedures, including interim steps and any statistics, equations, and computer algorithms that will be used:**

- If verification and validation requirements are not satisfied the data will be qualified. The data will be classified as estimated (J, UJ) for minor QC deviations that not likely to compromise the data usability significantly, or the data will be classified as rejected (R, UR) for major QC deviations that are likely to have a significant effect on data usability. The impact of rejected data will be evaluated and the need for corrective actions such as re-sampling will be evaluated. This determination will be made by the Tetra Tech project team and will be based on an evaluation of whether project objectives can be achieved without resampling. The use of estimated data, if any, will be discussed in the project report.
- All of the Precision, Accuracy, Representativeness, Completeness, Comparability and Sensitivity (PARCCS) parameters will be evaluated during a DQR to determine the overall usability of the data compared to project criteria outlined in this SAP. Precision, accuracy, sensitivity and completeness will be evaluated based on numerical data; representativeness and comparability will be qualitative evaluations.
- Deviations from the SAP will be reviewed to assess whether the deviations are significant enough to compromise the attainment of project objectives. If project objectives are compromised, as determined by the project team, additional planning meetings may be required to revise DQOs. This will be team decision based on the numerous variables and interactions of variables that cannot be predicted before collecting the data.
- Analytical data will be checked to ensure that they are accurately transferred to the electronic project database. These inspections involve a series of cross-checks and inspections that are performed manually or with database software.
- The data will be reviewed to identify potential outliers. This may involve statistical testing at the discretion of the Tetra Tech PM with input from the project team. If a review of the field and laboratory documentation indicates that the suspected outliers have an assignable cause for being out of line with other results, the outliers will be removed from the data sets and any reprocessing required to compute aggregate statistics such as maximum and minimum values will be performed as necessary.
- Whether or not the project required quantitation limits listed in Worksheet #15 were achieved will be evaluated.
- For statistical comparisons and mathematical manipulations, non-detected values will be represented by a concentration equal to one-half the sample-specific reporting limit when appropriate. Laboratory duplicate results (original and duplicate) will not be averaged for the purpose of representing the range of concentrations. However, the average of the original and field duplicate will be used to represent the concentration at particular sample locations.
- Calculation of the mean and the lowest and highest detected concentrations for each parameter will be presented in summary tables in the RI report. These calculations may be performed in Microsoft SQL 2000 version 8 and subsequent upgrades, Microsoft Excel 2003 and subsequent upgrades, or Statsoft Statistica version 6 or 7 and subsequent upgrades, depending on the nature of the computation. These are industry standard software packages used without modification except to customize them by preparing "canned" data management routines that have been used successfully numerous times on various data sets and do not require any additional validation
- Discussion will be held with the NAVFAC RPM and Regulatory RPMs on data issues that affect the attainment of project objectives to determine whether the data are usable for project decisions.

**Describe the evaluative procedures used to assess overall measurement error associated with the project:**

- If a significant deviation occurs between laboratory and field precision, the cause will be investigated. The expectation is that laboratory precision values will be no greater than relative percent differences RPDs for field duplicates of the same matrix. If deviations occur they will be described in the data package and interpreted for their impact on decision making in the RI Report. Precision computations will be based on calculation of RPD.  $RPD = (\text{Difference of two results}) / (\text{average of two results}) * 100 \text{ percent}$ .
- If significant biases are detected (represented by low or high matrix spike, LCS, or surrogate recoveries), this will be noted and evaluated for impact on decision making. The tendency will be to emphasize review of low biases more than high biases unless biased results are near action levels. Low biases will be emphasized more because they are likely to represent an inability to detect compounds that are present at the site and, on a percentage basis, generally represent a greater proportion of the magnitude of individual values. Biases greater than  $\pm 30$  percent from the ideal of 0 percent will generally be reviewed. Whether corrective action is necessary will be determined by the Tetra Tech project chemist. This judgment will be based on numerous variables such as number of deviant bias indicators in a batch of samples and in related sample batches, the degree of bias, the number of precision indicators in a batch of samples and related samples, the type of bias indicator that is deviant (e.g., laboratory control samples versus matrix spikes). Bias computations will be made by computing the difference between observed and expected results and dividing by the expected result then multiplying by 100 percent.

**Identify the personnel responsible for performing the usability assessment:**

- Tetra Tech PM and Project Chemist or designee with contributions from other team members, as necessary, will perform these evaluations. Ultimately, NAVFAC will determine whether project objectives have been attained. Regulators will provide oversight of this process and will agree with the results if they find the results satisfactory.

**Describe the documentation that will be generated during usability assessment and how usability assessment results will be presented so that they identify trends, relationships (correlations), and anomalies:**

- The project DQR report will identify and describe the data usability limitations and suggest re-sampling if necessary to fill out the data gaps. A description of the PARCCS parameter evaluations will be included in the DQR report. This may include a short summary with supporting documentation, or a more detailed summary, depending on the number and significance of deficiencies or SAP deviations.
- The DQR report and discussion of SAP deviations will be included in the investigation data package. Impacts to the project based on the DQR and SAP deviations will be evaluated as part of the RI Report. The investigation data package and RI Report will be provided to the NAVFAC and regulators for review and comment.

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Aerial photograph provided by ESRI's ArcGIS Online World Imagery map service (© 2011 ESRI and its data suppliers).



PISCATAQUA RIVER

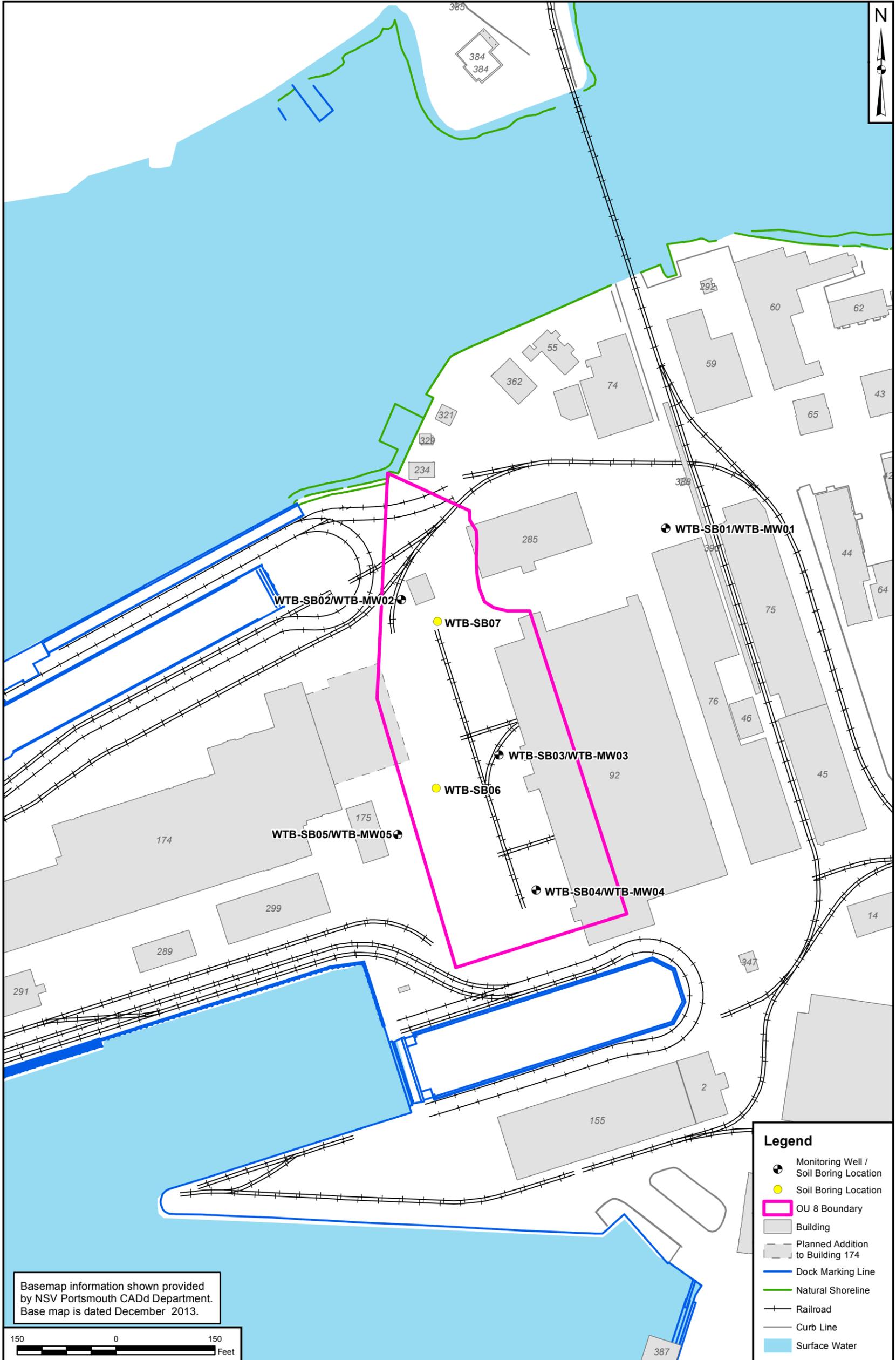


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M. BOERIO	03/06/14
REVISED BY	DATE
S. PAXTON	03/06/14
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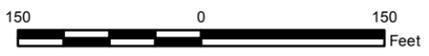


OPERABLE UNIT 8 VICINITY MAP  
PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE

CONTRACT NUMBER	CTO NUMBER
3270	WE32
APPROVED BY	DATE
---	---
APPROVED BY	DATE
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FIGURE NO.	REV
FIGURE 1	0



Basemap information shown provided by NSV Portsmouth CADd Department. Base map is dated December 2013.



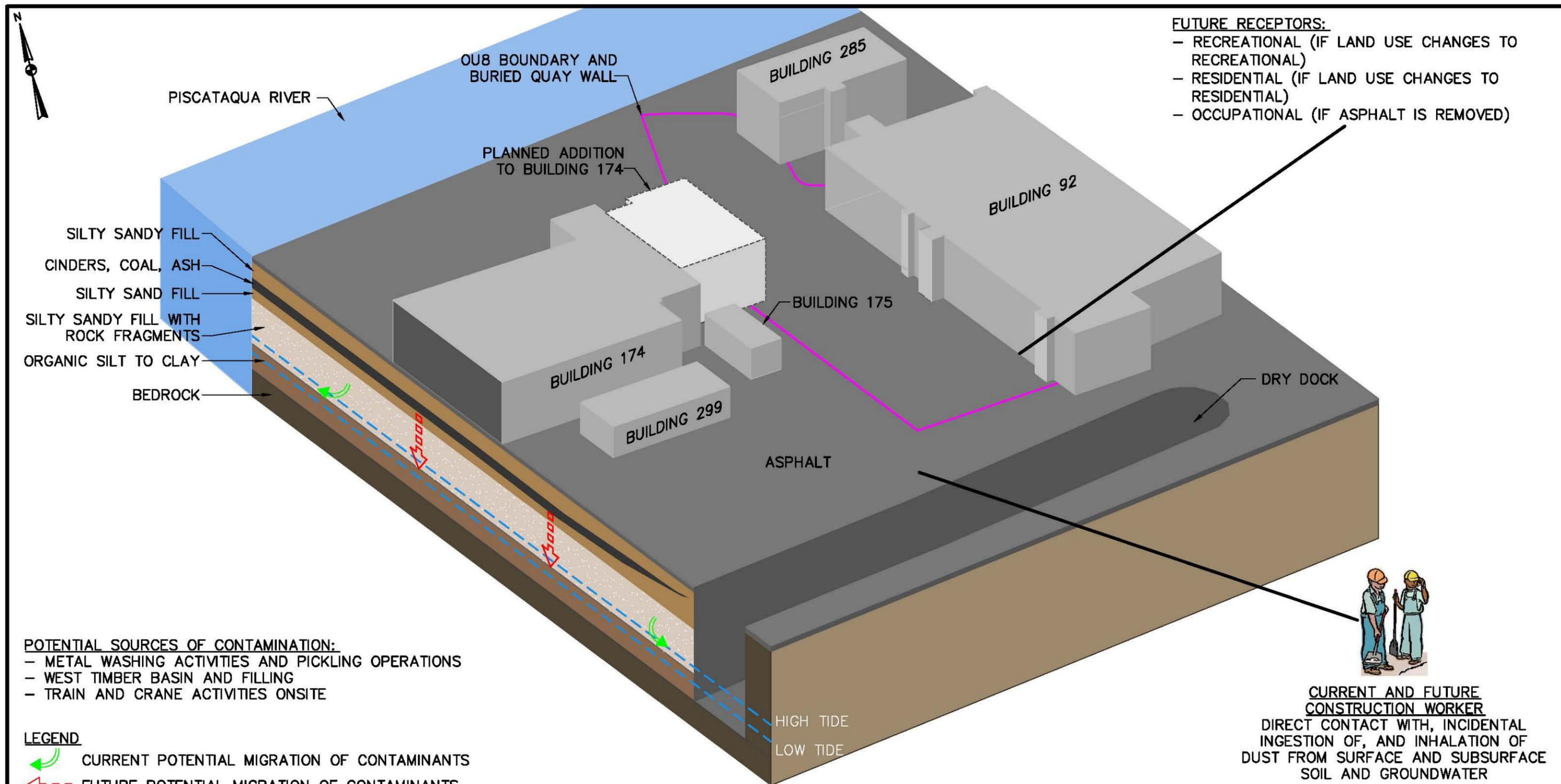
- Legend**
- Monitoring Well / Soil Boring Location
  - Soil Boring Location
  - OU 8 Boundary
  - Building
  - Planned Addition to Building 174
  - Dock Marking Line
  - Natural Shoreline
  - Railroad
  - Curb Line
  - Surface Water

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J. ENGLISH	04/28/11
CHECKED BY	DATE
M. BOERIO	04/28/14
REVISD BY	DATE
D. COUCH	04/28/14
SCALE AS NOTED	



OPERABLE UNIT 8 SITE LAYOUT  
PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE

CONTRACT NUMBER	CTO NUMBER
3270	WE32
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO.	REV
FIGURE 2	0



**POTENTIAL SOURCES OF CONTAMINATION:**  
 - METAL WASHING ACTIVITIES AND PICKLING OPERATIONS  
 - WEST TIMBER BASIN AND FILLING  
 - TRAIN AND CRANE ACTIVITIES ONSITE

**LEGEND**  
 CURRENT POTENTIAL MIGRATION OF CONTAMINANTS  
 FUTURE POTENTIAL MIGRATION OF CONTAMINANTS IF ASPHALT IS REMOVED  
 --- BUILDING 174 ADDITION

**NOTES:**  
 1. GEOLOGY DEPICTED IS SPECIFIC TO OU8.  
 2. MIGRATION RADIAL TO OFFSHORE AREA, SEE SITE FIGURE FOR LOCATION OF OFFSHORE.  
 3. NO ECOLOGICAL RECEPTORS.

**FUTURE RECEPTORS:**  
 - RECREATIONAL (IF LAND USE CHANGES TO RECREATIONAL)  
 - RESIDENTIAL (IF LAND USE CHANGES TO RESIDENTIAL)  
 - OCCUPATIONAL (IF ASPHALT IS REMOVED)

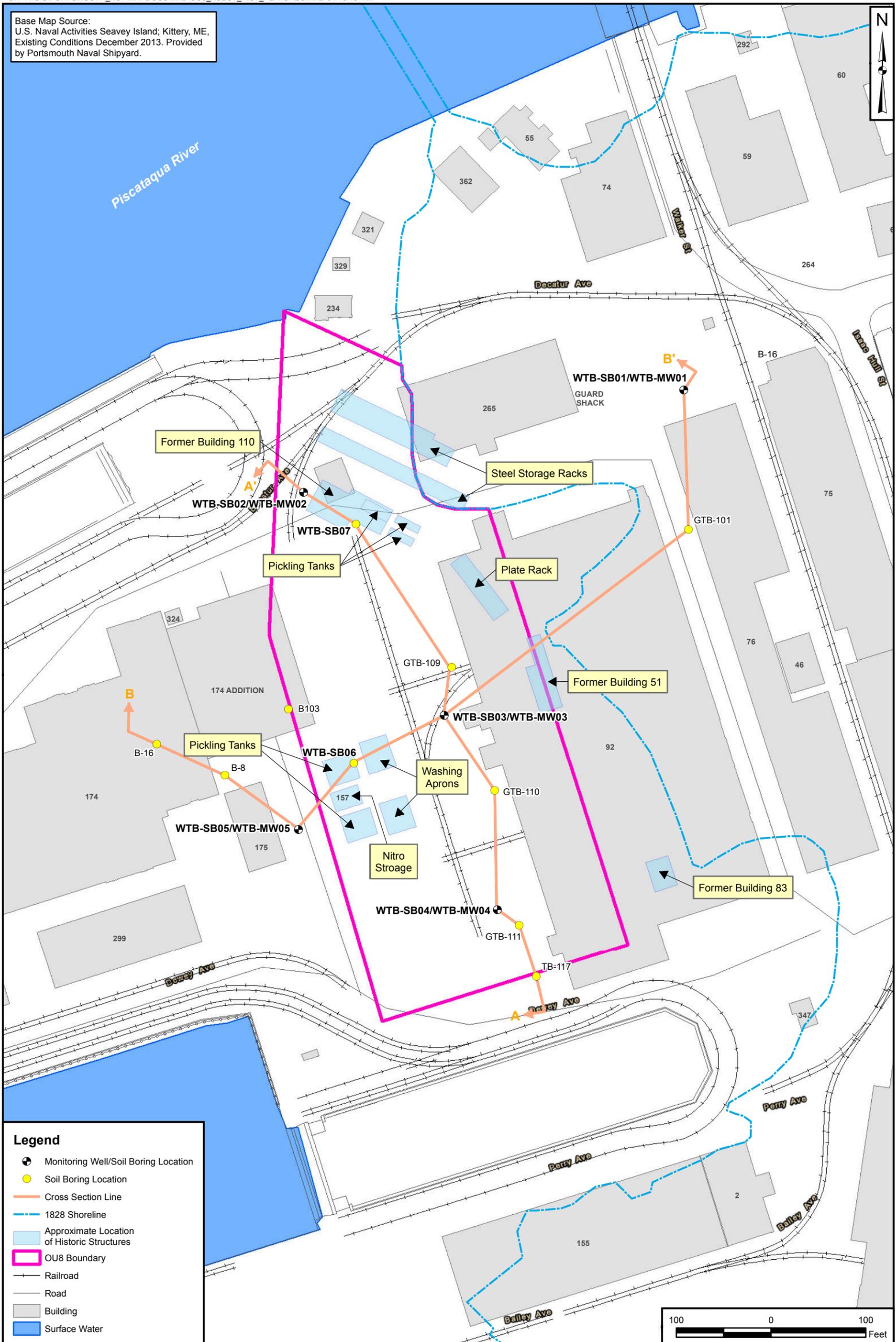
**CURRENT AND FUTURE CONSTRUCTION WORKER**  
 DIRECT CONTACT WITH, INCIDENTAL INGESTION OF, AND INHALATION OF DUST FROM SURFACE AND SUBSURFACE SOIL AND GROUNDWATER

**TETRA TECH**  
 WWW.TETRATECH.COM  
 661 ANDERSEN DRIVE - FOSTER PLAZA 7  
 PITTSBURGH, PA 15220  
 T: (412) 921-7090 | F: (412) 921-4040

PORTSMOUTH NAVAL SHIPYARD  
 KITTERY, MAINE  
**CONCEPTUAL SITE MODEL  
 OPERABLE UNIT 8**  
 SCALE: NOT TO SCALE

DATE:	2/8/11
PROJECT NO.:	112G03270
DESIGNED BY:	
DRAWN BY:	CK
CHECKED BY:	
SHEET:	1 OF 1
COPYRIGHT TETRA TECH INC.	
<b>FIGURE 3</b>	

Base Map Source:  
 U.S. Naval Activities Seavey Island; Kittery, ME,  
 Existing Conditions December 2013. Provided  
 by Portsmouth Naval Shipyard.



**Legend**

- Monitoring Well/Soil Boring Location
- Soil Boring Location
- Cross Section Line
- 1828 Shoreline
- Approximate Location of Historic Structures
- OU8 Boundary
- Railroad
- Road
- Building
- Surface Water



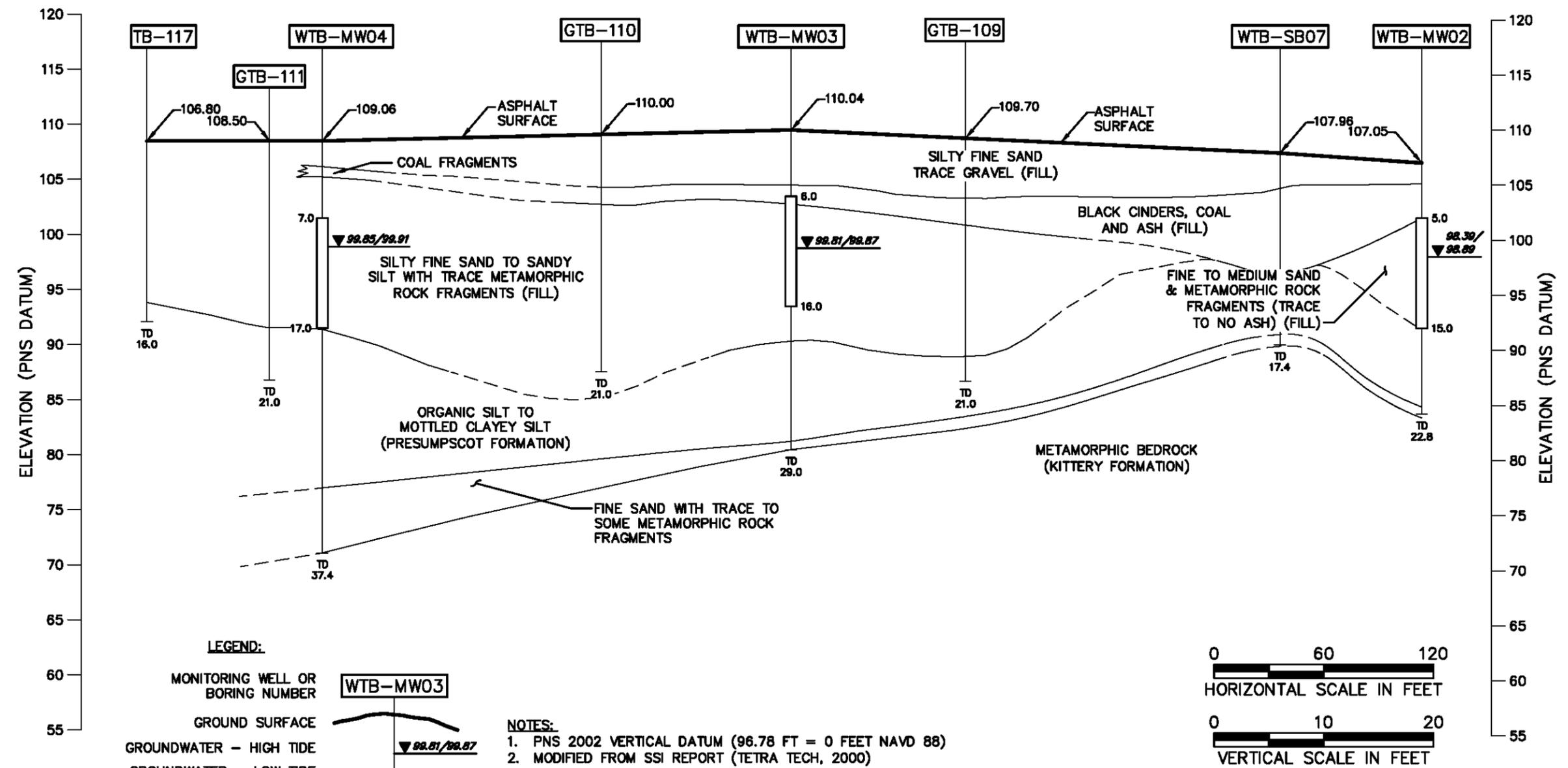
DRAWN BY	DATE
D. COUCH	10/29/13
CHECKED BY	DATE
M. VED	01/15/15
REVISED BY	DATE
K. MOORE	01/15/15
SCALE	
AS NOTED	

  
**OPERABLE UNIT 8**  
**CROSS-SECTION LINE LOCATION MAP**  
**PORTSMOUTH NAVAL SHIPYARD**  
**KITTERY, MAINE**

CONTRACT NUMBER	CTO NUMBER
3270	
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO.	REV
FIGURE 4	0

SOUTH  
A

NORTH  
A'

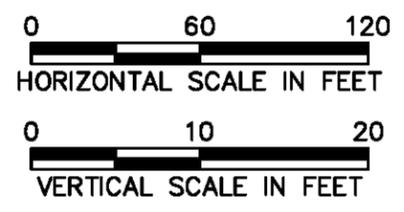


**LEGEND:**

- MONITORING WELL OR BORING NUMBER
- GROUND SURFACE
- GROUNDWATER - HIGH TIDE
- GROUNDWATER - LOW TIDE
- TOP OF SCREENED INTERVAL (FT BGS)
- LITHOLOGIC CONTACT (DASHED WHERE INFERRED)
- BOTTOM OF SCREENED INTERVAL (FT BGS)
- TOTAL DEPTH OF WELL OR BORING (FT BGS)

**NOTES:**

1. PNS 2002 VERTICAL DATUM (96.78 FT = 0 FEET NAVD 88)
2. MODIFIED FROM SSI REPORT (TETRA TECH, 2000)



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 WWW.TETRATECH.COM  
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 PITTSBURGH, PA 15220  
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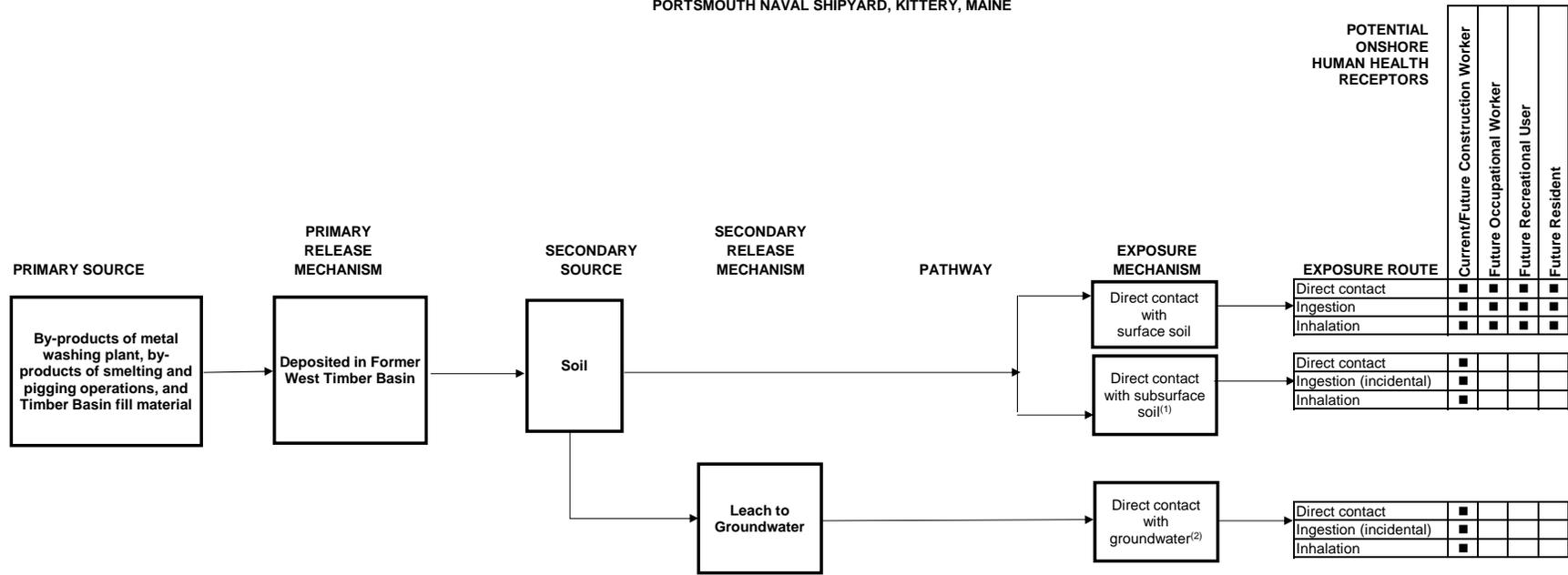
**CROSS SECTION A-A'  
 OPERABLE UNIT 8  
 PORTSMOUTH NAVAL SHIPYARD  
 KITTELY, MAINE**

DATE:	3/7/14
PROJECT NO.:	112G03270
DESIGNED BY:	
DRAWN BY:	CK
CHECKED BY:	
SHEET:	1 OF 2

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**FIGURE 5**



**FIGURE 7  
OU8 RISK EXPOSURE MODEL  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**

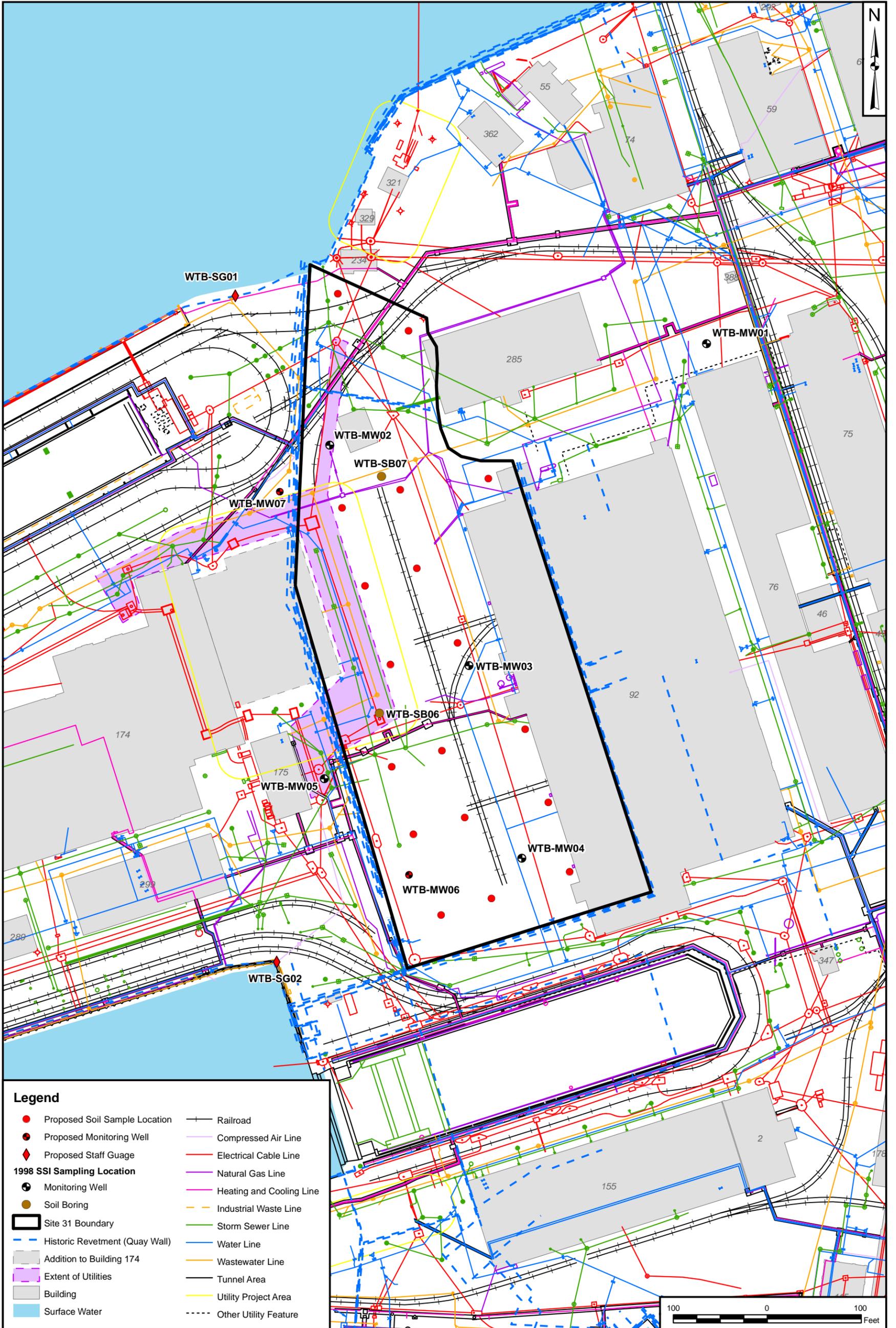


■ = POTENTIALLY COMPLETE EXPOSURE PATHWAY

Surface soil at OU8 is currently covered. Any surface soil exposures assume uncovered soil during a theoretical future exposure event.

1. Direct contact with subsurface soil is considered to be an incomplete pathway for occupational workers, recreational users, and residents because site conditions (e.g., shallow groundwater) make it unlikely that subsurface soil will become exposed. However, exposure to subsurface soil for these receptors is considered as part of the Uncertainty Analysis.

2. Exposure to groundwater is considered to be a potentially complete pathway only for the construction worker because the groundwater at OU8 is saline/brackish. Dermal contact for construction workers is considered to be a potentially complete pathway because contact could occur during excavation activities.



**Legend**

- Proposed Soil Sample Location
- Proposed Monitoring Well
- ◆ Proposed Staff Gauge
- 1998 SSI Sampling Location**
- ⊕ Monitoring Well
- Soil Boring
- ▭ Site 31 Boundary
- - - Historic Revetment (Quay Wall)
- Addition to Building 174
- Extent of Utilities
- Building
- Surface Water
- Railroad
- Compressed Air Line
- Electrical Cable Line
- Natural Gas Line
- Heating and Cooling Line
- Industrial Waste Line
- Storm Sewer Line
- Water Line
- Wastewater Line
- Tunnel Area
- Utility Project Area
- - - Other Utility Feature

DRAWN BY	DATE
J. ENGLISH	03/07/14
CHECKED BY	DATE
M. BOERIO	11/14/14
REVISED BY	DATE
J. ENGLISH	11/14/14
SCALE	
AS NOTED	

  
**OPERABLE UNIT 8**  
**PROPOSED SAMPLING LOCATIONS WITH UTILITY LINES**  
**PORTSMOUTH NAVAL SHIPYARD**  
**KITTERY, MAINE**

CONTRACT NUMBER	CTO NUMBER
3270	
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO.	REV
8	0

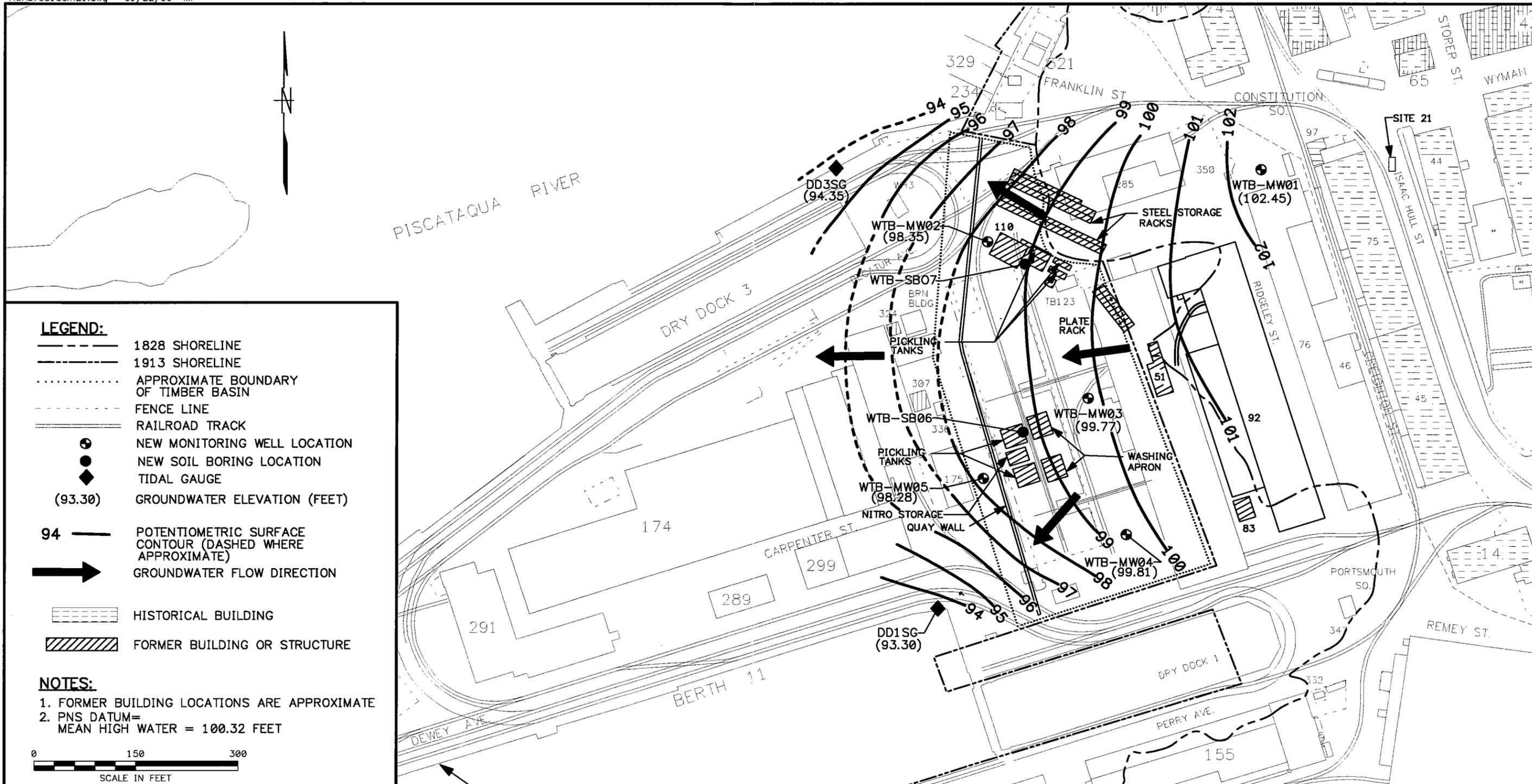
## **APPENDIX A**

### **SUPPORTING INFORMATION**

- A.1 SSI POTENTIOMETRIC SURFACE MAPS**
- A.2 VISUAL SAMPLE PLAN OUTPUT FOR OU8**
- A.3 TABLES 1, 2, AND 3**
- A.4 RISK BASED SCREENING LEVEL DEVELOPMENT FOR  
CONSTRUCTION WORKERS EXPOSED TO GROUNDWATER  
AT PORTSMOUTH NAVAL SHIPYARD**
- A-5 GEOTECHNICAL EVALUATIONS AND BORING LOGS**

## **A.1 SSI POTENTIOMETRIC SURFACE MAPS**

ACAD: 6515cm21.dwg 01/22/99 MF



**LEGEND:**

- 1828 SHORELINE
- 1913 SHORELINE
- ..... APPROXIMATE BOUNDARY OF TIMBER BASIN
- FENCE LINE
- RAILROAD TRACK
- ⊕ NEW MONITORING WELL LOCATION
- NEW SOIL BORING LOCATION
- ◆ TIDAL GAUGE
- (93.30) GROUNDWATER ELEVATION (FEET)
- 94 --- POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE APPROXIMATE)
- ➔ GROUNDWATER FLOW DIRECTION
- ▨ HISTORICAL BUILDING
- ▩ FORMER BUILDING OR STRUCTURE

**NOTES:**

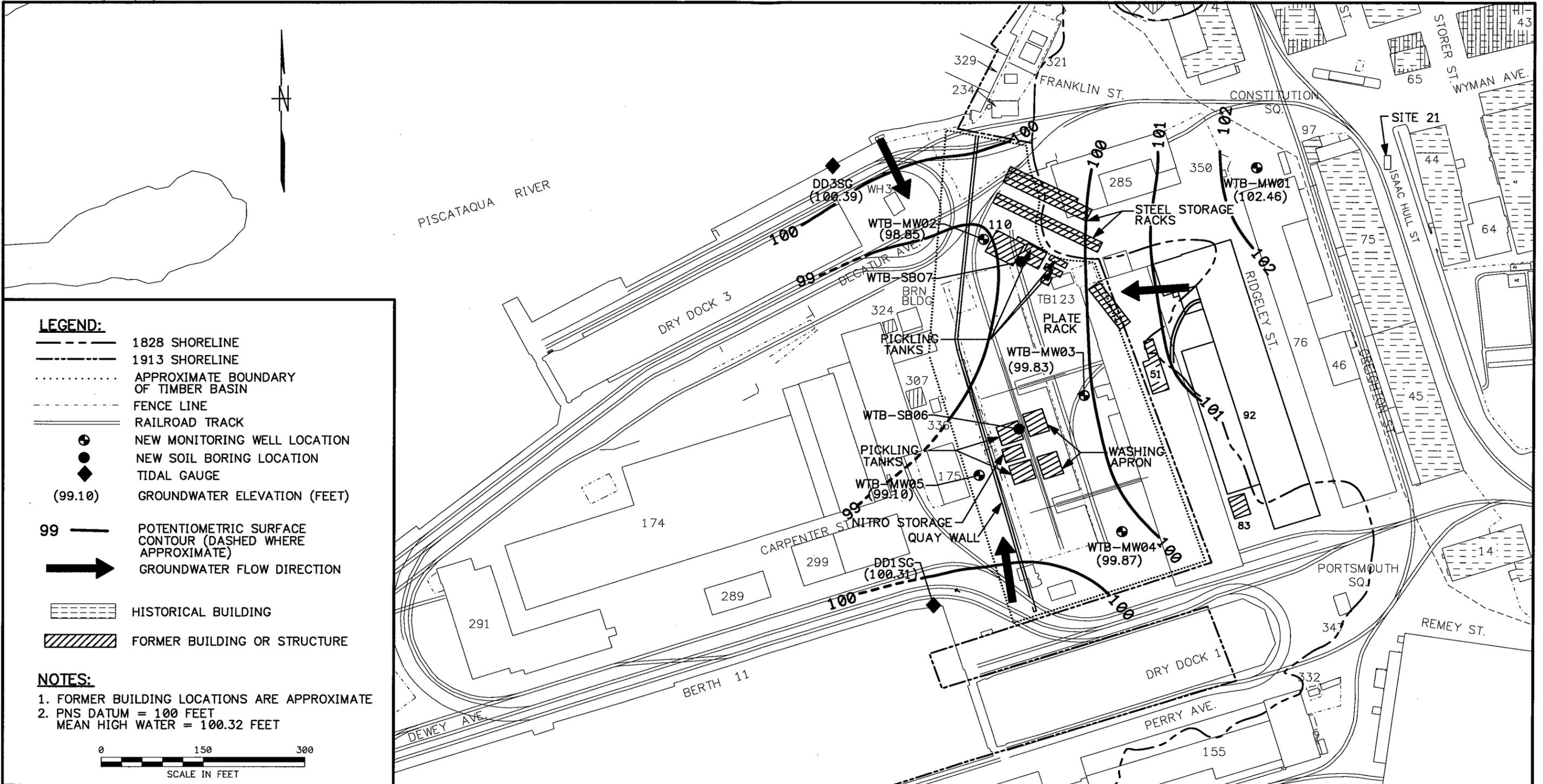
1. FORMER BUILDING LOCATIONS ARE APPROXIMATE
2. PNS DATUM = MEAN HIGH WATER = 100.32 FEET



NO.	DATE	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE	Tetra Tech NUS, Inc.	CONTRACT NO.	OWNER NO.
								KW	12/18/98		6515	0232
								CHECKED BY	DATE	POTENTIOMETRIC SURFACE MAP (LOW TIDE) WEST TIMBER BASIN (SITE 31) PORTSMOUTH NAVAL SHIPYARD KITTEHY, MAINE	APPROVED BY	DATE
								MLM	1/24/99		Mark A. Mengel	1/24/99
								COST/SCHED-AREA			APPROVED BY	DATE
								SCALE	AS NOTED		DRAWING NO.	REV.
											FIGURE 4-5	0

FORM CADD NO. T:NUS\_BH.DGN - REV 0 - 1/20/98

ACAD: 6515cm22.dwg 02/28/00 HJP

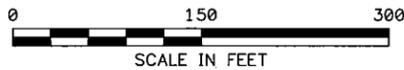


**LEGEND:**

- 1828 SHORELINE
- 1913 SHORELINE
- APPROXIMATE BOUNDARY OF TIMBER BASIN
- FENCE LINE
- RAILROAD TRACK
- NEW MONITORING WELL LOCATION
- NEW SOIL BORING LOCATION
- TIDAL GAUGE
- (99.10) GROUNDWATER ELEVATION (FEET)
- 99 POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE APPROXIMATE)
- GROUNDWATER FLOW DIRECTION
- HISTORICAL BUILDING
- FORMER BUILDING OR STRUCTURE

**NOTES:**

1. FORMER BUILDING LOCATIONS ARE APPROXIMATE
2. PNS DATUM = 100 FEET  
MEAN HIGH WATER = 100.32 FEET



NO.	DATE	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY KW 12/18/98	DATE 12/18/98	Tetra Tech NUS, Inc.	CONTRACT NO. 6515	OWNER NO. 0232
								CHECKED BY MLM 3/24/00	DATE 3/24/00		POTENTIOMETRIC SURFACE MAP (HIGH TIDE) WEST TIMBER BASIN (SITE 31) PORTSMOUTH NAVAL SHIPYARD KITTERY, MAINE	APPROVED BY <i>Mark H. Morgan</i>
								COST/SCHED-AREA			APPROVED BY	DATE
								SCALE AS NOTED			DRAWING NO. FIGURE 4-6	REV. 0

FORM CADD NO. T+NUS\_BH.DGN - REV 0 - 1/20/98

## **A.2 VISUAL SAMPLE PLAN OUTPUT FOR OU8**

## Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

### Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Simple random sampling
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	18

### Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

### Selected Sampling Approach

A nonparametric random sampling approach was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points randomly provides data that are separated by many distances, whereas systematic samples are all equidistant apart. Therefore, random sampling provides more information about the spatial structure of the potential contamination than systematic sampling does. As with systematic sampling, random sampling also provides information regarding the mean value, but there is the possibility that areas of the site will not be represented with the same frequency as if uniform grid sampling were performed.

### Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(\text{Sign}P - 0.5)^2}$$

where

$$\text{Sign}P = \Phi\left(\frac{\Delta}{S_{total}}\right)$$

- $\Phi(z)$  is the cumulative standard normal distribution on  $(-\infty, z)$  (see PNNL-13450 for details),
- $n$  is the number of samples,
- $S_{total}$  is the estimated standard deviation of the measured values including analytical error,
- $\Delta$  is the width of the gray region,
- $\alpha$  is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
- $\beta$  is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
- $Z_{1-\alpha}$  is the value of the standard normal distribution such that the proportion of the distribution less than  $Z_{1-\alpha}$  is  $1-\alpha$ ,
- $Z_{1-\beta}$  is the value of the standard normal distribution such that the proportion of the distribution less than  $Z_{1-\beta}$  is  $1-\beta$ .

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of  $n$ . VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n <sup>a</sup>	Parameter					
		S	$\Delta$	$\alpha$	$\beta$	$Z_{1-\alpha}$ <sup>b</sup>	$Z_{1-\beta}$ <sup>c</sup>
Iron	18	24108 mg/kg	14400 mg/kg	0.15	0.2	1.03643	0.841621

<sup>a</sup> The final number of samples has been increased by the MARSSIM Overage of 0%.

<sup>b</sup> This value is automatically calculated by VSP based upon the user defined value of  $\alpha$ .

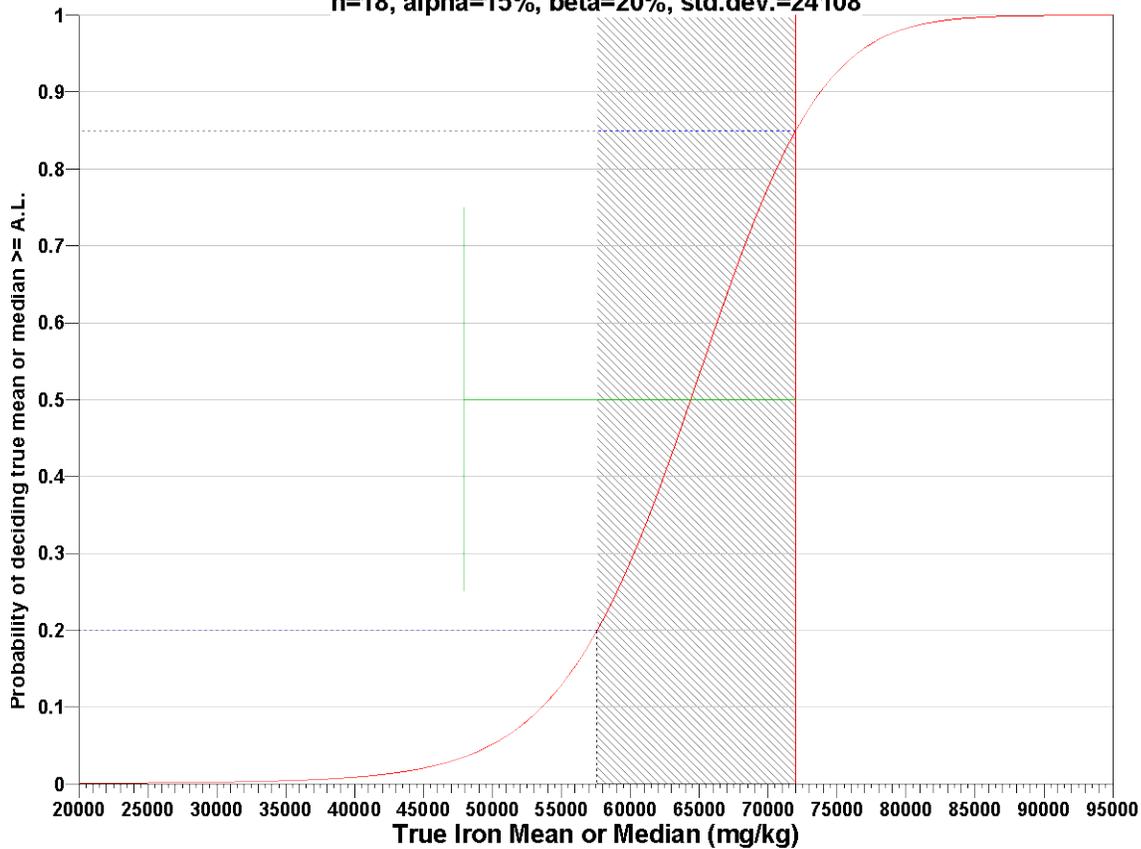
<sup>c</sup> This value is automatically calculated by VSP based upon the user defined value of  $\beta$ .

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to  $\Delta$ ; the upper horizontal dashed blue line is positioned at  $1-\alpha$  on the vertical axis; the lower horizontal dashed blue line is positioned at  $\beta$  on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of  $\Delta$  at  $\beta$  and the upper bound of  $\Delta$  at  $1-\alpha$ . If any of the inputs change, the number of samples that result in the correct curve changes.

## MARSSIM Sign Test

n=18, alpha=15%, beta=20%, std.dev.=24108



### Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate,  $S^2$ , is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected randomly.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the sample locations were selected using a random process.

### Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that  $\mu >$  action level and alpha (%), probability of mistakenly concluding that  $\mu <$  action level. The following table shows the results of this analysis.

AL=72000		Number of Samples					
		$\alpha=10$		$\alpha=15$		$\alpha=20$	
		s=48216	s=24108	s=48216	s=24108	s=48216	s=24108
LBGR=90	$\beta=15$	382	98	305	78	251	64
	$\beta=20$	320	82	251	64	202	52
	$\beta=25$	272	70	208	54	164	42
LBGR=80	$\beta=15$	98	27	78	22	64	18
	$\beta=20$	82	23	64	18	52	15

	$\beta=25$	70	19	54	15	42	12
<b>LBGR=70</b>	$\beta=15$	45	14	36	11	30	9
	$\beta=20$	38	12	30	9	24	8
	$\beta=25$	32	10	25	8	20	6

s = Standard Deviation

LBGR = Lower Bound of Gray Region (% of Action Level)

$\beta$  = Beta (%), Probability of mistakenly concluding that  $\mu >$  action level

$\alpha$  = Alpha (%), Probability of mistakenly concluding that  $\mu <$  action level

AL = Action Level (Threshold)

### Recommended Data Analysis Activities

Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median(mean) value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

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### **A.3 TABLES 1, 2, AND 3**

**TABLE 1**  
**OU8 SSI SURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 1 OF 4**

LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Sample	Site Samples						
				WTB-MW01 WTB-SS01-0001-98 7/13/1998	WTB-MW02 WTB-SS02-0001-98 7/8/1998	WTB-MW05 WTB-SS05-0001-98 7/7/1998	WTB-SB06 WTB-SS06-0001-98 7/15/1998	WTB-SB07 WTB-SS07-0001-98 7/11/1998			
				METALS (MG/KG)							
ALUMINUM	7700 N	110000 N	4,930 - 33,500	10000	8170	11100	8520	15700			
ANTIMONY	3.1 N	47 N	7 - 9.4	0.39 UR	3.2 J	0.3 UR	0.62 U	0.91 U			
ARSENIC	0.67 C	3.0 C	4.4 - 58.6	15.3 J	9 J	10.6 J	9.7	5.6 J			
BARIUM	1500 N	22000 N	22.3 - 223	76.8	56 J	50.3 J	52.5	97.2			
BERYLLIUM	16 N	230 N	0.34 - 1.1	0.29	0.38 U	0.43 J	0.37	0.6			
CADMIUM	7 N	98 N	0.82 - 3.4	0.45 U	0.42 J	0.45 J	1.9 J	0.8 U			
CALCIUM	NA	NA	682 - 7910	5820 J	2260 J	4580 J	3440	13000 J			
CHROMIUM	12000 N	180000 N	11.6 - 103	40.2 J	60.8 J	43.3 J	146	82.5 J			
COBALT	2.3 N	35 N	3.1 - 24.2	10.1	13	11.3	10.7	19.5			
COPPER	310 N	4700 N	8.5 - 316	155 J	257 J	37.6 J	182 J	152 J			
IRON	5500 N	82000 N	8730 - 45000	23700	38100	24000	22100	40700			
LEAD	400	800	9.5 - 1100	293 J	154	46.4	147 J	124 J			
MAGNESIUM	NA	NA	1500 - 17200	6970	5470	6800	5280	12400			
MANGANESE	180 N	2600 N	110 - 611	224 J	516	346	271	598 J			
MERCURY <sup>(1)</sup>	0.94 N	4.0 N	0.0825 - 1.8	0.18 J	0.45 J	109	1.4 J	0.22 J			
NICKEL	150 N	2200 N	8.1 - 73.2	40.4	53.7 J	31.5 J	78	65.1			
POTASSIUM	NA	NA	585 - 6580	3360	2270	3040	2200	5610			
SELENIUM	39 N	580 N	0.32 - 2.1	0.63 UJ	0.49 UJ	0.48 UJ	0.53 U	0.52 UJ			
SILVER	39 N	580 N	ND	0.52 U	0.41 U	0.6 J	0.31 U	0.44 U			
SODIUM	NA	NA	35.1 - 1370	340 U	146	397	116 U	266 U			
THALLIUM	0.078 N	1.2 N	0.22 - 0.23	1.2 U	0.5 U	0.51 U	0.53 UJ	1 U			
VANADIUM	39 N	580 N	13.5 - 89.5	34.9	40.8	34.1	26.9 J	58.5			
ZINC	2300 N	35000 N	23.1 - 1390	152 J	323 J	84.5 J	900 J	276 J			
<b>MISCELLANEOUS PARAMETERS</b>											
CYANIDE (MG/KG)	2.1 N	13 N	NA	2 UJ	2 U	2 U	2 U	2 UJ			
HEXAVALENT CHROMIUM (MG/KG)	0.30 C	6.3 C	NA	0.52 U	0.5 UJ	0.5 UJ	7.9 UJ	0.51 UJ			
TOTAL ORGANIC CARBON (MG/KG)	NA	NA	NA	27000	20000	15000	48000	17000			
PH (S.U.)	NA	NA	NA	8.3	7.3	8.7	7.9	8			
<b>SEMIVOLATILES (UG/KG)</b>											
1,2,4-TRICHLOROENZENE	5800 N	26000 N	ND	360 U	330 U	1700 U	360 U	330 U			
1,2-DICHLOROENZENE	180000 N	930000 N	ND	360 U	330 U	1700 U	360 U	330 U			
1,3-DICHLOROENZENE	NA	NA	ND	360 U	330 U	1700 U	360 U	330 U			
1,4-DICHLOROENZENE	2600 C	11000 C	67 - 67	360 U	330 U	1700 U	360 U	330 U			
2,2'-OXYBIS(1-CHLOROPROPANE)	4900 C	22000 C	ND	360 U	330 U	1700 U	360 U	330 U			
2,4,5-TRICHLOROPHENOL	620000 N	8200000 N	ND	910 U	830 U	4300 U	910 U	830 U			
2,4,6-TRICHLOROPHENOL	6200 N	82000 N	ND	360 U	330 U	1700 U	360 U	330 U			
2,4-DICHLOROPHENOL	18000 N	250000 N	ND	360 U	330 U	1700 U	360 U	330 U			
2,4-DIMETHYLPHENOL	120000 N	1600000 N	ND	360 U	330 U	1700 U	360 U	330 U			
2,4-DINITROPHENOL	12000 N	160000 N	ND	910 U	830 UJ	4300 UJ	910 UJ	830 U			
2,4-DINITROTOLUENE	1700 C	7400 C	ND	360 U	330 U	1700 U	360 U	330 U			
2,6-DINITROTOLUENE	360 C	1500 C	ND	360 U	330 U	1700 U	360 U	330 U			
2-CHLORONAPHTHALENE	630000 N	9300000 N	ND	360 U	330 U	1700 U	360 U	330 U			
2-CHLOROPHENOL	39000 N	580000 N	ND	360 U	330 U	1700 U	360 U	330 U			
2-METHYLPHENOL	310000 N	4100000 N	ND	360 U	330 U	1700 U	360 U	330 U			
2-NITROANILINE	61000 N	800000 N	ND	910 U	830 U	4300 U	910 UJ	830 U			
2-NITROPHENOL	NA	NA	ND	360 U	330 U	1700 U	360 U	330 U			
3,3'-DICHLOROBENZIDINE	1200 C	5100 C	ND	360 U	330 U	1700 U	360 U	330 U			
3-NITROANILINE	NA	NA	ND	910 U	830 U	4300 U	910 U	830 U			
4,6-DINITRO-2-METHYLPHENOL	490 N	6600 N	ND	910 U	830 U	4300 U	910 U	830 U			

**TABLE 1**  
**OU8 SSI SURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 2 OF 4**

LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Sample	Site Samples				
				WTB-MW01 WTB-SS01-0001-98 7/13/1998	WTB-MW02 WTB-SS02-0001-98 7/8/1998	WTB-MW05 WTB-SS05-0001-98 7/7/1998	WTB-SB06 WTB-SS06-0001-98 7/15/1998	WTB-SB07 WTB-SS07-0001-98 7/11/1998	
				4-BROMOPHENYL PHENYL ETHER	NA	NA	ND	360 U	330 U
4-CHLORO-3-METHYLPHENOL	620000 N	8200000 N	ND	360 U	330 U	1700 U	360 U	330 U	
4-CHLOROANILINE	2700 C	1200 C	ND	360 U	330 U	1700 U	360 U	330 U	
4-CHLOROPHENYL PHENYL ETHER	NA	NA	ND	360 U	330 U	1700 U	360 U	330 U	
4-METHYLPHENOL	620000 N	8200000 N	ND	360 U	330 U	1700 U	360 U	330 U	
4-NITROANILINE	25000 N	120000 C	ND	910 U	830 U	4300 U	910 U	830 U	
4-NITROPHENOL	NA	NA	ND	910 U	830 U	4300 UJ	910 UJ	830 U	
BIS(2-CHLOROETHOXY)METHANE	18000 N	250000 N	ND	360 U	330 U	1700 U	360 U	330 U	
BIS(2-CHLOROETHYL)ETHER	230 C	1000 C	ND	360 U	330 U	1700 U	360 U	330 U	
BIS(2-ETHYLHEXYL)PHTHALATE	38000 C	160000 C	58 - 650	360 U	330 U	1700 U	160 U	330 U	
BUTYL BENZYL PHTHALATE	280000 C	120000 C	ND	360 U	330 U	1700 U	36 J	330 U	
CARBAZOLE	NA	NA	94 - 94	360 U	76 J	1700 U	28 J	330 U	
DIETHYL PHTHALATE	4900000 N	66000000 N	ND	360 U	330 U	1700 U	360 U	330 U	
DIMETHYL PHTHALATE	NA	NA	42 - 42	360 U	330 U	1700 U	360 U	330 U	
DI-N-BUTYL PHTHALATE	620000 N	8200000 N	100 - 100	360 U	330 U	1700 U	24 J	330 U	
DI-N-OCTYL PHTHALATE	62000 N	820000 N	100 - 100	360 U	330 UJ	1700 UJ	360 U	330 U	
HEXACHLOROBENZENE	330 C	1400 C	ND	360 U	330 U	1700 U	360 U	330 U	
HEXACHLOROBTADIENE	6200 N	30000 C	ND	360 U	330 U	1700 UJ	360 U	330 U	
HEXACHLOROCYCLOPENTADIENE	37000 N	490000 N	ND	360 U	330 UJ	1700 U	360 U	330 U	
HEXACHLOROETHANE	4300 N	58000 C	ND	360 U	330 U	1700 U	360 U	330 U	
ISOPHORONE	560000 C	2400000 C	ND	360 U	330 U	1700 U	360 U	330 U	
NITROBENZENE	5100 C	22000 C	ND	360 U	330 U	1700 U	360 U	330 U	
N-NITROSO-DI-N-PROPYLAMINE	76 C	330 C	ND	360 U	330 U	1700 U	360 U	330 U	
N-NITROSODIPHENYLAMINE	110000 C	470000 C	ND	360 U	330 U	1700 U	360 U	330 U	
PENTACHLOROPHENOL	990 C	4000 C	ND	910 UJ	830 U	4300 U	910 UJ	830 UJ	
PHENOL	1800000 N	25000000 N	98 - 98	360 U	330 U	1700 U	360 U	330 U	
<b>VOLATILES (UG/KG)</b>									
1,1,1-TRICHLOROETHANE	810000 N	3600000 N	ND	11 UJ	11 U	11 U	11 UJ	10 U	
1,1,2,2-TETRACHLOROETHANE	600 C	2700 C	ND	11 UR	11 UJ	11 UJ	11 UJ	10 U	
1,1,2-TRICHLOROETHANE	150 N	630 N	ND	11 UJ	11 U	11 U	11 UJ	10 U	
1,1,2-TRICHLOROTRIFLUOROETHANE	4000000 N	17000000 N	NA	11 UJ	11 U	11 U	11 U	10 U	
1,1-DICHLOROETHANE	3600 C	16000 C	ND	11 UJ	11 U	11 U	11 U	10 U	
1,1-DICHLOROETHENE	23000 N	100000 N	3 - 3	11 UJ	11 U	11 U	11 U	10 U	
1,2-DICHLOROETHANE	460 C	2000 C	ND	11 UJ	11 U	11 U	11 U	10 U	
1,2-DICHLOROPROPANE	1000 C	4400 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
2-BUTANONE	2700000 N	19000000 N	ND	11 U	11 U	11 U	11 U	10 U	
2-HEXANONE	20000 N	130000 N	ND	11 UR	11 UJ	11 UJ	11 UJ	10 U	
4-METHYL-2-PENTANONE	530000 N	5600000 N	ND	11 UR	11 UJ	11 UJ	11 UJ	10 U	
ACETONE	6100000 N	67000000 N	ND	26 U	11 U	11 U	11 U	11 U	
BENZENE	1200 C	5100 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
BROMODICHLOROMETHANE	290 C	1300 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
BROMOFORM	67000 C	290000 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
BROMOMETHANE	680 N	3000 N	ND	11 UJ	11 U	11 U	1 J	10 U	
CARBON DISULFIDE	77000 N	350000 N	ND	11 UJ	11 U	11 U	11 U	10 U	
CARBON TETRACHLORIDE	650 C	2900 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
CHLOROETHANE	28000 N	130000 N	ND	11 UR	11 UJ	11 UJ	11 UJ	10 U	
CHLORODIBROMOMETHANE	730 C	3200 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
CHLOROETHANE	1400000 N	5700000 N	ND	11 UJ	11 U	11 U	11 U	10 U	
CHLOROFORM	320 C	1400 C	ND	1 J	11 U	11 U	11 U	10 U	
CHLOROMETHANE	11000 N	46000 N	ND	11 UJ	11 U	11 U	11 U	10 U	

**TABLE 1**  
**OU8 SSI SURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 3 OF 4**

LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Sample	Site Samples				
				WTB-MW01 WTB-SS01-0001-98 7/13/1998	WTB-MW02 WTB-SS02-0001-98 7/8/1998	WTB-MW05 WTB-SS05-0001-98 7/7/1998	WTB-SB06 WTB-SS06-0001-98 7/15/1998	WTB-SB07 WTB-SS07-0001-98 7/11/1998	
				CIS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	11 UJ	11 U
ETHYLBENZENE	5800 C	25000 C	ND	11 UR	11 UJ	11 UJ	11 UJ	10 U	
METHYLENE CHLORIDE	35000 N	320000 N	1 - 2	14 U	18 U	18 U	28 U	77 U	
STYRENE	600000 N	3500000 N	ND	11 UR	11 UJ	11 UJ	11 UJ	10 U	
TETRACHLOROETHENE	8100 N	39000 N	5.5 - 8	11 UR	11 UJ	11 UJ	11 UJ	10 U	
TOLUENE	490000 N	4700000 N	1 - 1	11 UR	11 UJ	11 UJ	11 UJ	10 U	
TOTAL 1,2-DICHLOROETHENE	NA	NA	ND	11 UJ	11 U	11 U	11 U	10 U	
TOTAL XYLENES	58000 N	250000 N	ND	11 UR	11 UJ	5 J	11 UJ	10 U	
TRANS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	11 UJ	11 U	11 U	11 UJ	10 U	
TRICHLOROETHENE	410 N	1900 N	ND	11 UJ	11 U	11 U	11 UJ	10 U	
VINYL CHLORIDE	59 C	1700 C	ND	11 UJ	11 U	11 U	11 U	10 U	
<b>POLYCYCLIC AROMATIC HYDROCARBONS (UG/KG)</b>									
2-METHYLNAPHTHALENE	23000 N	300000 N	44 - 44	78 J	38 J	1700 U	25 J	330 U	
ACENAPHTHENE	350000 N	4500000 N	ND	360 U	330 U	1700 U	25 J	330 U	
ACENAPHTHYLENE <sup>(2)</sup>	350000 N	4500000 N	74 - 74	360 U	19 J	1700 U	360 U	330 U	
ANTHRACENE	1700000 N	23000000 N	58 - 62	360 U	29 J	1700 U	50 J	330 U	
BENZO(A)ANTHRACENE	150 C	2900 C	37 - 640	57 J	120 J	600 J	140 J	55 J	
BENZO(A)PYRENE	15 C	290 C	36 - 1100	51 J	360	610 J	130 J	55 J	
BENZO(B)FLUORANTHENE	150 C	2900 C	41 - 1700	110 J	210 J	950 J	150 J	64 J	
BENZO(G,H,I)PERYLENE <sup>(3)</sup>	170000 N	2300000 N	39 - 410	92 J	49 J	1700 UJ	270 J	63 J	
BENZO(K)FLUORANTHENE	1500 C	29000 C	38 - 1100	51 J	168 J	730 J	100 J	52 J	
CHRYSENE	15000 C	290000 C	37 - 1600	120 J	210 J	710 J	210 J	75 J	
DIBENZO(A,H)ANTHRACENE	15 C	290 C	180 - 190	360 U	55 J	200 J	61 J	36 J	
DIBENZOFURAN	7200 N	100000 N	ND	360 U	330 U	1700 U	28 J	330 U	
FLUORANTHENE	230000 N	3000000 N	43 - 1700	48 J	200 J	600 J	250 J	74 J	
FLUORENE	230000 N	3000000 N	42 - 42	19 J	20 J	1700 U	28 J	330 U	
INDENO(1,2,3-CD)PYRENE	150 C	2900 C	38 - 440	53 J	120 J	330 J	93 J	53 J	
NAPHTHALENE	3800 C	17000 C	42 - 43	38 J	23 J	1700 U	32 J	330 U	
PHENANTHRENE <sup>(3)</sup>	170000 N	2300000 N	40 - 470	84 J	120 J	140 J	230 J	22 J	
PYRENE	170000 N	2300000 N	42 - 1400	120 J	540	660 J	380	79 J	
<b>PESTICIDES/PCBS (UG/KG)</b>									
4,4'-DDD	2200 C	9600 C	0.6 - 170	3.5 U	3.5 U	4.3	3.5 U	3.4 U	
4,4'-DDE	1600 C	6800 C	5.2 - 7100	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
4,4'-DDT	1900 C	8600 C	5.1 - 4100	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
ALDRIN	31 C	140 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
ALPHA-BHC	85 C	370 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
ALPHA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
AROCLOR-1016	400 N	5200 N	ND	35 U	35 U	34 U	35 U	34 U	
AROCLOR-1221	150 C	660 C	ND	72 U	71 U	70 U	72 U	69 U	
AROCLOR-1232	150 C	660 C	ND	35 U	35 U	34 U	35 U	34 U	
AROCLOR-1242	240 C	1000 C	ND	35 U	35 U	34 U	35 U	34 U	
AROCLOR-1248	240 C	1000 C	ND	35 U	35 U	34 U	35 U	34 U	
AROCLOR-1254	110 N	1000 C	ND	35 U	35 U	34 U	35 U	34 U	
AROCLOR-1260	240 C	1000 C	ND	35 U	35 U	34 U	35 U	34 U	
BETA-BHC	300 C	1300 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
DELTA-BHC <sup>(5)</sup>	85 C	370 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
DIELDRIN	33 C	140 C	ND	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
ENDOSULFAN I <sup>(6)</sup>	37000 N	490000 N	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
ENDOSULFAN II <sup>(6)</sup>	37000 N	490000 N	ND	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
ENDOSULFAN SULFATE <sup>(6)</sup>	37000 N	490000 N	ND	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	

**TABLE 1**  
**OU8 SSI SURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Sample	Site Samples				
				WTB-MW01 WTB-SS01-0001-98 7/13/1998	WTB-MW02 WTB-SS02-0001-98 7/8/1998	WTB-MW05 WTB-SS05-0001-98 7/7/1998	WTB-SB06 WTB-SS06-0001-98 7/15/1998	WTB-SB07 WTB-SS07-0001-98 7/11/1998	
ENDRIN	1800 N	25000 N	ND	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
ENDRIN ALDEHYDE <sup>(7)</sup>	1800 N	25000 N	ND	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
ENDRIN KETONE <sup>(7)</sup>	1800 N	25000 N	ND	3.5 U	3.5 U	3.4 U	3.5 U	3.4 U	
GAMMA-BHC (LINDANE)	560 C	2500 C	ND	1.8 U	1.8 UJ	1.8 UJ	1.8 U	1.8 U	
GAMMA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
HEPTACHLOR	120 C	510 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
HEPTACHLOR EPOXIDE	59 C	250 C	ND	1.8 U	1.8 U	1.8 U	1.8 U	1.8 U	
METHOXYCHLOR	31000 N	410000 N	ND	18 U	18 U	18 U	18 U	18 U	
TOXAPHENE	480 C	2100 C	ND	180 U	180 U	180 U	180 U	180 U	
<b>PETROLEUM HYDROCARBONS (MG/KG)</b>									
DIESEL RANGE ORGANICS	NA	NA	NA	440 U	160 J	120 J	170	84 U	
GASOLINE RANGE ORGANICS	NA	NA	NA	2.5 U	3.1	2.5 U	2.5 U	2.5 U	

USEPA RSLs are from May 2014 and are based on ILCR =  $1 \times 10^{-6}$  (C) and HI = 0.1 (N). C = carcinogen; N=Non-carcinogen.

NA = The chemical was not analyzed or no value was available. ND = The chemical was not detected.

Data Qualifiers: J = The chemical was detected but the concentration reported is an estimated value. U= The chemical was not detected. R= The chemical was rejected.

WTB-MW05 is located west of the quay wall that forms the western boundary of OU8 and may not represent site data.

Shaded values indicate industrial RSL was exceeded.

- (1) RSL is for elemental mercury
- (2) RSL is for acenaphthene
- (3) RSL is for pyrene
- (4) RSL is for chlordane
- (5) RSL is for alpha-BHC
- (6) RSL is for endosulfan
- (7) RSL is for endrin

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Location WTB- MW01 WTB-SB01-0305-98 7/13/1998	WTB-MW02 WTB-SB02-0709-98 7/8/1998	WTB-MW02 WTB-SB02-1517-98 7/8/1998	WTB-MW02 WTB-SB02-0305-98 7/8/1998	WTB-MW03 WTB-SB03-0911-98 7/11/1998
<b>METALS (MG/KG)</b>								
ALUMINUM	7700 N	110000 N	4,930 - 33,500	13100	4660	13500	4940	14600
ANTIMONY	3.1 N	47 N	7 - 9.4	0.46 UR	0.6 UR	0.52 UR	0.34 U	0.47 UR
ARSENIC	0.67 C	3.0 C	4.4 - 58.6	13.2 J	26.3 J	9.7 J	45.6 J	17.5 J
BARIUM	1500 N	22000 N	22.3 - 223	56	148 J	81 J	364 J	76
BERYLLIUM	16 N	230 N	0.34 - 1.1	0.74	0.69	0.76	0.59 J	0.58
CADMIUM	7 N	98 N	0.82 - 3.4	0.53 U	0.69 U	0.61 U	0.4 U	0.55 U
CALCIUM	NA	NA	682 - 7910	2470 J	2660 J	2670 J	20800 J	1860 J
CHROMIUM	12000 N	180000 N	11.6 - 103	27.8 J	14.7 J	36.5 J	20.8 J	52.4 J
COBALT	2.3 N	35 N	3.1 - 24.2	12.6	4.4	5.6	4	13.3
COPPER	310 N	4700 N	8.5 - 316	21.3 J	324 J	127 J	361 J	45.4 J
IRON	5500 N	82000 N	8730 - 45000	21400	25400	26200	28000	23700
LEAD	400	800	9.5 - 1100	14.6 U	773	413	9080	36.9 U
MAGNESIUM	NA	NA	1500 - 17200	4880	690	6210	2260	7060
MANGANESE	180 N	2600 N	110 - 611	488 J	252	193	143	475 J
MERCURY <sup>(1)</sup>	0.94 N	4.0 N	0.0825 - 1.8	0.01 UJ	8.1 J	0.39 J	0.28 J	0.17 J
NICKEL	150 N	2200 N	8.1 - 73.2	29.2	9.1 J	19.1 J	16.5 J	49.5
POTASSIUM	NA	NA	585 - 6580	2600	634	3710	1920	2260
SELENIUM	39 N	580 N	0.32 - 2.1	0.74 UJ	2.7 U	1.1 U	3.6 U	0.76 UJ
SILVER	39 N	580 N	ND	0.61 U	0.81 U	0.71 U	0.81 J	0.64 U
SODIUM	NA	NA	35.1 - 1370	480	1050	3690	754	189 U
THALLIUM	0.078 N	1.2 N	0.22 - 0.23	1.6 U	0.98 U	0.86 U	0.56 U	0.77 U
VANADIUM	39 N	580 N	13.5 - 89.5	29.1	25.7	37.8	32.8	31.9
ZINC	2300 N	35000 N	23.1 - 1390	54.8 J	212 J	261 J	130 J	73.2 J
<b>MISCELLANEOUS PARAMETERS</b>								
CYANIDE (MG/KG)	2.1 N	13 N	NA	2 UJ	2 U	2 U	34	2 UJ
HEXAVALENT CHROMIUM (MG/KG)	0.30 C	6.3 C	NA	0.56 U	0.5 UJ	2 UJ	0.5 UJ	0.56 UJ
TOTAL ORGANIC CARBON (MG/KG)	NA	NA	NA	3200	69000	--	--	25000
PH (S.U.)	NA	NA	NA	4.9	7.9	8.2	10.1	7.8
<b>SEMIVOLATILES (UG/KG)</b>								
1,2,4-TRICHLOROBENZENE	5800 N	26000 N	ND	400 U	530 U	2500 U	360 U	400 U
1,2-DICHLOROBENZENE	180000 N	930000 N	ND	400 U	530 U	2500 U	360 U	400 U
1,3-DICHLOROBENZENE	NA	NA	ND	400 U	530 U	2500 U	360 U	400 U
1,4-DICHLOROBENZENE	2600 C	11000 C	67 - 67	400 U	530 U	2500 U	360 U	400 U
2,2'-OXYBIS(1-CHLOROPROPANE)	4900 C	22000 C	ND	400 U	530 U	2500 U	360 U	400 U
2,4,5-TRICHLOROPHENOL	620000 N	8200000 N	ND	1000 U	1300 U	6300 U	910 U	1000 U
2,4,6-TRICHLOROPHENOL	6200 N	82000 N	ND	400 U	530 U	2500 U	360 U	400 U
2,4-DICHLOROPHENOL	18000 N	250000 N	ND	400 U	530 U	2500 U	360 U	400 U
2,4-DIMETHYLPHENOL	120000 N	1600000 N	ND	400 U	530 U	2500 U	360 U	400 U
2,4-DINITROPHENOL	12000 N	160000 N	ND	1000 U	1300 UJ	6300 UJ	910 UJ	1000 UJ
2,4-DINITROTOLUENE	1700 C	7400 C	ND	400 U	530 U	2500 U	360 U	400 U
2,6-DINITROTOLUENE	360 C	1500 C	ND	400 U	530 U	2500 U	360 U	400 U
2-CHLORONAPHTHALENE	630000 N	9300000 N	ND	400 U	530 U	2500 U	360 U	400 U
2-CHLOROPHENOL	39000 N	580000 N	ND	400 U	530 U	2500 U	360 U	400 U
2-METHYLPHENOL	310000 N	4100000 N	ND	400 U	530 U	2500 U	360 U	400 U
2-NITROANILINE	61000 N	800000 N	ND	1000 U	1300 U	6300 U	910 U	1000 U
2-NITROPHENOL	NA	NA	ND	400 U	530 U	2500 U	360 U	400 U
3,3'-DICHLOROBENZIDINE	1200 C	5100 C	ND	400 U	530 U	2500 U	360 U	400 UJ
3-NITROANILINE	NA	NA	ND	1000 U	1300 U	6300 U	910 U	1000 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Location WTB- MW01 WTB-SB01-0305-98 7/13/1998	WTB-MW02 WTB-SB02-0709-98 7/8/1998	WTB-MW02 WTB-SB02-1517-98 7/8/1998	WTB-MW02 WTB-SB02-0305-98 7/8/1998	WTB-MW03 WTB-SB03-0911-98 7/11/1998
4,6-DINITRO-2-METHYLPHENOL	490 N	6600 N	ND	1000 U	1300 UJ	6300 U	910 U	1000 U
4-BROMOPHENYL PHENYL ETHER	NA	NA	ND	400 U	530 U	2500 U	360 U	400 U
4-CHLORO-3-METHYLPHENOL	620000 N	8200000 N	ND	400 U	530 U	2500 U	360 U	400 U
4-CHLOROANILINE	2700 C	1200 C	ND	400 U	530 U	2500 U	360 U	400 UJ
4-CHLOROPHENYL PHENYL ETHER	NA	NA	ND	400 U	530 U	2500 U	360 U	400 U
4-METHYLPHENOL	620000 N	8200000 N	ND	400 U	530 U	2500 U	360 U	400 U
4-NITROANILINE	25000 N	120000 C	ND	1000 U	1300 U	6300 U	910 U	1000 U
4-NITROPHENOL	NA	NA	ND	1000 U	1300 U	6300 UJ	910 UJ	1000 U
BIS(2-CHLOROETHOXY)METHANE	18000 N	250000 N	ND	400 U	530 U	2500 U	360 U	400 U
BIS(2-CHLOROETHYL)ETHER	230 C	1000 C	ND	400 U	530 U	2500 U	360 U	400 UJ
BIS(2-ETHYLHEXYL)PHTHALATE	38000 C	160000 C	58 - 650	400 U	530 U	2500 U	360 U	420 U
BUTYL BENZYL PHTHALATE	280000 C	120000 C	ND	400 U	530 U	2500 U	360 U	400 U
CARBAZOLE	NA	NA	94 - 94	400 U	32 J	4000	220 J	400 U
DIETHYL PHTHALATE	4900000 N	66000000 N	ND	400 U	530 U	2500 U	360 U	400 U
DIMETHYL PHTHALATE	NA	NA	42 - 42	400 U	530 U	2500 U	360 U	400 U
DI-N-BUTYL PHTHALATE	620000 N	8200000 N	100 - 100	400 U	530 U	2500 U	360 U	400 U
DI-N-OCTYL PHTHALATE	62000 N	820000 N	100 - 100	400 U	530 U	2500 UJ	360 UJ	400 U
HEXACHLOROBENZENE	330 C	1400 C	ND	400 U	530 U	2500 U	360 U	400 U
HEXACHLOROBUTADIENE	6200 N	30000 C	ND	400 U	530 U	2500 UJ	360 UJ	400 U
HEXACHLOROCYCLOPENTADIENE	37000 N	490000 N	ND	400 U	530 UJ	2500 U	360 U	400 U
HEXACHLOROETHANE	4300 N	58000 C	ND	400 U	530 U	2500 U	360 U	400 U
ISOPHORONE	560000 C	2400000 C	ND	400 U	530 U	2500 U	360 U	400 U
NITROBENZENE	5100 C	22000 C	ND	400 U	530 U	2500 U	360 U	400 U
N-NITROSO-DI-N-PROPYLAMINE	76 C	330 C	ND	400 U	530 U	2500 U	360 U	400 U
N-NITROSODIPHENYLAMINE	110000 C	470000 C	ND	400 U	530 U	2500 U	360 U	400 U
PENTACHLOROPHENOL	990 C	4000 C	ND	1000 UJ	1300 U	6300 U	910 U	1000 UJ
PHENOL	1800000 N	25000000 N	98 - 98	400 U	530 U	2500 U	360 U	400 UJ
<b>VOLATILES (UG/KG)</b>								
1,1,1-TRICHLOROETHANE	810000 N	3600000 N	ND	12 U	16 UJ	15 U	12 UJ	12 U
1,1,2,2-TETRACHLOROETHANE	600 C	2700 C	ND	12 U	16 UR	15 U	12 UJ	12 U
1,1,2-TRICHLOROETHANE	150 N	630 N	ND	12 U	16 UJ	15 U	12 UJ	12 U
1,1,2-TRICHLOROTRIFLUOROETHANE	4000000 N	17000000 N	NA	12 U	16 UJ	15 U	12 U	12 U
1,1-DICHLOROETHANE	3600 C	16000 C	ND	12 U	16 UJ	15 U	12 U	12 U
1,1-DICHLOROETHENE	23000 N	100000 N	3 - 3	12 U	16 UJ	15 U	12 U	12 U
1,2-DICHLOROETHANE	460 C	2000 C	ND	12 U	16 UJ	15 U	12 U	12 U
1,2-DICHLOROPROPANE	1000 C	4400 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
2-BUTANONE	2700000 N	19000000 N	ND	12 U	16 UJ	16 U	8 J	12 U
2-HEXANONE	20000 N	130000 N	ND	12 U	16 UR	15 U	12 UJ	12 U
4-METHYL-2-PENTANONE	530000 N	5600000 N	ND	12 U	16 UR	15 U	12 UJ	12 U
ACETONE	6100000 N	67000000 N	ND	12 U	54 U	290	40 U	52 U
BENZENE	1200 C	5100 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
BROMODICHLOROMETHANE	290 C	1300 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
BROMOFORM	67000 C	290000 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
BROMOMETHANE	680 N	3000 N	ND	12 U	16 UJ	15 U	12 U	12 U
CARBON DISULFIDE	77000 N	350000 N	ND	12 U	16 UJ	35 U	12 U	12 U
CARBON TETRACHLORIDE	650 C	2900 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
CHLOROBENZENE	28000 N	130000 N	ND	12 U	16 UR	15 U	12 UJ	12 U
CHLORODIBROMOMETHANE	730 C	3200 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
CHLOROETHANE	1400000 N	5700000 N	ND	12 U	16 UJ	15 U	12 U	12 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Location WTB-MW01 WTB-SB01-0305-98 7/13/1998	WTB-MW02 WTB-SB02-0709-98 7/8/1998	WTB-MW02 WTB-SB02-1517-98 7/8/1998	WTB-MW02 WTB-SB02-0305-98 7/8/1998	WTB-MW03 WTB-SB03-0911-98 7/11/1998
CHLOROFORM	320 C	1400 C	ND	1 J	16 UJ	15 U	12 U	1 J
CHLOROMETHANE	11000 N	46000 N	ND	12 U	16 UJ	15 U	12 U	12 U
CIS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
ETHYLBENZENE	5800 C	25000 C	ND	12 U	16 UR	15 U	12 UJ	12 U
METHYLENE CHLORIDE	35000 N	320000 N	1 - 2	12 U	32 U	46 U	38 U	12 U
STYRENE	600000 N	3500000 N	ND	12 U	16 UR	15 U	12 UJ	12 U
TETRACHLOROETHENE	8100 N	39000 N	5.5 - 8	12 U	16 UR	15 U	12 UJ	12 U
TOLUENE	490000 N	4700000 N	1 - 1	12 U	6 J	15 J	12 UJ	12 U
TOTAL 1,2-DICHLOROETHENE	NA	NA	ND	12 U	16 UJ	15 U	12 U	12 U
TOTAL XYLENES	58000 N	250000 N	ND	12 U	2 UR	2 U	12 UJ	12 U
TRANS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	12 U	16 UJ	15 U	12 UJ	12 U
TRICHLOROETHENE	410 N	1900 N	ND	12 U	3 UJ	15 U	12 UJ	12 U
VINYL CHLORIDE	59 C	1700 C	ND	12 U	16 UJ	15 U	12 U	12 U
<b>POLYCYCLIC AROMATIC HYDROCARBONS (UG/KG)</b>								
2-METHYLNAPHTHALENE	23000 N	300000 N	44 - 44	400 U	180 J	890 J	130 J	28 J
ACENAPHTHENE	350000 N	4500000 N	ND	400 U	530 U	3800	130 J	400 U
ACENAPHTHYLENE <sup>(2)</sup>	350000 N	4500000 N	74 - 74	400 U	530 U	2500 U	360 U	400 U
ANTHRACENE	1700000 N	23000000 N	58 - 62	400 U	530 U	8900	580	32 J
BENZO(A)ANTHRACENE	150 C	2900 C	37 - 640	400 U	110 J	10000	1600	170 J
BENZO(A)PYRENE	15 C	290 C	36 - 1100	400 U	59 J	8600	1000	190 J
BENZO(B)FLUORANTHENE	150 C	2900 C	41 - 1700	400 U	110 J	9800	1900	250 J
BENZO(G,H,I)PERYLENE <sup>(3)</sup>	170000 N	2300000 N	39 - 410	400 U	55 J	2500 UJ	360 UJ	82 J
BENZO(K)FLUORANTHENE	1500 C	29000 C	38 - 1100	400 U	530 U	5300	870	110 J
CHRYSENE	15000 C	290000 C	37 - 1600	400 U	310 J	11000	1700	250 J
DIBENZO(A,H)ANTHRACENE	15 C	290 C	180 - 190	400 U	53 J	1600 J	280 J	71 J
DIBENZOFURAN	7200 N	100000 N	ND	400 U	530 U	3200	160 J	400 U
FLUORANTHENE	230000 N	3000000 N	43 - 1700	400 U	50 J	30000	2900	200 J
FLUORENE	230000 N	3000000 N	42 - 42	400 U	530 U	4100	190 J	23 J
INDENO(1,2,3-CD)PYRENE	150 C	2900 C	38 - 440	400 U	37 J	4200 J	500 J	87 J
NAPHTHALENE	3800 C	17000 C	42 - 43	400 U	68 J	1600 J	150 J	66 J
PHENANTHRENE <sup>(3)</sup>	170000 N	2300000 N	40 - 470	400 U	310 J	26000	2200	160 J
PYRENE	170000 N	2300000 N	42 - 1400	400 U	100 J	18000	2100	270 J
<b>PESTICIDES/PCBS (UG/KG)</b>								
4,4'-DDD	2200 C	9600 C	0.6 - 170	3.9 U	5.3 U	4.9 U	3.8 U	4 U
4,4'-DDE	1600 C	6800 C	5.2 - 7100	3.9 U	5.3 U	4.9 U	3.8 U	4 U
4,4'-DDT	1900 C	8600 C	5.1 - 4100	3.9 U	5.3 U	4.9 U	3.8 U	4 U
ALDRIN	31 C	140 C	ND	2 U	2.7 U	2.5 U	2 U	3 J
ALPHA-BHC	85 C	370 C	ND	2 U	2.7 U	2.5 U	2 U	2 U
ALPHA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2 U	2.7 U	2.5 U	2 U	2 U
AROCLOR-1016	400 N	5200 N	ND	39 U	53 U	49 U	38 U	40 U
AROCLOR-1221	150 C	660 C	ND	80 U	110 U	100 U	77 U	80 U
AROCLOR-1232	150 C	660 C	ND	39 U	53 U	49 U	38 U	40 U
AROCLOR-1242	240 C	1000 C	ND	39 U	53 U	49 U	38 U	40 U
AROCLOR-1248	240 C	1000 C	ND	39 U	53 U	49 U	38 U	40 U
AROCLOR-1254	110 N	1000 C	ND	39 U	53 U	49 U	38 U	40 U
AROCLOR-1260	240 C	1000 C	ND	39 U	53 U	49 U	38 U	40 U
BETA-BHC	300 C	1300 C	ND	2 U	2.7 U	2.5 U	2.4 R	2 U
DELTA-BHC <sup>(5)</sup>	85 C	370 C	ND	2 U	2.7 U	2.5 U	2 U	2 U
DIELDRIN	33 C	140 C	ND	3.9 U	5.3 U	4.9 U	3.8 U	4 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	Upgradient Location WTB- MW01 WTB-SB01-0305-98 7/13/1998	WTB-MW02 WTB-SB02-0709-98 7/8/1998	WTB-MW02 WTB-SB02-1517-98 7/8/1998	WTB-MW02 WTB-SB02-0305-98 7/8/1998	WTB-MW03 WTB-SB03-0911-98 7/11/1998
ENDOSULFAN I <sup>(6)</sup>	37000 N	490000 N	ND	2 U	2.7 U	2.5 U	2 U	2 U
ENDOSULFAN II <sup>(6)</sup>	37000 N	490000 N	ND	3.9 U	5.3 U	4.9 U	3.8 U	4 U
ENDOSULFAN SULFATE <sup>(6)</sup>	37000 N	490000 N	ND	3.9 U	5.3 U	4.9 U	3.8 U	4 U
ENDRIN	1800 N	25000 N	ND	3.9 U	5.3 U	4.9 U	3.8 U	4 U
ENDRIN ALDEHYDE <sup>(7)</sup>	1800 N	25000 N	ND	3.9 U	5.3 U	4.9 U	3.8 U	4 U
ENDRIN KETONE <sup>(7)</sup>	1800 N	25000 N	ND	3.9 U	5.3 U	54	3.8 U	4 U
GAMMA-BHC (LINDANE)	560 C	2500 C	ND	2 U	2.7 UJ	2.5 UJ	4.8 UJ	2 U
GAMMA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2 U	2.7 U	2.5 U	2 U	2 U
HEPTACHLOR	120 C	510 C	ND	2 U	2.7 U	2.5 U	2 U	2 U
HEPTACHLOR EPOXIDE	59 C	250 C	ND	2 U	2.7 U	2.5 U	2 U	2 U
METHOXYCHLOR	31000 N	410000 N	ND	20 U	27 U	25 U	20 U	20 U
TOXAPHENE	480 C	2100 C	ND	200 U	270 U	250 U	200 U	200 U
<b>PETROLEUM HYDROCARBONS (MG/KG)</b>								
DIESEL RANGE ORGANICS	NA	NA	NA	6 U	160 J	1000 J	340 J	150 U
GASOLINE RANGE ORGANICS	NA	NA	NA	2.5 U	4.8 U	4.3	13	2.5 U

USEPA RSLs are from May 2014 and are based on ILCR =  $1 \times 10^{-6}$  (C) and HI = 0.1 (N). C = carcinogen; N = Non-carcinogen.

NA = The chemical was not analyzed or no value was available.

ND = The chemical was not detected.

Data Qualifiers:

J = The chemical was detected but the concentration reported is an estimated value.

U = The chemical was not detected.

R = The chemical was rejected.

WTB-MW05 is located west of the quay wall that forms the western boundary of OU8 and may not represent site data.

Shaded values indicate industrial RSL was exceeded.

- (1) RSL is for elemental mercury
- (2) RSL is for acenaphthene
- (3) RSL is for pyrene
- (4) RSL is for chlordane
- (5) RSL is for alpha BHC
- (6) RSL is for endosulfan
- (7) RSL is for endrin

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW03 WTB-SB03-1820-98 7/11/1998	WTB-MW03 WTB-SB03-0305-98 7/11/1998	WTB-MW04 WTB-SB04-0305-98 7/8/1998	WTB-MW04 WTB-SB04-0911-98 7/8/1998	WTB-MW04 WTB-SB04-0709-98 7/8/1998
<b>METALS (MG/KG)</b>								
ALUMINUM	7700 N	110000 N	4,930 - 33,500	22100	16300	14800	11100	10300
ANTIMONY	3.1 N	47 N	7 - 9.4	0.41 UR	0.35 UR	0.36 UR	0.74 U	0.55 U
ARSENIC	0.67 C	3.0 C	4.4 - 58.6	8 J	8.8 J	11.5 J	18.7 J	11.2 J
BARIUM	1500 N	22000 N	22.3 - 223	78.1	84.3	60.8	86.3	54
BERYLLIUM	16 N	230 N	0.34 - 1.1	1.6	0.77	0.63	0.78	0.58
CADMIUM	7 N	98 N	0.82 - 3.4	0.53 U	0.4 U	0.42 U	1.6 U	0.48 U
CALCIUM	NA	NA	682 - 7910	2490 J	8930 J	3110 J	10000 J	1890 J
CHROMIUM	12000 N	180000 N	11.6 - 103	40.3 J	55.6 J	54 J	146 J	27.7 J
COBALT	2.3 N	35 N	3.1 - 24.2	14	15.6	11.4	20.3	8.8
COPPER	310 N	4700 N	8.5 - 316	29.4 J	42.9 J	19.1 J	3170 J	88.7 J
IRON	5500 N	82000 N	8730 - 45000	34000	26400	20900	133000	19200
LEAD	400	800	9.5 - 1100	17.9 U	52.2 J	21.9 U	197 J	265 J
MAGNESIUM	NA	NA	1500 - 17200	8510	9960	6690	5260	4220
MANGANESE	180 N	2600 N	110 - 611	325 J	482 J	307 J	1150 J	224 J
MERCURY <sup>(1)</sup>	0.94 N	4.0 N	0.0825 - 1.8	0.01 U	0.1 J	0.16 J	0.17 J	3.6 J
NICKEL	150 N	2200 N	8.1 - 73.2	28.4 J	45.7	32.8	342	29.9
POTASSIUM	NA	NA	585 - 6580	8350	4640	1960	1380	1440
SELENIUM	39 N	580 N	0.32 - 2.1	0.65 UJ	0.56 UJ	0.78 U	1.8 U	0.68 UJ
SILVER	39 N	580 N	ND	0.54 U	0.47 U	0.49 U	2.3 U	0.56 U
SODIUM	NA	NA	35.1 - 1370	1360	274 U	369	290 U	195 U
THALLIUM	0.078 N	1.2 N	0.22 - 0.23	0.66 U	0.95 U	0.62 U	0.67 U	0.68 U
VANADIUM	39 N	580 N	13.5 - 89.5	55.6	45.7	36.1	79.7	25.7
ZINC	2300 N	35000 N	23.1 - 1390	91.7 J	88.1 J	49.3 J	657 J	233 J
<b>MISCELLANEOUS PARAMETERS</b>								
CYANIDE (MG/KG)	2.1 N	13 N	NA	2 UJ	2 UJ	2 U	2 U	2 U
HEXAVALENT CHROMIUM (MG/KG)	0.30 C	6.3 C	NA	0.64 UJ	0.53 UJ	0.58 U	0.63 U	0.62 U
TOTAL ORGANIC CARBON (MG/KG)	NA	NA	NA	7900	13000	41000	9600	18000
PH (S.U.)	NA	NA	NA	8.7	8.4	8.2	7.8	7.7
<b>SEMIVOLATILES (UG/KG)</b>								
1,2,4-TRICHLOROBENZENE	5800 N	26000 N	ND	430 U	360 U	360 U	400 U	400 U
1,2-DICHLOROBENZENE	180000 N	930000 N	ND	430 U	360 U	360 U	400 U	400 U
1,3-DICHLOROBENZENE	NA	NA	ND	430 U	360 U	360 U	400 U	400 U
1,4-DICHLOROBENZENE	2600 C	11000 C	67 - 67	430 U	360 U	360 U	400 U	400 U
2,2'-OXYBIS(1-CHLOROPROPANE)	4900 C	22000 C	ND	430 UJ	360 U	360 U	400 U	400 U
2,4,5-TRICHLOROPHENOL	620000 N	8200000 N	ND	1100 U	910 U	910 U	1000 U	1000 U
2,4,6-TRICHLOROPHENOL	6200 N	82000 N	ND	430 U	360 U	360 U	400 U	400 U
2,4-DICHLOROPHENOL	18000 N	250000 N	ND	430 U	360 U	360 U	400 U	400 U
2,4-DIMETHYLPHENOL	120000 N	1600000 N	ND	430 U	360 U	360 U	400 U	400 U
2,4-DINITROPHENOL	12000 N	160000 N	ND	1100 UJ	910 UJ	910 UJ	1000 UJ	1000 UJ
2,4-DINITROTOLUENE	1700 C	7400 C	ND	430 U	360 U	360 U	400 U	400 U
2,6-DINITROTOLUENE	360 C	1500 C	ND	430 U	360 U	360 U	400 U	400 U
2-CHLORONAPHTHALENE	630000 N	9300000 N	ND	430 U	360 U	360 U	400 U	400 U
2-CHLOROPHENOL	39000 N	580000 N	ND	430 U	360 U	360 U	400 U	400 U
2-METHYLPHENOL	310000 N	4100000 N	ND	430 U	360 U	360 U	400 U	400 U
2-NITROANILINE	61000 N	800000 N	ND	1100 UJ	910 U	910 U	1000 U	1000 U
2-NITROPHENOL	NA	NA	ND	430 U	360 U	360 U	400 U	400 U
3,3'-DICHLOROBENZIDINE	1200 C	5100 C	ND	430 U	360 UJ	360 U	400 U	400 U
3-NITROANILINE	NA	NA	ND	1100 U	910 U	910 U	1000 U	1000 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW03 WTB-SB03-1820-98 7/11/1998	WTB-MW03 WTB-SB03-0305-98 7/11/1998	WTB-MW04 WTB-SB04-0305-98 7/8/1998	WTB-MW04 WTB-SB04-0911-98 7/8/1998	WTB-MW04 WTB-SB04-0709-98 7/8/1998
4,6-DINITRO-2-METHYLPHENOL	490 N	6600 N	ND	1100 U	910 U	910 U	1000 U	1000 U
4-BROMOPHENYL PHENYL ETHER	NA	NA	ND	430 U	360 U	360 U	400 U	400 U
4-CHLORO-3-METHYLPHENOL	620000 N	8200000 N	ND	430 U	360 U	360 U	400 U	400 U
4-CHLOROANILINE	2700 C	1200 C	ND	430 U	360 UJ	360 U	400 U	400 U
4-CHLOROPHENYL PHENYL ETHER	NA	NA	ND	430 U	360 U	360 U	400 U	400 U
4-METHYLPHENOL	620000 N	8200000 N	ND	430 U	360 U	360 U	400 U	400 U
4-NITROANILINE	25000 N	120000 C	ND	1100 UJ	910 U	910 U	1000 U	1000 U
4-NITROPHENOL	NA	NA	ND	1100 UJ	910 U	910 U	1000 U	1000 U
BIS(2-CHLOROETHOXY)METHANE	18000 N	250000 N	ND	430 U	360 U	360 U	400 U	400 U
BIS(2-CHLOROETHYL)ETHER	230 C	1000 C	ND	430 U	360 UJ	360 UJ	400 UJ	400 UJ
BIS(2-ETHYLHEXYL)PHTHALATE	38000 C	160000 C	58 - 650	430 U	2000	390 U	610	400 U
BUTYL BENZYL PHTHALATE	280000 C	120000 C	ND	430 UJ	360 U	360 U	400 U	400 U
CARBAZOLE	NA	NA	94 - 94	430 U	41 J	190 J	400 U	400 U
DIETHYL PHTHALATE	4900000 N	66000000 N	ND	430 U	360 U	360 U	400 U	400 U
DIMETHYL PHTHALATE	NA	NA	42 - 42	430 U	360 U	360 U	400 U	400 U
DI-N-BUTYL PHTHALATE	620000 N	8200000 N	100 - 100	430 U	360 U	360 U	400 U	400 U
DI-N-OCTYL PHTHALATE	62000 N	820000 N	100 - 100	430 UJ	360 U	360 U	400 U	400 U
HEXACHLOROBENZENE	330 C	1400 C	ND	430 U	360 U	360 U	400 U	400 U
HEXACHLOROBUTADIENE	6200 N	30000 C	ND	430 U	360 U	360 U	400 U	400 U
HEXACHLOROCYCLOPENTADIENE	37000 N	490000 N	ND	430 U	360 U	360 U	400 U	400 U
HEXACHLOROETHANE	4300 N	58000 C	ND	430 U	360 U	360 U	400 U	400 U
ISOPHORONE	560000 C	2400000 C	ND	430 UJ	360 U	360 U	400 U	400 U
NITROBENZENE	5100 C	22000 C	ND	430 U	360 U	360 U	400 U	400 U
N-NITROSO-DI-N-PROPYLAMINE	76 C	330 C	ND	430 UJ	360 U	360 U	400 U	400 U
N-NITROSODIPHENYLAMINE	110000 C	470000 C	ND	430 U	360 U	360 U	400 U	400 U
PENTACHLOROPHENOL	990 C	4000 C	ND	1100 UJ	910 UJ	910 UJ	1000 UJ	1000 UJ
PHENOL	1800000 N	25000000 N	98 - 98	430 U	360 UJ	360 UJ	400 UJ	400 UJ
<b>VOLATILES (UG/KG)</b>								
1,1,1-TRICHLOROETHANE	810000 N	3600000 N	ND	13 UJ	11 U	11 UJ	12 U	11 U
1,1,2,2-TETRACHLOROETHANE	600 C	2700 C	ND	13 UJ	11 U	11 UR	12 U	11 U
1,1,2-TRICHLOROETHANE	150 N	630 N	ND	13 UJ	11 U	11 UJ	12 U	11 U
1,1,2-TRICHLOROTRIFLUOROETHANE	4000000 N	17000000 N	NA	13 UJ	6 J	2 J	12 U	11 U
1,1-DICHLOROETHANE	3600 C	16000 C	ND	13 U	11 U	11 UJ	12 U	11 U
1,1-DICHLOROETHENE	23000 N	100000 N	3 - 3	13 U	11 U	11 UJ	12 U	11 U
1,2-DICHLOROETHANE	460 C	2000 C	ND	13 U	11 U	11 UJ	12 U	11 U
1,2-DICHLOROPROPANE	1000 C	4400 C	ND	13 U	11 U	11 UJ	12 U	11 U
2-BUTANONE	2700000 N	19000000 N	ND	13 U	11 U	11 UJ	16 U	11 U
2-HEXANONE	20000 N	130000 N	ND	13 UJ	11 U	11 UR	12 U	11 U
4-METHYL-2-PENTANONE	530000 N	5600000 N	ND	13 UJ	11 U	11 UR	12 U	11 U
ACETONE	6100000 N	67000000 N	ND	600 U	1900 U	30 U	240	11 U
BENZENE	1200 C	5100 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
BROMODICHLOROMETHANE	290 C	1300 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
BROMOFORM	67000 C	290000 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
BROMOMETHANE	680 N	3000 N	ND	13 U	11 U	11 UJ	12 U	11 U
CARBON DISULFIDE	77000 N	350000 N	ND	4 J	11 U	11 UJ	4 J	11 U
CARBON TETRACHLORIDE	650 C	2900 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
CHLOROBENZENE	28000 N	130000 N	ND	13 UJ	11 U	11 UR	12 U	11 U
CHLORODIBROMOMETHANE	730 C	3200 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
CHLOROETHANE	1400000 N	5700000 N	ND	13 U	11 U	11 UJ	12 U	11 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW03 WTB-SB03-1820-98 7/11/1998	WTB-MW03 WTB-SB03-0305-98 7/11/1998	WTB-MW04 WTB-SB04-0305-98 7/8/1998	WTB-MW04 WTB-SB04-0911-98 7/8/1998	WTB-MW04 WTB-SB04-0709-98 7/8/1998
CHLOROFORM	320 C	1400 C	ND	2 J	11 U	11 UJ	12 U	11 U
CHLOROMETHANE	11000 N	46000 N	ND	13 U	11 U	11 UJ	12 U	11 U
CIS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
ETHYLBENZENE	5800 C	25000 C	ND	13 UJ	11 U	11 UR	12 U	11 U
METHYLENE CHLORIDE	35000 N	320000 N	1 - 2	13 U	2500 U	43 U	12 U	16 U
STYRENE	600000 N	3500000 N	ND	13 UJ	11 U	11 UR	12 U	11 U
TETRACHLOROETHENE	8100 N	39000 N	5.5 - 8	13 UJ	11 U	11 UR	12 U	11 U
TOLUENE	490000 N	4700000 N	1 - 1	13 UJ	11 U	11 UR	12 U	11 U
TOTAL 1,2-DICHLOROETHENE	NA	NA	ND	13 U	11 U	11 UJ	12 U	11 U
TOTAL XYLENES	58000 N	250000 N	ND	13 UJ	11 U	11 UR	12 U	11 U
TRANS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	13 UJ	11 U	11 UJ	12 U	11 U
TRICHLOROETHENE	410 N	1900 N	ND	13 UJ	11 U	11 UJ	12 U	11 U
VINYL CHLORIDE	59 C	1700 C	ND	13 U	11 U	11 UJ	12 U	11 U
<b>POLYCYCLIC AROMATIC HYDROCARBONS (UG/KG)</b>								
2-METHYLNAPHTHALENE	23000 N	300000 N	44 - 44	430 U	360 U	51 J	26 J	400 U
ACENAPHTHENE	350000 N	4500000 N	ND	430 U	27 J	150 J	400 U	400 U
ACENAPHTHYLENE <sup>(2)</sup>	350000 N	4500000 N	74 - 74	430 U	140 J	360 U	400 U	400 U
ANTHRACENE	1700000 N	23000000 N	58 - 62	41 J	74 J	340 J	46 J	51 J
BENZO(A)ANTHRACENE	150 C	2900 C	37 - 640	180 J	310 J	460	130 J	170 J
BENZO(A)PYRENE	15 C	290 C	36 - 1100	180 J	590	400	100 J	160 J
BENZO(B)FLUORANTHENE	150 C	2900 C	41 - 1700	180 J	810	400	120 J	130 J
BENZO(G,H,I)PERYLENE <sup>(3)</sup>	170000 N	2300000 N	39 - 410	120 J	220 J	360 U	42 J	81 J
BENZO(K)FLUORANTHENE	1500 C	29000 C	38 - 1100	150 J	340 J	290 J	77 J	140 J
CHRYSENE	15000 C	290000 C	37 - 1600	200 J	380	490	150 J	180 J
DIBENZO(A,H)ANTHRACENE	15 C	290 C	180 - 190	44 J	120 J	86 J	41 J	43 J
DIBENZOFURAN	7200 N	100000 N	ND	430 U	360 U	100 J	400 U	400 U
FLUORANTHENE	230000 N	3000000 N	43 - 1700	270 J	630	1100	200 J	280 J
FLUORENE	230000 N	3000000 N	42 - 42	30 J	37 J	150 J	400 U	400 U
INDENO(1,2,3-CD)PYRENE	150 C	2900 C	38 - 440	100 J	230 J	200 J	60 J	81 J
NAPHTHALENE	3800 C	17000 C	42 - 43	23 J	360 U	100 J	23 J	400 U
PHENANTHRENE <sup>(3)</sup>	170000 N	2300000 N	40 - 470	150 J	220 J	1100	140 J	48 J
PYRENE	170000 N	2300000 N	42 - 1400	320 J	1100	860	180 J	260 J
<b>PESTICIDES/PCBS (UG/KG)</b>								
4,4'-DDD	2200 C	9600 C	0.6 - 170	4.9 U	3.6 U	3.7 U	4 U	3.9 U
4,4'-DDE	1600 C	6800 C	5.2 - 7100	4.9 U	3.6 U	3.7 U	4 U	3.9 U
4,4'-DDT	1900 C	8600 C	5.1 - 4100	4.9 U	3.6 U	3.7 U	4 U	3.9 U
ALDRIN	31 C	140 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
ALPHA-BHC	85 C	370 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
ALPHA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
AROCLOR-1016	400 N	5200 N	ND	49 U	36 U	37 U	40 U	39 U
AROCLOR-1221	150 C	660 C	ND	100 U	73 U	74 U	81 U	80 U
AROCLOR-1232	150 C	660 C	ND	49 U	36 U	37 U	40 U	39 U
AROCLOR-1242	240 C	1000 C	ND	49 U	36 U	37 U	40 U	39 U
AROCLOR-1248	240 C	1000 C	ND	49 U	36 U	37 U	40 U	39 U
AROCLOR-1254	110 N	1000 C	ND	49 U	36 U	37 U	40 U	39 U
AROCLOR-1260	240 C	1000 C	ND	49 U	36 U	37 U	40 U	39 U
BETA-BHC	300 C	1300 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
DELTA-BHC <sup>(5)</sup>	85 C	370 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
DIELDRIN	33 C	140 C	ND	4.9 U	3.6 U	3.7 U	4 U	3.9 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 8 OF 16**

LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW03 WTB-SB03-1820-98 7/11/1998	WTB-MW03 WTB-SB03-0305-98 7/11/1998	WTB-MW04 WTB-SB04-0305-98 7/8/1998	WTB-MW04 WTB-SB04-0911-98 7/8/1998	WTB-MW04 WTB-SB04-0709-98 7/8/1998
ENDOSULFAN I <sup>(6)</sup>	37000 N	490000 N	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
ENDOSULFAN II <sup>(6)</sup>	37000 N	490000 N	ND	4.9 U	3.6 U	3.7 U	4 U	3.9 U
ENDOSULFAN SULFATE <sup>(6)</sup>	37000 N	490000 N	ND	4.9 U	3.6 U	3.7 U	4 U	3.9 U
ENDRIN	1800 N	25000 N	ND	4.9 U	3.6 U	3.7 U	4 U	3.9 U
ENDRIN ALDEHYDE <sup>(7)</sup>	1800 N	25000 N	ND	4.9 U	3.6 U	3.7 U	4 U	3.9 U
ENDRIN KETONE <sup>(7)</sup>	1800 N	25000 N	ND	4.9 U	3.6 U	3.7 U	4 U	3.9 U
GAMMA-BHC (LINDANE)	560 C	2500 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
GAMMA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
HEPTACHLOR	120 C	510 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
HEPTACHLOR EPOXIDE	59 C	250 C	ND	2.5 U	1.8 U	1.9 U	2.1 U	2 U
METHOXYCHLOR	31000 N	410000 N	ND	25 U	18 U	19 U	21 U	20 U
TOXAPHENE	480 C	2100 C	ND	250 U	180 U	190 U	210 U	200 U
<b>PETROLEUM HYDROCARBONS (MG/KG)</b>								
DIESEL RANGE ORGANICS	NA	NA	NA	9.9 U	170 U	28 U	260 U	330 U
GASOLINE RANGE ORGANICS	NA	NA	NA	3 U	2.5 U	3 U	2.5 U	2.8 U

USEPA RSLs are from May 2014 and are based on ILCR =  $1 \times 10^{-6}$  (C) and HI = 0.1 (N). C = carcinogen; N = Non-carcinogen.

NA = The chemical was not analyzed or no value was available.

ND = The chemical was not detected.

Data Qualifiers:

J = The chemical was detected but the concentration reported is an estimated value.

U = The chemical was not detected.

R = The chemical was rejected.

WTB-MW05 is located west of the quay wall that forms the western boundary of OU8 and may not represent site data.

Shaded values indicate industrial RSL was exceeded.

- (1) RSL is for elemental mercury
- (2) RSL is for acenaphthene
- (3) RSL is for pyrene
- (4) RSL is for chlordane
- (5) RSL is for alpha BHC
- (6) RSL is for endosulfan
- (7) RSL is for endrin

**TABLE 2  
OU8 SSI SUBSURFACE SOIL DATA  
PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE  
PAGE 9 OF 16**

LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW05 WTB-SB05-1315-98 7/7/1998	WTB-MW05 WTB-SB05-0305-98 7/7/1998	WTB-MW05 WTB-SB05-0709-98 7/7/1998	WTB-SB06 WTB-SB06-1820-98 7/15/1998	WTB-SB06 WTB-SB06-0507-98 7/15/1998
<b>METALS (MG/KG)</b>								
ALUMINUM	7700 N	110000 N	4,930 - 33,500	15400	8650	11600	19400	6870
ANTIMONY	3.1 N	47 N	7 - 9.4	0.53 UR	0.41 UR	0.43 UR	0.44 UJ	1.1 U
ARSENIC	0.67 C	3.0 C	4.4 - 58.6	<b>30.9 J</b>	<b>10.5 J</b>	<b>14.3 J</b>	<b>8.2</b>	<b>5.6</b>
BARIUM	1500 N	22000 N	22.3 - 223	148 J	41.7 J	74.2 J	74.6	71.2
BERYLLIUM	16 N	230 N	0.34 - 1.1	0.87 J	0.32	0.42 J	1.4	0.47
CADMIUM	7 N	98 N	0.82 - 3.4	0.61 U	0.48 U	0.49 U	0.9 J	5.1 J
CALCIUM	NA	NA	682 - 7910	8790 J	2810 J	2250 J	1790	11800
CHROMIUM	12000 N	180000 N	11.6 - 103	52.8 J	41.5 J	218 J	40.5	17.3
COBALT	2.3 N	35 N	3.1 - 24.2	7.1	10.5	8.5	11.4	7.7
COPPER	310 N	4700 N	8.5 - 316	4090 J	17.2 J	392 J	39.5 J	1820 J
IRON	5500 N	82000 N	8730 - 45000	31400	19000	42400	34900	22500
LEAD	400	800	9.5 - 1100	<b>1020</b>	8.4	98.7	33.2 J	750 J
MAGNESIUM	NA	NA	1500 - 17200	8820	5610	8910	8190	3480
MANGANESE	180 N	2600 N	110 - 611	362	291	363	366	338
MERCURY <sup>(1)</sup>	0.94 N	4.0 N	0.0825 - 1.8	2.4 J	0.01 UJ	0.22 J	0.02 U	0.07 U
NICKEL	150 N	2200 N	8.1 - 73.2	24.8 J	33.7 J	34.7 J	27.8	88
POTASSIUM	NA	NA	585 - 6580	4610	2340	4240	7390	838
SELENIUM	39 N	580 N	0.32 - 2.1	0.86 UJ	0.67 UJ	1.1 U	0.71 U	0.53 U
SILVER	39 N	580 N	ND	1.2 J	0.56 U	0.84 J	0.17 U	0.42 U
SODIUM	NA	NA	35.1 - 1370	6750	429	2060	2140	259 U
THALLIUM	0.078 N	1.2 N	0.22 - 0.23	0.86 U	0.67 U	0.69 U	0.72 UJ	0.68 U
VANADIUM	39 N	580 N	13.5 - 89.5	46.4	25.8	36.6	50.3 J	17.5 J
ZINC	2300 N	35000 N	23.1 - 1390	317 J	38.3 J	158 J	117 J	2040 J
<b>MISCELLANEOUS PARAMETERS</b>								
CYANIDE (MG/KG)	2.1 N	13 N	NA	2 U	2 U	2 U	2 U	2 U
HEXAVALENT CHROMIUM (MG/KG)	0.30 C	6.3 C	NA	1 UJ	0.5 UJ	0.5 UJ	0.55 UJ	0.72 UJ
TOTAL ORGANIC CARBON (MG/KG)	NA	NA	NA	33000	3100	8100	4600	9700
PH (S.U.)	NA	NA	NA	8.8	8.2	7.8	8.4	8.2
<b>SEMIVOLATILES (UG/KG)</b>								
1,2,4-TRICHLOROBENZENE	5800 N	26000 N	ND	500 U	360 U	400 U	430 U	400 U
1,2-DICHLOROBENZENE	180000 N	930000 N	ND	500 U	360 U	400 U	430 U	400 U
1,3-DICHLOROBENZENE	NA	NA	ND	500 U	360 U	400 U	430 U	400 U
1,4-DICHLOROBENZENE	2600 C	11000 C	67 - 67	500 U	360 U	400 U	430 U	400 U
2,2'-OXYBIS(1-CHLOROPROPANE)	4900 C	22000 C	ND	500 U	360 U	400 U	430 U	400 U
2,4,5-TRICHLOROPHENOL	620000 N	8200000 N	ND	1200 U	910 U	1000 U	1100 U	1000 U
2,4,6-TRICHLOROPHENOL	6200 N	82000 N	ND	500 U	360 U	400 U	430 U	400 U
2,4-DICHLOROPHENOL	18000 N	250000 N	ND	500 U	360 U	400 U	430 U	400 U
2,4-DIMETHYLPHENOL	120000 N	1600000 N	ND	500 U	360 U	400 U	430 U	400 U
2,4-DINITROPHENOL	12000 N	160000 N	ND	1200 UJ	910 UJ	1000 UJ	1100 UJ	1000 UJ
2,4-DINITROTOLUENE	1700 C	7400 C	ND	500 U	360 U	400 U	430 U	400 U
2,6-DINITROTOLUENE	360 C	1500 C	ND	500 U	360 U	400 U	430 U	400 U
2-CHLORONAPHTHALENE	630000 N	9300000 N	ND	500 U	360 U	400 U	430 U	400 U
2-CHLOROPHENOL	39000 N	580000 N	ND	500 U	360 U	400 U	430 U	400 U
2-METHYLPHENOL	310000 N	4100000 N	ND	500 U	360 U	400 U	430 U	400 U
2-NITROANILINE	61000 N	800000 N	ND	1200 U	910 U	1000 U	1100 U	1000 U
2-NITROPHENOL	NA	NA	ND	500 U	360 U	400 U	430 U	400 U
3,3'-DICHLOROBENZIDINE	1200 C	5100 C	ND	500 U	360 U	400 U	430 U	400 U
3-NITROANILINE	NA	NA	ND	1200 U	910 U	1000 U	1100 U	1000 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 10 OF 16**

LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW05 WTB-SB05-1315-98 7/7/1998	WTB-MW05 WTB-SB05-0305-98 7/7/1998	WTB-MW05 WTB-SB05-0709-98 7/7/1998	WTB-SB06 WTB-SB06-1820-98 7/15/1998	WTB-SB06 WTB-SB06-0507-98 7/15/1998
4,6-DINITRO-2-METHYLPHENOL	490 N	6600 N	ND	1200 U	910 UJ	1000 U	1100 U	1000 U
4-BROMOPHENYL PHENYL ETHER	NA	NA	ND	500 U	360 U	400 U	430 U	400 U
4-CHLORO-3-METHYLPHENOL	620000 N	8200000 N	ND	500 U	360 U	400 U	430 U	400 U
4-CHLOROANILINE	2700 C	1200 C	ND	500 U	360 U	400 U	430 U	400 U
4-CHLOROPHENYL PHENYL ETHER	NA	NA	ND	500 U	360 U	400 U	430 U	400 U
4-METHYLPHENOL	620000 N	8200000 N	ND	500 U	360 U	400 U	430 U	400 U
4-NITROANILINE	25000 N	120000 C	ND	1200 U	910 U	1000 U	1100 U	1000 U
4-NITROPHENOL	NA	NA	ND	1200 UJ	910 U	1000 UJ	1100 U	1000 U
BIS(2-CHLOROETHOXY)METHANE	18000 N	250000 N	ND	500 U	360 U	400 U	430 U	400 U
BIS(2-CHLOROETHYL)ETHER	230 C	1000 C	ND	500 U	360 U	400 U	430 U	400 U
BIS(2-ETHYLHEXYL)PHTHALATE	38000 C	160000 C	58 - 650	550	400 U	910	150 U	210 U
BUTYL BENZYL PHTHALATE	280000 C	120000 C	ND	27 J	360 U	21 J	26 J	400 U
CARBAZOLE	NA	NA	94 - 94	500 U	360 U	400 U	430 U	380 J
DIETHYL PHTHALATE	4900000 N	66000000 N	ND	500 U	360 U	21 J	430 U	400 U
DIMETHYL PHTHALATE	NA	NA	42 - 42	500 U	360 U	400 U	430 U	400 U
DI-N-BUTYL PHTHALATE	620000 N	8200000 N	100 - 100	500 U	360 U	400 U	430 U	400 U
DI-N-OCTYL PHTHALATE	62000 N	820000 N	100 - 100	500 UJ	360 U	400 UJ	430 U	400 U
HEXACHLOROBENZENE	330 C	1400 C	ND	500 U	360 U	400 U	430 U	400 U
HEXACHLOROBUTADIENE	6200 N	30000 C	ND	500 UJ	360 U	400 UJ	430 U	400 U
HEXACHLOROCYCLOPENTADIENE	37000 N	490000 N	ND	500 U	360 UJ	400 U	430 UJ	400 UJ
HEXACHLOROETHANE	4300 N	58000 C	ND	500 U	360 U	400 U	430 U	400 U
ISOPHORONE	560000 C	2400000 C	ND	500 U	360 U	400 U	430 U	400 U
NITROBENZENE	5100 C	22000 C	ND	500 U	360 U	400 U	430 U	400 U
N-NITROSO-DI-N-PROPYLAMINE	76 C	330 C	ND	500 U	360 U	400 U	430 U	400 U
N-NITROSODIPHENYLAMINE	110000 C	470000 C	ND	500 U	360 U	400 U	430 U	400 U
PENTACHLOROPHENOL	990 C	4000 C	ND	1200 U	910 U	1000 U	1100 UJ	1000 UJ
PHENOL	1800000 N	25000000 N	98 - 98	500 U	360 U	400 U	430 U	400 U
<b>VOLATILES (UG/KG)</b>								
1,1,1-TRICHLOROETHANE	810000 N	3600000 N	ND	15 U	11 U	12 U	13 U	12 UJ
1,1,2,2-TETRACHLOROETHANE	600 C	2700 C	ND	15 UJ	11 U	12 U	13 U	12 UJ
1,1,2-TRICHLOROETHANE	150 N	630 N	ND	15 U	11 U	12 U	13 U	12 UJ
1,1,2-TRICHLOROTRIFLUOROETHANE	4000000 N	17000000 N	NA	15 U	11 U	12 U	13 U	12 U
1,1-DICHLOROETHANE	3600 C	16000 C	ND	15 U	11 U	12 U	13 U	12 U
1,1-DICHLOROETHENE	23000 N	100000 N	3 - 3	15 U	11 U	12 U	13 U	12 U
1,2-DICHLOROETHANE	460 C	2000 C	ND	15 U	11 U	12 U	13 U	12 U
1,2-DICHLOROPROPANE	1000 C	4400 C	ND	15 U	11 U	12 U	13 U	12 UJ
2-BUTANONE	2700000 N	19000000 N	ND	13	11 U	4 J	13 U	12 U
2-HEXANONE	20000 N	130000 N	ND	15 UJ	11 U	12 U	13 U	12 UJ
4-METHYL-2-PENTANONE	530000 N	5600000 N	ND	15 UJ	11 U	12 U	13 U	12 UJ
ACETONE	6100000 N	67000000 N	ND	230	12 U	48 U	120	58 U
BENZENE	1200 C	5100 C	ND	15 U	11 U	12 U	13 U	12 UJ
BROMODICHLOROMETHANE	290 C	1300 C	ND	15 U	11 U	12 U	13 U	12 UJ
BROMOFORM	67000 C	290000 C	ND	15 U	11 U	12 U	13 U	12 UJ
BROMOMETHANE	680 N	3000 N	ND	15 U	11 U	12 U	13 U	12 U
CARBON DISULFIDE	77000 N	350000 N	ND	4 J	11 U	2 J	11 J	12 U
CARBON TETRACHLORIDE	650 C	2900 C	ND	15 U	11 U	12 U	13 U	12 UJ
CHLOROBENZENE	28000 N	130000 N	ND	15 UJ	11 U	12 U	13 U	12 UJ
CHLORODIBROMOMETHANE	730 C	3200 C	ND	15 U	11 U	12 U	13 U	12 UJ
CHLOROETHANE	1400000 N	5700000 N	ND	15 U	11 U	12 U	13 U	12 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW05 WTB-SB05-1315-98 7/7/1998	WTB-MW05 WTB-SB05-0305-98 7/7/1998	WTB-MW05 WTB-SB05-0709-98 7/7/1998	WTB-SB06 WTB-SB06-1820-98 7/15/1998	WTB-SB06 WTB-SB06-0507-98 7/15/1998
CHLOROFORM	320 C	1400 C	ND	15 U	11 U	12 U	13 U	12 U
CHLOROMETHANE	11000 N	46000 N	ND	15 U	11 U	12 U	13 U	12 U
CIS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	15 U	11 U	12 U	13 U	12 UJ
ETHYLBENZENE	5800 C	25000 C	ND	15 UJ	11 U	12 U	13 U	12 UJ
METHYLENE CHLORIDE	35000 N	320000 N	1 - 2	15 U	18 U	14 U	25 U	42 U
STYRENE	600000 N	3500000 N	ND	15 UJ	11 U	12 U	13 U	12 UJ
TETRACHLOROETHENE	8100 N	39000 N	5.5 - 8	15 UJ	11 U	12 U	13 U	12 UJ
TOLUENE	490000 N	4700000 N	1 - 1	15 UJ	11 U	12 U	13 U	12 UJ
TOTAL 1,2-DICHLOROETHENE	NA	NA	ND	15 U	11 U	12 U	13 U	12 U
TOTAL XYLENES	58000 N	250000 N	ND	15 UJ	11 U	12 U	13 U	12 UJ
TRANS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	15 U	11 U	12 U	13 U	12 UJ
TRICHLOROETHENE	410 N	1900 N	ND	25	11 U	12 U	13 U	12 UJ
VINYL CHLORIDE	59 C	1700 C	ND	15 U	11 U	12 U	13 U	12 U
<b>POLYCYCLIC AROMATIC HYDROCARBONS (UG/KG)</b>								
2-METHYLNAPHTHALENE	23000 N	300000 N	44 - 44	500 U	360 U	400 U	430 U	300 J
ACENAPHTHENE	350000 N	4500000 N	ND	500 U	360 U	400 U	430 U	400
ACENAPHTHYLENE <sup>(2)</sup>	350000 N	4500000 N	74 - 74	500 U	360 U	400 U	430 U	400 U
ANTHRACENE	1700000 N	23000000 N	58 - 62	500 U	360 U	400 U	430 U	1400
BENZO(A)ANTHRACENE	150 C	2900 C	37 - 640	66 J	360 U	63 J	430 U	5700
BENZO(A)PYRENE	15 C	290 C	36 - 1100	65 J	360 U	65 J	430 U	4300
BENZO(B)FLUORANTHENE	150 C	2900 C	41 - 1700	65 J	360 U	77 J	430 U	5400
BENZO(G,H,I)PERYLENE <sup>(3)</sup>	170000 N	2300000 N	39 - 410	34 J	360 U	400 UJ	430 U	400 U
BENZO(K)FLUORANTHENE	1500 C	29000 C	38 - 1100	54 J	360 U	61 J	430 U	3900
CHRYSENE	15000 C	290000 C	37 - 1600	59 J	360 U	61 J	430 U	6000
DIBENZO(A,H)ANTHRACENE	15 C	290 C	180 - 190	26 J	360 U	400 UJ	430 U	1100
DIBENZOFURAN	7200 N	100000 N	ND	500 U	360 U	400 U	430 U	320 J
FLUORANTHENE	230000 N	3000000 N	43 - 1700	120 J	360 U	100 J	23 J	9400
FLUORENE	230000 N	3000000 N	42 - 42	500 U	360 U	400 U	430 U	380 J
INDENO(1,2,3-CD)PYRENE	150 C	2900 C	38 - 440	41 J	360 U	39 J	21 J	1800
NAPHTHALENE	3800 C	17000 C	42 - 43	500 U	360 U	400 U	430 U	250 J
PHENANTHRENE <sup>(3)</sup>	170000 N	2300000 N	40 - 470	66 J	360 U	42 J	430 U	6100
PYRENE	170000 N	2300000 N	42 - 1400	130 J	360 U	110 J	24 J	7800
<b>PESTICIDES/PCBS (UG/KG)</b>								
4,4'-DDD	2200 C	9600 C	0.6 - 170	5 U	3.6 U	3.8 U	4.1 U	3.8 U
4,4'-DDE	1600 C	6800 C	5.2 - 7100	5 U	3.6 U	3.8 U	4.1 U	3.8 U
4,4'-DDT	1900 C	8600 C	5.1 - 4100	5 U	3.6 U	3.8 U	4.1 U	3.8 U
ALDRIN	31 C	140 C	ND	2.6 U	1.9 U	2 U	2.1 U	1.9 J
ALPHA-BHC	85 C	370 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
ALPHA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
AROCLOR-1016	400 N	5200 N	ND	50 U	36 U	38 U	41 U	38 U
AROCLOR-1221	150 C	660 C	ND	100 U	74 U	78 U	82 U	77 U
AROCLOR-1232	150 C	660 C	ND	50 U	36 U	38 U	41 U	38 U
AROCLOR-1242	240 C	1000 C	ND	50 U	36 U	38 U	41 U	38 U
AROCLOR-1248	240 C	1000 C	ND	50 U	36 U	38 U	41 U	38 U
AROCLOR-1254	110 N	1000 C	ND	50 U	36 U	38 U	41 U	38 U
AROCLOR-1260	240 C	1000 C	ND	50 U	36 U	38 U	41 U	38 U
BETA-BHC	300 C	1300 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
DELTA-BHC <sup>(5)</sup>	85 C	370 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
DIELDRIN	33 C	140 C	ND	5 U	3.6 U	3.8 U	4.1 U	3.8 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION SAMPLE ID SAMPLE DATE	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-MW05 WTB-SB05-1315-98 7/7/1998	WTB-MW05 WTB-SB05-0305-98 7/7/1998	WTB-MW05 WTB-SB05-0709-98 7/7/1998	WTB-SB06 WTB-SB06-1820-98 7/15/1998	WTB-SB06 WTB-SB06-0507-98 7/15/1998
ENDOSULFAN I <sup>(6)</sup>	37000 N	490000 N	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
ENDOSULFAN II <sup>(6)</sup>	37000 N	490000 N	ND	5 U	3.6 U	3.8 U	4.1 U	3.8 U
ENDOSULFAN SULFATE <sup>(6)</sup>	37000 N	490000 N	ND	5 U	3.6 U	3.8 U	4.1 U	3.8 U
ENDRIN	1800 N	25000 N	ND	5 U	3.6 U	3.8 U	4.1 U	3.8 U
ENDRIN ALDEHYDE <sup>(7)</sup>	1800 N	25000 N	ND	5 U	3.6 U	3.8 U	4.1 U	3.8 U
ENDRIN KETONE <sup>(7)</sup>	1800 N	25000 N	ND	5 U	3.6 U	3.8 U	4.1 U	3.8 U
GAMMA-BHC (LINDANE)	560 C	2500 C	ND	2.6 UJ	1.9 UJ	2 UJ	2.1 U	2 U
GAMMA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
HEPTACHLOR	120 C	510 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
HEPTACHLOR EPOXIDE	59 C	250 C	ND	2.6 U	1.9 U	2 U	2.1 U	2 U
METHOXYCHLOR	31000 N	410000 N	ND	26 U	19 U	20 U	21 U	20 U
TOXAPHENE	480 C	2100 C	ND	260 U	190 U	200 U	210 U	200 U
<b>PETROLEUM HYDROCARBONS (MG/KG)</b>								
DIESEL RANGE ORGANICS	NA	NA	NA	740 J	20	100 J	11	330
GASOLINE RANGE ORGANICS	NA	NA	NA	4.2	2.5 U	2.5 U	3 U	2.8 U

USEPA RSLs are from May 2014 and are based on ILCR =  $1 \times 10^{-6}$  (C) and HI = 0.1 (N). C = carcinogen; N = Non-carcinogen.

NA = The chemical was not analyzed or no value was available.

ND = The chemical was not detected.

Data Qualifiers:

J = The chemical was detected but the concentration reported is an estimated value.

U = The chemical was not detected.

R = The chemical was rejected.

WTB-MW05 is located west of the quay wall that forms the western boundary of OU8 and may not represent site data.

Shaded values indicate industrial RSL was exceeded.

- (1) RSL is for elemental mercury
- (2) RSL is for acenaphthene
- (3) RSL is for pyrene
- (4) RSL is for chlordane
- (5) RSL is for alpha BHC
- (6) RSL is for endosulfan
- (7) RSL is for endrin

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-SB06 WTB-SB06-1820-98-D 7/15/1998	WTB-SB06 WTB-SB06-0305-98 7/15/1998	WTB-SB07 WTB-SB07-0305-98 7/11/1998	WTB-SB07 WTB-SB07-1315-98 7/11/1998	WTB-SB07 WTB-SB07-0709-98 7/11/1998
<b>METALS (MG/KG)</b>								
ALUMINUM	7700 N	110000 N	4,930 - 33,500	18400	8220	2300	14700	1910
ANTIMONY	3.1 N	47 N	7 - 9.4	0.36 UJ	0.32 UJ	0.5 U	0.83 U	0.68 U
ARSENIC	0.67 C	3.0 C	4.4 - 58.6	<b>8.5</b>	<b>13.8</b>	<b>5.9 J</b>	<b>8.3 J</b>	<b>6.8 J</b>
BARIUM	1500 N	22000 N	22.3 - 223	71.1	80.2	295	55.9	302
BERYLLIUM	16 N	230 N	0.34 - 1.1	1.3	0.57	0.54	0.98	0.46
CADMIUM	7 N	98 N	0.82 - 3.4	0.79 J	0.76 J	0.56 U	1.1 U	0.55 U
CALCIUM	NA	NA	682 - 7910	1780	10900	3610 J	4900 J	3760 J
CHROMIUM	12000 N	180000 N	11.6 - 103	38.8	25	7 U	66.6 J	6.7 U
COBALT	2.3 N	35 N	3.1 - 24.2	11.7	6.6	6.5	9.4	4.4
COPPER	310 N	4700 N	8.5 - 316	28 J	357 J	124 J	91.8 J	102 J
IRON	5500 N	82000 N	8730 - 45000	32900	16700	27300	28900	20700
LEAD	400	800	9.5 - 1100	21.2 J	390 J	<b>3610 J</b>	278 J	492 J
MAGNESIUM	NA	NA	1500 - 17200	8100	2970	406	6940	794
MANGANESE	180 N	2600 N	110 - 611	352	213	59.3 J	224 J	33.3 J
MERCURY <sup>(1)</sup>	0.94 N	4.0 N	0.0825 - 1.8	0.06 U	0.44 J	2.4 J	<b>4.6 J</b>	1 J
NICKEL	150 N	2200 N	8.1 - 73.2	27.9	37.4	10.3 U	22.7 U	8.7 U
POTASSIUM	NA	NA	585 - 6580	7200	1320	1870	4300	821
SELENIUM	39 N	580 N	0.32 - 2.1	0.58 U	0.52 U	1.6 U	1.2 UJ	1.3 U
SILVER	39 N	580 N	ND	0.14 U	0.26 U	1 U	0.96 U	0.64 U
SODIUM	NA	NA	35.1 - 1370	2090	315	1860	5720	593
THALLIUM	0.078 N	1.2 N	0.22 - 0.23	0.93 U	0.54 U	0.73 U	1.2 U	0.77 U
VANADIUM	39 N	580 N	13.5 - 89.5	49.6 J	19.6 J	9.8	43.9	11.6
ZINC	2300 N	35000 N	23.1 - 1390	91.7 J	335 J	64.5 J	155 J	31.3 J
<b>MISCELLANEOUS PARAMETERS</b>								
CYANIDE (MG/KG)	2.1 N	13 N	NA	2 U	2 U	2 UJ	2 UJ	2 UJ
HEXAVALENT CHROMIUM (MG/KG)	0.30 C	6.3 C	NA	0.57 UJ	0.71 UJ	1.2 UJ	1.9 UJ	1.2 UJ
TOTAL ORGANIC CARBON (MG/KG)	NA	NA	NA	3200	19000	220000	51000	--
PH (S.U.)	NA	NA	NA	8.3	10.4	8.4	8.2	9
<b>SEMIVOLATILES (UG/KG)</b>								
1,2,4-TRICHLOROBENZENE	5800 N	26000 N	ND	430 U	360 U	400 U	590 U	430 U
1,2-DICHLOROBENZENE	180000 N	930000 N	ND	430 U	360 U	400 U	590 U	430 U
1,3-DICHLOROBENZENE	NA	NA	ND	430 U	360 U	400 U	590 U	430 U
1,4-DICHLOROBENZENE	2600 C	11000 C	67 - 67	430 U	360 U	400 U	590 U	430 U
2,2'-OXYBIS(1-CHLOROPROPANE)	4900 C	22000 C	ND	430 U	360 U	400 UJ	590 U	430 UJ
2,4,5-TRICHLOROPHENOL	620000 N	8200000 N	ND	1100 U	910 U	1000 U	1500 U	1100 U
2,4,6-TRICHLOROPHENOL	6200 N	82000 N	ND	430 U	360 U	400 U	590 U	430 U
2,4-DICHLOROPHENOL	18000 N	250000 N	ND	430 U	360 U	400 U	590 U	430 U
2,4-DIMETHYLPHENOL	120000 N	1600000 N	ND	430 U	360 U	400 U	590 U	430 U
2,4-DINITROPHENOL	12000 N	160000 N	ND	1100 UJ	910 UJ	1000 UJ	1500 U	1100 UJ
2,4-DINITROTOLUENE	1700 C	7400 C	ND	430 U	360 U	400 U	590 U	430 U
2,6-DINITROTOLUENE	360 C	1500 C	ND	430 U	360 U	400 U	590 U	430 U
2-CHLORONAPHTHALENE	630000 N	9300000 N	ND	430 U	360 U	400 U	590 U	430 U
2-CHLOROPHENOL	39000 N	580000 N	ND	430 U	360 U	400 U	590 U	430 U
2-METHYLPHENOL	310000 N	4100000 N	ND	430 U	360 U	400 U	590 U	430 U
2-NITROANILINE	61000 N	800000 N	ND	1100 U	910 U	1000 UJ	1500 U	1100 UJ
2-NITROPHENOL	NA	NA	ND	430 U	360 U	400 U	590 U	430 U
3,3'-DICHLOROBENZIDINE	1200 C	5100 C	ND	430 U	360 U	400 U	590 U	430 U
3-NITROANILINE	NA	NA	ND	1100 U	910 U	1000 U	1500 U	1100 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 14 OF 16**

LOCATION	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-SB06 WTB-SB06-1820-98-D 7/15/1998	WTB-SB06 WTB-SB06-0305-98 7/15/1998	WTB-SB07 WTB-SB07-0305-98 7/11/1998	WTB-SB07 WTB-SB07-1315-98 7/11/1998	WTB-SB07 WTB-SB07-0709-98 7/11/1998
4,6-DINITRO-2-METHYLPHENOL	490 N	6600 N	ND	1100 U	910 U	1000 U	1500 U	1100 U
4-BROMOPHENYL PHENYL ETHER	NA	NA	ND	430 U	360 U	400 U	590 U	430 U
4-CHLORO-3-METHYLPHENOL	620000 N	8200000 N	ND	430 U	360 U	400 U	590 U	430 U
4-CHLOROANILINE	2700 C	1200 C	ND	430 U	360 U	400 U	590 U	430 U
4-CHLOROPHENYL PHENYL ETHER	NA	NA	ND	430 U	360 U	400 U	590 U	430 U
4-METHYLPHENOL	620000 N	8200000 N	ND	430 U	360 U	400 U	590 U	430 U
4-NITROANILINE	25000 N	120000 C	ND	1100 U	910 U	1000 UJ	1500 U	1100 UJ
4-NITROPHENOL	NA	NA	ND	1100 U	910 U	1000 UJ	1500 U	1100 UJ
BIS(2-CHLOROETHOXY)METHANE	18000 N	250000 N	ND	430 U	360 U	400 U	590 U	430 U
BIS(2-CHLOROETHYL)ETHER	230 C	1000 C	ND	430 U	360 U	400 U	590 U	430 U
BIS(2-ETHYLHEXYL)PHTHALATE	38000 C	160000 C	58 - 650	150 U	510 U	400 U	590 U	430 U
BUTYL BENZYL PHTHALATE	280000 C	120000 C	ND	30 J	38 J	400 UJ	590 U	430 UJ
CARBAZOLE	NA	NA	94 - 94	430 U	24 J	400 U	71 J	430 U
DIETHYL PHTHALATE	4900000 N	66000000 N	ND	430 U	360 U	400 U	590 U	430 U
DIMETHYL PHTHALATE	NA	NA	42 - 42	430 U	360 U	400 U	590 U	430 U
DI-N-BUTYL PHTHALATE	620000 N	8200000 N	100 - 100	26 J	22 J	400 U	590 U	430 U
DI-N-OCTYL PHTHALATE	62000 N	820000 N	100 - 100	430 U	360 U	400 UJ	590 U	430 UJ
HEXACHLOROBENZENE	330 C	1400 C	ND	430 U	360 U	400 U	590 U	430 U
HEXACHLOROBUTADIENE	6200 N	30000 C	ND	430 U	360 U	400 U	590 U	430 U
HEXACHLOROCYCLOPENTADIENE	37000 N	490000 N	ND	430 UJ	360 UJ	400 U	590 U	430 U
HEXACHLOROETHANE	4300 N	58000 C	ND	430 U	360 U	400 U	590 U	430 U
ISOPHORONE	560000 C	2400000 C	ND	430 U	360 U	400 UJ	590 U	430 UJ
NITROBENZENE	5100 C	22000 C	ND	430 U	360 U	400 U	590 U	430 U
N-NITROSO-DI-N-PROPYLAMINE	76 C	330 C	ND	430 U	360 U	400 UJ	590 U	430 UJ
N-NITROSODIPHENYLAMINE	110000 C	470000 C	ND	430 U	360 U	400 U	590 U	430 U
PENTACHLOROPHENOL	990 C	4000 C	ND	1100 UJ	910 UJ	1000 UJ	1500 UJ	1100 UJ
PHENOL	1800000 N	25000000 N	98 - 98	430 U	360 U	400 U	590 U	430 U
<b>VOLATILES (UG/KG)</b>								
1,1,1-TRICHLOROETHANE	810000 N	3600000 N	ND	13 U	11 UJ	12 UR	92 U	13 UJ
1,1,2,2-TETRACHLOROETHANE	600 C	2700 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
1,1,2-TRICHLOROETHANE	150 N	630 N	ND	13 U	11 UJ	12 UR	92 U	13 UJ
1,1,2-TRICHLOROTRIFLUOROETHANE	4000000 N	17000000 N	NA	13 U	11 U	12 UJ	92 U	1 J
1,1-DICHLOROETHANE	3600 C	16000 C	ND	13 U	11 U	12 UJ	92 U	13 UJ
1,1-DICHLOROETHENE	23000 N	100000 N	3 - 3	13 U	11 U	12 UJ	92 U	13 UJ
1,2-DICHLOROETHANE	460 C	2000 C	ND	13 U	11 U	12 UJ	92 U	13 UJ
1,2-DICHLOROPROPANE	1000 C	4400 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
2-BUTANONE	2700000 N	19000000 N	ND	13 U	11 U	12 UJ	92 U	13 UJ
2-HEXANONE	20000 N	130000 N	ND	13 U	11 UJ	12 UR	92 U	13 UJ
4-METHYL-2-PENTANONE	530000 N	5600000 N	ND	13 U	11 UJ	12 UR	92 U	13 UJ
ACETONE	6100000 N	67000000 N	ND	180	2500 J	65 U	5600 U	330 U
BENZENE	1200 C	5100 C	ND	13 U	11 UJ	12 UR	92 U	2 J
BROMODICHLOROMETHANE	290 C	1300 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
BROMOFORM	67000 C	290000 C	ND	13 U	11 UJ	12 UJ	92 U	13 UJ
BROMOMETHANE	680 N	3000 N	ND	13 U	11 U	12 UJ	92 U	13 UJ
CARBON DISULFIDE	77000 N	350000 N	ND	6 J	11 U	12 UJ	20 J	13 UJ
CARBON TETRACHLORIDE	650 C	2900 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
CHLOROBENZENE	28000 N	130000 N	ND	13 U	11 UJ	12 UJ	92 U	13 UJ
CHLORODIBROMOMETHANE	730 C	3200 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
CHLOROETHANE	1400000 N	5700000 N	ND	13 U	11 U	12 UJ	92 U	13 UJ

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-SB06 WTB-SB06-1820-98-D 7/15/1998	WTB-SB06 WTB-SB06-0305-98 7/15/1998	WTB-SB07 WTB-SB07-0305-98 7/11/1998	WTB-SB07 WTB-SB07-1315-98 7/11/1998	WTB-SB07 WTB-SB07-0709-98 7/11/1998
CHLOROFORM	320 C	1400 C	ND	13 U	11 U	2 J	92 U	4 J
CHLOROMETHANE	11000 N	46000 N	ND	13 U	11 U	12 UJ	92 U	13 UJ
CIS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
ETHYLBENZENE	5800 C	25000 C	ND	13 U	11 UJ	12 UJ	92 U	2 J
METHYLENE CHLORIDE	35000 N	320000 N	1 - 2	19 U	22 U	27 U	920 J	710 U
STYRENE	600000 N	3500000 N	ND	13 U	11 UJ	12 UJ	92 U	13 UJ
TETRACHLOROETHENE	8100 N	39000 N	5.5 - 8	13 U	11 UJ	12 UJ	92 U	6 J
TOLUENE	490000 N	4700000 N	1 - 1	13 U	11 UJ	12 UR	92 U	6 J
TOTAL 1,2-DICHLOROETHENE	NA	NA	ND	13 U	11 U	12 UJ	92 U	13 UJ
TOTAL XYLENES	58000 N	250000 N	ND	13 U	11 UJ	12 U	92 U	13 UJ
TRANS-1,3-DICHLOROPROPENE	1800 C	8200 C	ND	13 U	11 UJ	12 UR	92 U	13 UJ
TRICHLOROETHENE	410 N	1900 N	ND	13 U	11 UJ	12 UR	92 U	7 J
VINYL CHLORIDE	59 C	1700 C	ND	13 U	11 U	12 UJ	92 U	13 UJ
<b>POLYCYCLIC AROMATIC HYDROCARBONS (UG/KG)</b>								
2-METHYLNAPHTHALENE	23000 N	300000 N	44 - 44	430 U	360 U	35 J	58 J	40 J
ACENAPHTHENE	350000 N	4500000 N	ND	430 U	360 U	400 U	52 J	430 U
ACENAPHTHYLENE <sup>(2)</sup>	350000 N	4500000 N	74 - 74	430 U	19 J	400 U	34 J	430 U
ANTHRACENE	1700000 N	23000000 N	58 - 62	430 U	50 J	24 J	88 J	430 U
BENZO(A)ANTHRACENE	150 C	2900 C	37 - 640	430 U	240 J	210 J	390 J	89 J
BENZO(A)PYRENE	15 C	290 C	36 - 1100	430 U	220 J	220 J	290 J	64 J
BENZO(B)FLUORANTHENE	150 C	2900 C	41 - 1700	430 U	370	310 J	390 J	110 J
BENZO(G,H,I)PERYLENE <sup>(3)</sup>	170000 N	2300000 N	39 - 410	430 U	36 J	150 J	200 J	68 J
BENZO(K)FLUORANTHENE	1500 C	29000 C	38 - 1100	430 U	170 J	140 J	220 J	52 J
CHRYSENE	15000 C	290000 C	37 - 1600	430 U	300 J	330 J	390 J	240 J
DIBENZO(A,H)ANTHRACENE	15 C	290 C	180 - 190	430 U	79 J	78 J	89 J	69 J
DIBENZOFURAN	7200 N	100000 N	ND	430 U	23 J	400 U	48 J	430 U
FLUORANTHENE	230000 N	3000000 N	43 - 1700	430 U	350 J	240 J	650	61 J
FLUORENE	230000 N	3000000 N	42 - 42	430 U	360 U	400 U	75 J	430 U
INDENO(1,2,3-CD)PYRENE	150 C	2900 C	38 - 440	430 U	140 J	140 J	170 J	50 J
NAPHTHALENE	3800 C	17000 C	42 - 43	430 U	42 J	24 J	96 J	25 J
PHENANTHRENE <sup>(3)</sup>	170000 N	2300000 N	40 - 470	430 U	200 J	170 J	330 J	160 J
PYRENE	170000 N	2300000 N	42 - 1400	430 U	370	260 J	610 J	93 J
<b>PESTICIDES/PCBS (UG/KG)</b>								
4,4'-DDD	2200 C	9600 C	0.6 - 170	4.1 U	3.6 U	4 U	6.1 U	4.4 U
4,4'-DDE	1600 C	6800 C	5.2 - 7100	4.1 U	3.6 U	4 U	6.1 U	4.4 U
4,4'-DDT	1900 C	8600 C	5.1 - 4100	4.1 U	3.6 U	4 U	6.1 U	4.4 U
ALDRIN	31 C	140 C	ND	2.1 U	1.9 U	5.3 J	3.1 U	7.2 R
ALPHA-BHC	85 C	370 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
ALPHA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
AROCLOR-1016	400 N	5200 N	ND	41 U	36 U	40 U	61 U	44 U
AROCLOR-1221	150 C	660 C	ND	84 U	73 U	81 U	120 U	89 U
AROCLOR-1232	150 C	660 C	ND	41 U	36 U	40 U	61 U	44 U
AROCLOR-1242	240 C	1000 C	ND	41 U	36 U	40 U	61 U	44 U
AROCLOR-1248	240 C	1000 C	ND	41 U	36 U	40 U	61 U	44 U
AROCLOR-1254	110 N	1000 C	ND	41 U	36 U	40 U	61 U	44 U
AROCLOR-1260	240 C	1000 C	ND	41 U	36 U	40 U	61 U	44 U
BETA-BHC	300 C	1300 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
DELTA-BHC <sup>(5)</sup>	85 C	370 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
DIELDRIN	33 C	140 C	ND	4.1 U	3.6 U	4 U	6.1 U	4.4 U

**TABLE 2**  
**OU8 SSI SUBSURFACE SOIL DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
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LOCATION	USEPA Residential Soil RSL	USEPA Industrial Soil RSL	PNS Facility Background Range of Detected Concentrations	WTB-SB06 WTB-SB06-1820-98-D 7/15/1998	WTB-SB06 WTB-SB06-0305-98 7/15/1998	WTB-SB07 WTB-SB07-0305-98 7/11/1998	WTB-SB07 WTB-SB07-1315-98 7/11/1998	WTB-SB07 WTB-SB07-0709-98 7/11/1998
ENDOSULFAN I <sup>(6)</sup>	37000 N	490000 N	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
ENDOSULFAN II <sup>(6)</sup>	37000 N	490000 N	ND	4.1 U	3.6 U	4 U	6.1 U	5 J
ENDOSULFAN SULFATE <sup>(6)</sup>	37000 N	490000 N	ND	4.1 U	3.6 U	4 U	6.1 U	4.4 U
ENDRIN	1800 N	25000 N	ND	4.1 U	3.6 U	4 U	6.1 U	4.4 U
ENDRIN ALDEHYDE <sup>(7)</sup>	1800 N	25000 N	ND	4.1 U	3.6 U	4 U	6.1 U	4.4 U
ENDRIN KETONE <sup>(7)</sup>	1800 N	25000 N	ND	4.1 U	3.6 U	4 U	6.1 U	4.4 U
GAMMA-BHC (LINDANE)	560 C	2500 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
GAMMA-CHLORDANE <sup>(4)</sup>	1800 C	8000 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
HEPTACHLOR	120 C	510 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
HEPTACHLOR EPOXIDE	59 C	250 C	ND	2.1 U	1.9 U	2.1 U	3.1 U	2.3 U
METHOXYCHLOR	31000 N	410000 N	ND	21 U	19 U	21 U	31 U	23 U
TOXAPHENE	480 C	2100 C	ND	210 U	190 U	210 U	310 U	230 U
<b>PETROLEUM HYDROCARBONS (MG/KG)</b>								
DIESEL RANGE ORGANICS	NA	NA	NA	7.6	57	140 U	100 U	190 U
GASOLINE RANGE ORGANICS	NA	NA	NA	3 U	2.8 U	4.3 U	5.3 U	4.5 U

USEPA RSLs are from May 2014 and are based on ILCR =  $1 \times 10^{-6}$  (C) and HI = 0.1 (N). C = carcinogen; N = Non-carcinogen.

NA = The chemical was not analyzed or no value was available.

ND = The chemical was not detected.

Data Qualifiers:

J = The chemical was detected but the concentration reported is an estimated value.

U = The chemical was not detected.

R = The chemical was rejected.

WTB-MW05 is located west of the quay wall that forms the western boundary of OU8 and may not represent site data.

Shaded values indicate industrial RSL was exceeded.

- (1) RSL is for elemental mercury
- (2) RSL is for acenaphthene
- (3) RSL is for pyrene
- (4) RSL is for chlordane
- (5) RSL is for alpha BHC
- (6) RSL is for endosulfan
- (7) RSL is for endrin

TABLE 3  
OU8 SSI GROUNDWATER DATA  
PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE  
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LOCATION	USEPA Tap water RSL	PNS Construction Worker Screening Level	PNS Facility Background	Upgradient WTB-MW01	WTB-MW02	WTB-MW03	WTB-MW04	WTB-MW05
SAMPLE ID			Range of Detected Concentrations	WTB-MW-01-11	WTB-MW-02-11	WTB-MW-03-11	WTB-MW-04-11	WTB-MW-05-11
SAMPLE DATE				8/3/1998	8/2/1998	8/3/1998	8/3/1998	8/2/1998
<b>METALS (UG/L)</b>								
ALUMINUM	2000 N	1150000 N	996 - 36600	4950 J	65.9 U	202 U	1300 U	72.6 U
ANTIMONY	0.78 N	138 N	ND	2 U	19.8 U	2.6 U	2 U	19.8 U
ARSENIC	0.052 C	345 N <sup>(10)</sup>	6.3 - 48.5	12.2 U	42.5 J	5.6 U	12.2 U	48.6 J
BARIUM	380 N	35700 N	7.6 - 376	164 J	90.8 J	25.3 U	120 J	279 J
BERYLLIUM	2.5 N	97.2 N	0.26 - 6.1	0.21 U	0.69 U	0.25 U	0.24 U	0.85 U
CADMIUM	0.92 N	65.4 N	2.1 - 8	2.3 U	2.3 U	2.3 U	2.3 U	2.5 U
CALCIUM	NA	NA	5260 - 145000	136000	195000	28800	40400	291000 U
CHROMIUM	2200 N <sup>(1)</sup>	27100 N <sup>(1)</sup>	0.76 - 53	27.2 U	3.4 U	12.5 U	11.9 U	4.1 U
COBALT	0.6 N	4570 N	1.4 - 32	14.1 U	2.7 U	2.7 U	3.1 U	2.7 U
COPPER	80 N	46000 N	2.4 - 158	7.8 U	51.1 U	2.6 U	38.2 U	1.8 U
IRON	1400 N	804000 N	66.6 - 46600	9930 J	266 U	589 U	4600 J	5000 J
LEAD	15	1340	1.3 - 87.1	6.1 U	64.7 U	7.6 U	35.7 J	13.1 UJ
MAGNESIUM	NA	NA	1200 - 23100	22400	495000	7970	7460 U	971000
MANGANESE	43 N	2550 N	6.1 - 3580	<b>9730 J</b>	0.59 UJ	459 J	600 J	1190 J
MERCURY	0.57 N <sup>(2)</sup>	357 N <sup>(2)</sup>	0.06 - 0.06	0.01 J	0.12 J	0.01 UJ	0.45 J	0.01 UJ
NICKEL	39 N	8710 N	2.7 - 110	55.8 U	18.4 U	17.4 U	19.2 U	37.1 U
POTASSIUM	NA	NA	3820 - 17200	11100	158000	6200	6340	334000
SELENIUM	10 N	5750 N	ND	4.3 J	31.9 U	3.2 U	3.2 U	31.9 U
SILVER	9.4 N	853 N	ND	2.7 U	2.7 U	2.7 U	2.7 U	2.7 U
SODIUM	NA	NA	38700 - 255000	227000	4E+06	98800	104000	7E+06
THALLIUM <sup>(11)</sup>	0.020 N	46.0 N	ND	14 U	<b>48.4 J</b>	3.2 UJ	3.2 U	32.2 UJ
VANADIUM	8.6 N	703 N	0.64 - 69	9.9 U	3.2 U	3.2 U	3.7 U	3.2 U
ZINC	600 N	412000 N	15.7 - 149	42.2 U	178 U	14.1 U	49.6 U	2.9 UJ
<b>DISSOLVED METALS (UG/L)</b>								
ALUMINUM	2000 N	1150000 N	252 - 547	--	--	--	47 U	--
ANTIMONY	0.78 N	138 N	ND	--	--	--	2.1 U	--
ARSENIC	0.052 C	345 N <sup>(10)</sup>	5.6 - 9.3	--	--	--	4.5 U	--
BARIUM	380 N	35700 N	5.9 - 18	--	--	--	109 J	--
BERYLLIUM	2.5 N	97.2 N	ND	--	--	--	0.17 UJ	--
CADMIUM	0.92 N	65.4 N	ND	--	--	--	2.3 U	--
CALCIUM	NA	NA	4810 - 38900	--	--	--	44000 U	--
CHROMIUM	2200 N <sup>(1)</sup>	27100 N <sup>(1)</sup>	4.2 - 10	--	--	--	3.4 U	--
COBALT	0.60 N	4570 N	ND	--	--	--	2.7 U	--
COPPER	80 N	46000 N	13 - 13	--	--	--	2.2 U	--
IRON	1400 N	804000 N	144 - 283	--	--	--	82.7 U	--
LEAD	15	1340	1.9 - 6.4	--	--	--	1.4 J	--
MAGNESIUM	NA	NA	1010 - 1140	--	--	--	7290 U	--
MANGANESE	43 N	2550 N	11.3 - 1310	--	--	--	664 J	--
MERCURY	0.57 N <sup>(2)</sup>	357 N <sup>(2)</sup>	ND	--	--	--	0.01 UJ	--
NICKEL	39 N	8710 N	ND	--	--	--	5.8 U	--
POTASSIUM	NA	NA	3420 - 4920	--	--	--	6440	--
SELENIUM	10 N	5750 N	ND	--	--	--	3.2 U	--
SILVER	9.4 N	853 N	ND	--	--	--	2.7 U	--
SODIUM	NA	NA	142000 - 150000	--	--	--	110000	--
THALLIUM <sup>(11)</sup>	0.020 N	46.0 N	ND	--	--	--	3.2 UJ	--
VANADIUM	8.6 N	703 N	ND	--	--	--	3.2 U	--
ZINC	600 N	412000 N	20 - 20	--	--	--	4.2 U	--

TABLE 3  
OU8 SSI GROUNDWATER DATA  
PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE  
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LOCATION	USEPA Tap water RSL	PNS Construction Worker Screening Level	PNS Facility Background	Upgradient WTB-MW01	WTB-MW02	WTB-MW03	WTB-MW04	WTB-MW05
SAMPLE ID			Range of Detected Concentrations	WTB-MW-01-11	WTB-MW-02-11	WTB-MW-03-11	WTB-MW-04-11	WTB-MW-05-11
SAMPLE DATE				8/3/1998	8/2/1998	8/3/1998	8/3/1998	8/2/1998
<b>MISCELLANEOUS PARAMETERS</b>								
BROMIDE (MG/L)	NA	NA	3.3 - 9.8	2 U	23	2 U	2 U	46
CARBONATE ALKALINITY (MG/L)	NA	NA	130 - 260	270	140	110	140	350
CHLORIDE (MG/L)	NA	NA	21 - 440	270 J	--	85 J	110 J	--
HEXAVALENT CHROMIUM (MG/L)	0.000035 C	1.14 C	NA	0.025 J	0.01 U	0.01 UJ	0.012	0.01 U
NITRATE (MG/L)	NA	3110 N	0.061 - 3.4	0.29	0.12	0.05 U	0.05 UJ	0.05 UJ
SULFATE (MG/L)	NA	NA	18 - 67	84	1000	10	2.1	1800
TOTAL ORGANIC CARBON (MG/L)	NA	NA	1.3 - 8	5.2	2.4	2.2	4.1	5.1
SALINITY (PPT)	NA	NA	NA	1.1	11	0.23	0.33	26
PH (S.U.)	NA	NA	7.2 - 8.3	6.9	7	7.5	7.4	7.5
CYANIDE (UG/L)	0.15 N	1170 N	ND	20 U	20 U	20 U	20 U	20 U
<b>SEMIVOLATILES (UG/L)</b>								
1,2,4-TRICHLOROENZENE	0.40 N <sup>(10)</sup>	491 C	ND	10 UJ	11 UJ	11 UJ	11 UJ	11 UJ
1,2-DICHLOROBENZENE	30 N	23700 N	ND	10 U	11 U	11 U	11 U	11 U
1,3-DICHLOROBENZENE	NA	568 N <sup>(10)</sup>	ND	10 U	11 U	11 U	11 U	11 U
1,4-DICHLOROBENZENE	0.48 C	2720 N <sup>(10)</sup>	ND	10 U	11 U	11 U	11 U	11 U
2,2'-OXYBIS(1-CHLOROPROPANE)	0.36 C	1770 C	ND	10 U	11 U	11 U	11 U	11 U
2,4,5-TRICHLOROPHENOL	120 N	10300 N	ND	25 U	28 U	28 U	28 U	28 U
2,4,6-TRICHLOROPHENOL	1.2 N <sup>(10)</sup>	34.9 N	ND	10 U	11 U	11 U	11 U	11 U
2,4-DICHLOROPHENOL	4.6 N	1440 N	ND	10 U	11 U	11 U	11 U	11 U
2,4-DIMETHYLPHENOL	36 N	7900 N	ND	10 U	11 U	11 U	11 U	11 U
2,4-DINITROPHENOL	3.9 N	12100 N	ND	25 UJ	28 UJ	28 UJ	28 UJ	28 UJ
2,4-DINITROTOLUENE	0.24 C	718 N <sup>(10)</sup>	ND	10 U	11 U	11 U	11 U	11 U
2,6-DINITROTOLUENE	0.048 C	229 C	ND	10 U	11 U	11 U	11 U	11 U
2-CHLORONAPHTHALENE	75 N	3730 N	ND	10 U	11 U	11 U	11 U	11 U
2-CHLOROPHENOL	9.1 N	1630 N	ND	10 U	11 U	11 U	11 U	11 U
2-METHYLNAPHTHALENE	3.6 N	77.1 N	ND	10 U	11 U	11 U	11 U	11 U
2-METHYLPHENOL	93 N	114000 N	ND	10 U	11 U	11 U	11 U	11 U
2-NITROANILINE	19 N	190 N	ND	25 U	28 U	28 U	28 U	28 U
2-NITROPHENOL	NA	NA	ND	10 U	11 U	11 U	11 U	11 U
3,3'-DICHLOROENZIDINE	0.12 C	101 C	ND	10 U	11 U	11 U	11 U	11 U
3-NITROANILINE	NA	571 N	ND	25 U	28 U	28 U	28 U	28 U
4,6-DINITRO-2-METHYLPHENOL	0.15 N	261 N	ND	25 U	28 U	28 U	28 U	28 U
4-BROMOPHENYL PHENYL ETHER	NA	NA	ND	10 U	11 U	11 U	11 U	11 U
4-CHLORO-3-METHYLPHENOL	140 N	5810 N	ND	10 U	11 U	11 U	11 U	11 U
4-CHLOROANILINE	0.36 C	156 N <sup>(10)</sup>	ND	10 U	11 U	11 U	11 U	11 U
4-CHLOROPHENYL PHENYL ETHER	NA	NA	ND	10 U	11 U	11 U	11 U	11 U
4-METHYLPHENOL	190 N	4570 N	ND	10 U	11 U	11 U	11 U	11 U
4-NITROANILINE	3.8 C	5590 N <sup>(10)</sup>	ND	25 U	28 U	28 U	28 U	28 U
4-NITROPHENOL	NA	NA	ND	25 U	28 U	28 U	28 U	28 U
BIS(2-CHLOROETHOXY)METHANE	5.9 N	22100 N	ND	10 U	11 U	11 U	11 U	11 U
BIS(2-CHLOROETHYL)ETHER	0.014 C	404 C	ND	10 U	11 U	11 U	11 U	11 U
BIS(2-ETHYLHEXYL)PHTHALATE	5.6 C	97300 C	18 - 18	10 U	11 U	11 U	11 U	11 U
BUTYL BENZYL PHTHALATE	16 C	5780 C	ND	1 J	11 U	11 U	1 J	11 U
CARBAZOLE	NA	NA	ND	10 U	11 U	11 U	11 U	11 U
CHRYSENE	3.4 C	187000 C	ND	10 U	11 U	11 U	11 U	11 U
DIETHYL PHTHALATE	1500 N	1420000 N	ND	10 U	11 U	11 U	11 U	11 U
DIMETHYL PHTHALATE	NA	NA	ND	10 U	11 U	11 U	11 U	11 U
DI-N-BUTYL PHTHALATE	90 N	33300 N	ND	10 U	11 U	11 U	11 U	11 U
DI-N-OCTYL PHTHALATE	20 N	15.6 N	ND	10 U	11 U	11 U	11 U	11 U
HEXACHLOROBENZENE	0.049 C	0.058 N	ND	10 U	11 U	11 U	11 U	11 U
HEXACHLOROBUTADIENE	0.30 C	11.1 N <sup>(10)</sup>	ND	10 U	11 U	11 U	11 U	11 U

TABLE 3  
OU8 SSI GROUNDWATER DATA  
PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE  
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LOCATION	USEPA Tap water RSL	PNS Construction Worker Screening Level	PNS Facility Background	Upgradient WTB-MW01	WTB-MW02	WTB-MW03	WTB-MW04	WTB-MW05
SAMPLE ID			Range of Detected Concentrations	WTB-MW-01-11	WTB-MW-02-11	WTB-MW-03-11	WTB-MW-04-11	WTB-MW-05-11
SAMPLE DATE				8/3/1998	8/2/1998	8/3/1998	8/3/1998	8/2/1998
HEXACHLOROCYCLOPENTADIENE	3.1 N	762 N	ND	10 UJ	11 UJ	11 UJ	11 UJ	11 UJ
HEXACHLOROETHANE	0.69 N <sup>(10)</sup>	312 N	ND	10 U	11 U	11 U	11 U	11 U
ISOPHORONE	78 C	297000 C	ND	10 U	11 U	11 U	11 U	11 U
NITROBENZENE	0.14 C	1470 N	ND	10 U	11 U	11 U	11 U	11 U
N-NITROSO-DI-N-PROPYLAMINE	0.011 C	55 C	ND	10 U	11 U	11 U	11 U	11 U
N-NITROSODIPHENYLAMINE	12 C	11500 C	ND	10 U	11 U	11 U	11 U	11 U
PENTACHLOROPHENOL	0.040 C	1950 N <sup>(10)</sup>	ND	25 UJ	28 UJ	28 UJ	28 UJ	28 UJ
PHENOL	580 N	231000 N	ND	10 U	11 U	11 U	11 U	11 U
<b>VOLATILES (UG/L)</b>								
1,1,1-TRICHLOROETHANE	800 N	920000 N	ND	10 U	10 U	10 U	10 U	10 U
1,1,2,2-TETRACHLOROETHANE	0.076 C	676 C	ND	10 U	10 U	10 U	10 U	10 U
1,1,2-TRICHLOROETHANE	0.041 N <sup>(10)</sup>	963 N <sup>(10)</sup>	ND	10 U	10 U	10 U	10 U	10 U
1,1,2-TRICHLOROTRIFLUOROETHANE	5500 N	2220000 N	NA	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHANE	2.7 C	32300 C	ND	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHENE	28 N	1470 N	ND	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROETHANE	0.17 C	3000 C	ND	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROPROPANE	0.44 C	4320 C	ND	10 U	10 U	10 U	10 U	10 U
2-BUTANONE	560 N	2110000 N	ND	10 U	10 U	10 U	10 U	10 U
2-HEXANONE	3.8 N	2220 N	ND	10 U	10 U	10 U	2 J	10 U
4-METHYL-2-PENTANONE	120 N	439000 N	ND	10 U	10 U	10 U	10 U	10 U
ACETONE	1400 N	2700000 N	ND	10 UJ	18 U	10 U	10 U	10 U
BENZENE	0.45 C	1390 N <sup>(10)</sup>	ND	10 UJ	10 U	10 U	10 U	10 U
BROMODICHLOROMETHANE	0.13 C	2260 N <sup>(10)</sup>	ND	10 U	10 U	10 U	10 U	10 U
BROMOFORM	9.2 C	9590 N <sup>(10)</sup>	ND	10 U	10 U	10 U	10 U	10 U
BROMOMETHANE	0.75 N	2650 N	ND	10 U	10 U	10 U	10 U	10 U
CARBON DISULFIDE	81 N	12100 N	ND	10 U	10 U	10 U	10 U	10 U
CARBON TETRACHLORIDE	0.45 C	650 N <sup>(10)</sup>	ND	10 U	10 U	10 U	10 U	10 U
CHLOROBENZENE	7.8 N	4780 N	ND	10 U	10 U	10 U	10 U	10 U
CHLORODIBROMOMETHANE	0.17 C	2510 C	ND	10 U	10 U	10 U	10 U	10 U
CHLOROETHANE	2100 N	31500 N	ND	10 U	10 U	10 U	10 U	10 U
CHLOROFORM	0.22 C	5470 C	ND	10 U	10 U	10 U	10 U	10 U
CHLOROMETHANE	19 N	NA	ND	10 UJ	10 U	10 U	10 UJ	10 U
CIS-1,3-DICHLOROPROPENE	0.47 C <sup>(3)</sup>	1550 C	ND	10 U	10 U	10 U	10 U	10 U
ETHYLBENZENE	1.5 C	2650 N	ND	10 U	10 U	10 U	10 U	10 U
METHYLENE CHLORIDE	11 N <sup>(10)</sup>	27700 N <sup>(10)</sup>	ND	10 U	10 U	10 U	10 U	10 U
STYRENE	120 N	10900 N	ND	10 U	10 U	10 U	10 U	10 U
TETRACHLOROETHENE	4.1 N <sup>(10)</sup>	4410 N <sup>(10)</sup>	ND	10 U	10 U	10 U	10 U	10 U
TOLUENE	110 N	54200 N	21 - 21	10 U	10 U	10 U	10 U	10 U
TOTAL 1,2-DICHLOROETHENE	NA	2120 N	ND	10 U	10 U	10 U	10 U	10 U
TOTAL XYLENES	19 N	17800 N	ND	10 U	10 U	10 U	10 U	10 U
TRANS-1,3-DICHLOROPROPENE	0.47 C <sup>(3)</sup>	1550 C	ND	10 U	10 U	10 U	10 U	10 U
TRICHLOROETHENE	0.28 N <sup>(10)</sup>	71.5 N	ND	10 U	10 U	10 U	10 U	10 U
VINYL CHLORIDE	0.019 C	328 C	ND	10 UJ	10 U	10 U	10 UJ	10 U

TABLE 3  
OU8 SSI GROUNDWATER DATA  
PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE  
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LOCATION	USEPA Tap water RSL	PNS Construction Worker Screening Level	PNS Facility Background	Upgradient WTB-MW01	WTB-MW02	WTB-MW03	WTB-MW04	WTB-MW05
SAMPLE ID			Range of Detected Concentrations	WTB-MW-01-11	WTB-MW-02-11	WTB-MW-03-11	WTB-MW-04-11	WTB-MW-05-11
SAMPLE DATE				8/3/1998	8/2/1998	8/3/1998	8/3/1998	8/2/1998
<b>POLYCYCLIC AROMATIC HYDROCARBONS (UG/L)</b>								
ACENAPHTHENE	53 N	3760 N	ND	10 U	11 U	11 U	11 U	11 U
ACENAPHTHYLENE	53 N <sup>(4)</sup>	3600 N	ND	10 U	11 U	11 U	11 U	11 U
ANTHRACENE	180 N	10100 N	ND	10 U	11 U	11 U	11 U	11 U
BENZO(A)ANTHRACENE	0.034 C	1870 C	ND	10 U	11 U	11 U	11 U	11 U
BENZO(A)PYRENE	0.0034 C	187 C	ND	10 U	11 U	11 U	11 U	11 U
BENZO(B)FLUORANTHENE	0.034 C	1870 C	ND	10 U	11 U	11 U	11 U	11 U
BENZO(G,H,I)PERYLENE	12 N <sup>(5)</sup>	21.0 N	ND	10 U	11 U	11 U	11 U	11 U
BENZO(K)FLUORANTHENE	0.34 C	18700 C	ND	10 U	11 U	11 U	11 U	11 U
DIBENZO(A,H)ANTHRACENE	0.0034 C	187 C	ND	10 U	11 U	11 U	11 U	11 U
DIBENZOFURAN	0.79 N	62.6 N	ND	10 U	11 U	11 U	11 U	11 U
FLUORANTHENE	80 N	779000 N	ND	10 U	11 U	11 U	11 U	11 U
FLUORENE	29 N	5650 N	ND	10 U	11 U	11 U	11 U	11 U
INDENO(1,2,3-CD)PYRENE	0.034 C	1870 C	ND	10 U	11 U	11 U	11 U	11 U
NAPHTHALENE	0.17 C	23600 N	ND	10 U	11 U	11 U	11 U	11 U
PHENANTHRENE	12 N <sup>(5)</sup>	58400 N	ND	10 U	11 U	11 U	11 U	11 U
PYRENE	12 N	1850 N	ND	10 UJ	11 UJ	11 UJ	11 UJ	11 UJ
<b>PESTICIDES/PCBS (UG/L)</b>								
4,4'-DDD	0.031 C	9.04 C	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
4,4'-DDE	0.23 C	4010 C	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
4,4'-DDT	0.23 C	973 N <sup>(10)</sup>	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
ALDRIN	0.0046 C	77.9 N <sup>(10)</sup>	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
ALPHA-BHC	0.0071 C	3.69 C	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
ALPHA-CHLORDANE	0.22 C <sup>(6)</sup>	6.53 N <sup>(10)</sup>	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
AROCLOR-1016	0.14 N	136 N	ND	1 U	1 U	2.3 U	1.1 U	1.2 U
AROCLOR-1221	0.0046 C	3.36 C	ND	2 U	2.1 U	<b>4.7 U</b>	2.2 U	2.3 U
AROCLOR-1232	0.0046 C	3.36 C	ND	1 U	1 U	2.3 U	1.1 U	1.2 U
AROCLOR-1242	0.039 C	681 C	ND	1 U	1 U	2.3 U	1.1 U	1.2 U
AROCLOR-1248	0.039 C	681 C	ND	1 U	1 U	2.3 U	1.1 U	1.2 U
AROCLOR-1254	0.039 C	58.4 N	ND	1 U	1 U	2.3 U	1.1 U	1.2 U
AROCLOR-1260	0.039 C	681 C	ND	1 U	1 U	2.3 U	1.1 U	1.2 U
BETA-BHC	0.025 C	12.9 C	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
DELTA-BHC	0.007 C <sup>(7)</sup>	3.69 C	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
DIELDRIN	0.0017 C	1.65 C	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
ENDOSULFAN I	10 N <sup>(8)</sup>	963 N	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
ENDOSULFAN II	10 N <sup>(8)</sup>	873 N	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
ENDOSULFAN SULFATE	10 N <sup>(8)</sup>	454 N	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
ENDRIN	0.23 N	75.3 N	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
ENDRIN ALDEHYDE	0.23 N <sup>(9)</sup>	178 N	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
ENDRIN KETONE	0.23 N <sup>(9)</sup>	41.0 N	ND	0.1 U	0.1 U	0.23 U	0.11 U	0.12 U
GAMMA-BHC (LINDANE)	0.041 C	0.666 N	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
GAMMA-CHLORDANE	0.22 C <sup>(6)</sup>	6.53 N <sup>(10)</sup>	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
HEPTACHLOR	0.002 C	5.54 N <sup>(10)</sup>	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
HEPTACHLOR EPOXIDE	0.0038 C	0.229 N <sup>(10)</sup>	ND	0.051 U	0.052 U	0.12 U	0.054 U	0.058 U
METHOXYCHLOR	3.7 N	57.3 N	ND	0.51 U	0.52 U	1.2 U	0.54 U	0.58 U
TOXAPHENE	0.015 C	20 C	ND	5.1 U	5.2 U	12 U	5.4 U	5.8 U

**TABLE 3**  
**OU8 SSI GROUNDWATER DATA**  
**PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE**  
**PAGE 5 OF 5**

LOCATION	USEPA Tap water RSL	PNS Construction Worker Screening Level	PNS Facility Background	Upgradient WTB-MW01	WTB-MW02	WTB-MW03	WTB-MW04	WTB-MW05
SAMPLE ID			Range of Detected Concentrations	WTB-MW-01-11	WTB-MW-02-11	WTB-MW-03-11	WTB-MW-04-11	WTB-MW-05-11
SAMPLE DATE				8/3/1998	8/2/1998	8/3/1998	8/3/1998	8/2/1998
<b>PETROLEUM HYDROCARBONS (UG/L)</b>								
DIESEL RANGE ORGANICS	NA	NA	50 - 5000	630	62	210	190	170
GASOLINE RANGE ORGANICS	NA	NA	0 - 100	18	10 U	10 U	10 U	10 U

**Footnotes:**

C = Carcinogen

N = Non-carcinogen

NA = The chemical was not analyzed or no value was available.

ND = The chemical was not detected.

Data Qualifiers:

J = The chemical was detected but the concentration reported is an estimated value.

U = The chemical was not detected.

R = The chemical was rejected.

-- = not analyzed

USEPA Tapwater Screening Levels are the May 2014 screening levels (ILCR =  $1 \times 10^{-6}$  and HI = 0.1). MCLs are presented if a tapwater screening level was not available.

PNS Construction Worker Screening Levels are for ingestion and dermal exposures to groundwater and were calculated based on the methodology provided in Appendix A.4.

Shaded values indicate PNS Construction Worker Screening Level was exceeded.

(1) Criteria are for trivalent chromium.

(2) Criteria are for mercuric chloride.

(3) Criteria are for 1,3-dichloropropene.

(4) Criteria are for acenaphthene.

(5) Criteria are for pyrene.

(6) Criteria are for chlordane.

(7) Criteria are for alpha-BHC.

(8) Criteria are for endosulfan.

(9) Criteria are for endrin.

(10) Non-carcinogenic value used because 1/10th the non-carcinogenic value is less than the carcinogenic value.

(11) Toxicity criteria used is only suitable for screening and is not to be used for quantifying risks.

**A.4 RISK BASED SCREENING LEVEL DEVELOPMENT FOR  
CONSTRUCTION WORKERS EXPOSED TO  
GROUNDWATER AT PORTSMOUTH NAVAL SHIPYARD**

# **RISK-BASED SCREENING LEVEL DEVELOPMENT FOR THE CONSTRUCTION WORKER EXPOSED TO GROUNDWATER AT PORTSMOUTH NAVAL SHIPYARD SEPTEMBER 2014**

Facility-specific risk-based screening levels for construction workers exposed to groundwater are used to screen groundwater data at sites at Portsmouth Naval Shipyard (PNS), Kittery, Maine. Development of the screening levels provided herein is based on the methodology provided in Appendix D.5.3 of the Remedial Investigation Report for Operable Unit 7 (Tetra Tech, July 2011) and the 2005 Technical Memorandum for Derivation of Lead Screening Levels provided in Appendix C.2, Attachment 2 of the Supplemental Remedial Investigation for Operable Unit 2 (Tetra Tech, March 2010). The construction worker screening levels were developed based on incidental ingestion of and dermal exposure to chemicals in groundwater and were calculated using current United States Environmental Protection Agency (USEPA) methods, input parameters, and models, as appropriate. Attachment 1 provides the 2005 Technical Memorandum and Attachment 2 provides screening level summary tables and calculation worksheets.

Developing risk-based concentrations (RBCs) was accomplished by calculating a theoretical risk based on an assumed chemical concentration and then back-calculating a RBC utilizing the ratio of the assumed chemical concentration multiplied by a target risk to the calculated theoretical risk. The assumed concentration of chemical in groundwater was 1.0 µg/L (0.001 mg/L). The models and parameters used to estimate intakes, risks, and RBCs are described in the following sections.

## **Incidental Ingestion of Groundwater**

Incidental ingestion groundwater was evaluated by methods and equations provided in Risk Assessment for Superfund, Volume I, Human Health Evaluation Manual Part A, (Interim Final RAGS Part A, USEPA, December 1989, 2010 updates).

The following equation is used to assess exposures resulting from incidental ingestion of groundwater:

$$\text{Incidental Ingestion Intake} = (IwR)(CF)(EF)(ED)/(BW)(AT)$$

where:

IwR	=	ingestion rate of groundwater 0.01 (L/day)
CF	=	conversion factor 0.001 (mg/µg)
EF	=	outdoor worker exposure frequency (150 days/yr)
ED	=	exposure duration (year)
BW	=	body weight (80 kg)
AT	=	averaging time (days)

for noncarcinogens, AT = ED x 365 days/yr

for carcinogens, AT = 70 yrs x 365 days/yr

### Dermal Contact with Groundwater

Dermal contact with groundwater was evaluated by methods and equations provided in Risk Assessment for Superfund, Volume I, Human Health Evaluation Manual Part E, Supplemental Guidance for Dermal Risk Assessment (RAGS Part E, USEPA, July 2004).

The following equation is used to assess exposures resulting from dermal contact with groundwater (USEPA, July 2004):

$$DAD_{wi} = (DA_{event})(EV)(ED)(EF)(A) / (BW)(AT)$$

where:

DAD <sub>wi</sub>	=	dermally absorbed dose of chemical "i" from water (mg/kg/day)
DA <sub>event</sub>	=	absorbed dose per event (mg/cm <sup>2</sup> -event)
EV	=	event frequency (1 event/day)
ED	=	exposure duration (year)
EF	=	exposure frequency (150 days/yr)
A	=	skin surface area available for contact (3,470cm <sup>2</sup> )
BW	=	body weight (80 kg)
AT	=	averaging time (days)
		for noncarcinogens, AT = ED x 365 days/yr
		for carcinogens, AT = 70 yrs x 365 days/yr

The absorbed dose per event (DA<sub>event</sub>) was estimated using a nonsteady-state approach for organic compounds and a traditional steady-state approach for inorganics. For organics, the following equations apply:

$$\text{If } t_{event} < t^*, \text{ then: } DA_{event} = (2FA)(K_p)(C_{wi})(CF) \left( \sqrt{\frac{6 \tau t_{event}}{\pi}} \right)$$

$$\text{If } t_{event} > t^*, \text{ then: } DA_{event} = (FA)(K_p)(C_{wi})(CF) \left( \frac{t_{event}}{1+B} + 2\tau \left( \frac{1+3B+3B^2}{(1+B)^2} \right) \right)$$

where:

t <sub>event</sub>	=	duration of event (hours/event)
FA	=	fraction absorbed (dimensionless)

$t^*$	=	time it takes to reach steady-state conditions (hr)
$K_p$	=	permeability coefficient from water through skin (cm/hr)
$C_{wi}$	=	concentration of chemical "i" in water (0.001 mg/L)
$T$	=	lag time (hr)
$\pi$	=	constant (dimensionless; equal to 3.1416)
CF	=	conversion factor ( $1 \times 10^{-3}$ L/cm <sup>3</sup> )
B	=	partitioning constant derived by Bunge Model (dimensionless)

Values for the chemical-specific parameters ( $t^*$ ,  $K_p$ ,  $T$ , and B) were obtained from the current dermal guidance (USEPA, July 2004). The following steady-state equation is used to estimate  $DA_{\text{event}}$  for inorganics:

$$DA_{\text{event}} = (K_p) (C_{wi}) (t_{\text{event}}) (CF)$$

The recommended dermal permeability value for inorganic constituents of  $1 \times 10^{-3}$  cm/hour was provided in the USEPA guidance. For most metals, dermal absorption is not a significant pathway because penetration through the skin is minimal. The parameters and calculations used to estimate  $DA_{\text{event}}$  are presented in the attached example calculations.

### **Toxicity Criteria**

Oral Reference Doses (RfDs) and Cancer Slope Factors (CSFs) were obtained from the USEPA Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites (RSL table for May 2014), which lists the toxicity values from a hierarchy of toxicological sources as follows:

- 1) USEPA's Integrated Risk Information System (IRIS) (<http://www.epa.gov/iris/>)
- 2) USEPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)
- 3) Other toxicity sources such as:
  - California Environmental Protection Agency  
(<http://www.oehha.ca.gov/risk/chemicalDB/index.asp>)
  - Agency for Toxic Substances and Disease Registry Minimal Risk Levels (<http://www.atsdr.cdc.gov/mrls.htm>)
  - Annual Health Effects Assessment Summary Tables

Under the guidelines established by the Superfund program, exposures to construction workers of one year or less are classified as subchronic exposures. Therefore, subchronic RfDs were used when available, and chronic RfDs were used if no subchronic RfD was available.

## **Toxicity Criteria for Dermal Exposure**

RfDs and CSFs found in literature may be expressed as administered doses; therefore, these values are considered to be inappropriate for estimating the risks associated with dermal routes of exposure. Oral dose-response parameters based on administered doses must be adjusted to absorbed doses before the comparison to estimated dermal exposure intakes is made. Because this information is not always readily available, oral dose-response parameters are adjusted to an absorbed dose using chemical-specific absorption efficiencies published in available guidance (USEPA, July 2004) and the following equations:

$$\text{RfD}_{\text{dermal}} = (\text{RfD}_{\text{oral}})(\text{ABS}_{\text{GI}})$$

$$\text{CSF}_{\text{dermal}} = (\text{CSF}_{\text{oral}}) / (\text{ABS}_{\text{GI}})$$

where:

$\text{ABS}_{\text{GI}}$  = absorption efficiency in the gastrointestinal tract

## **Exposure Assumptions**

The assumptions used to develop the construction worker screening levels are as follows:

- Skin Surface Area Available for Contact – 3,470 cm<sup>2</sup>
- Exposure Duration – 1 year
- Exposure Frequency – 150 days/year
- Duration of Event – 2 hours/day
- Body Weight – 80 kg
- Averaging Time (Cancer) – 25,550 days
- Averaging Time (Non-Cancer) – 365 days

## **Theoretical Risk Calculations**

Quantitative estimates of risk based on a groundwater concentration of 0.001 mg/L were calculated according to risk assessment methods outlined in USEPA guidance (USEPA, 1989). Incremental lifetime cancer risks are expressed in the form of dimensionless probabilities, referred to as incremental lifetime carcinogenic risks (ILCRs), based on CSFs. Noncarcinogenic risk estimates are presented in the form of Hazard Quotients (HQs) that are determined through a comparison of intakes with published RfDs.

Carcinogenic risk estimates were generated for each chemical using estimated exposure intakes and published CSFs, as follows:

$$ILCR = (\text{Intake}_{\text{ing}} \times \text{CSF}_{\text{oral}}) + ((\text{Intake}_{\text{derm}} \times \text{DA}_{\text{event}}) \times \text{CSF}_{\text{dermal}})$$

where:

$\text{CSF}_{\text{oral}}$	=	oral cancer slope factor
$\text{CSF}_{\text{dermal}}$	=	dermal cancer slope factor
$\text{Intake}_{\text{ing}}$	=	ingestion intake
$\text{Intake}_{\text{derm}}$	=	dermal intake
$\text{DA}_{\text{event}}$	=	absorbed dose per event

Noncarcinogenic risks were assessed using the concept of HQs and Hazard Indices (HIs). The HQ for a COPC is the ratio of the estimated intake to the RfD, as follows:

$$\text{HQ} = (\text{Intake}_{\text{ing}} / \text{RfD}_{\text{oral}}) + ((\text{Intake}_{\text{derm}} \times \text{DA}_{\text{event}}) / \text{RfD}_{\text{dermal}})$$

where:

$\text{RfD}_{\text{oral}}$	=	oral reference dose
$\text{RfD}_{\text{dermal}}$	=	dermal reference dose
$\text{Intake}_{\text{ing}}$	=	ingestion intake
$\text{Intake}_{\text{derm}}$	=	dermal intake
$\text{DA}_{\text{event}}$	=	absorbed dose per event

### **Calculation of Risk-Based Screening Levels**

The risk assessment equation for incidental ingestion and dermal exposure to water is linear in the concentration term; therefore, a risk-based groundwater concentration can be calculated by a ratio of an assumed example concentration (0.001 mg/L) and the theoretical risks calculated from this concentration. A target cancer risk (TCR) of  $1 \times 10^{-6}$  and a target hazard index (THI) of unity (1) were used for calculating screening levels using the following equation.

$$\text{SL} = \frac{C(\text{TCR or THI})}{\text{ILCR or HQ}}$$

where:

SL	=	screening level (mg/L).
C	=	assumed water concentration on which theoretical risks were calculated.
TCR	=	Target Cancer Risk = $1 \times 10^{-6}$
THI	=	Target Hazard Index = 1
ILCR	=	Calculated cancer risk
HQ	=	Calculated noncancer risk

The screening level was then adjusted to represent the lower of noncarcinogenic value divided by 10 to represent an HQ of 0.1 or carcinogenic or ILCR of  $1 \times 10^{-6}$ , as shown in the summary tables for inorganics and organics in Attachment 2.

### **Lead Screening Level Development Update Calculation of Risk-Based Screening Levels**

Lead screening levels were calculated for groundwater using the methodology provided in the 2005 Technical Memorandum (see Attachment 1). The Adult Lead Model (ALM) was used to calculate a screening level for the construction worker exposed to groundwater. The ALM uses an equation to calculate lead screening levels for soil exposures which was manipulated as described in Attachment 1 to calculate construction worker screening levels to groundwater exposure via the dermal and incidental ingestion pathways. In 2009, USEPA issued an update to the ALM that changed the values of two constants in the ALM equation including the geometric standard deviation and the baseline lead concentration in blood. The updated groundwater lead screening level presented in this report accounts for the 2009 updates to the geometric standard deviation and baseline lead blood concentration values used in the ALM. The updated lead groundwater screening level calculation is presented in Attachment 2.

**ATTACHMENT 1**

**2005 TECHNICAL MEMORANDUM FOR LEAD SCREENING LEVEL  
DERIVATION**

## TECHNICAL MEMORANDUM

### DERIVATION OF LEAD SCREENING LEVELS

#### FOR

### RECREATIONAL USERS EXPOSED TO INTERTIDAL SURFACE WATER AND CONSTRUCTION WORKERS EXPOSED TO SHALLOW GROUNDWATER AT PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

This technical memorandum presents the approaches used to develop aqueous lead screening levels for recreational users and construction workers to use in assessing potential human health risks from lead at Installation Restoration Program (IRP) sites at Portsmouth Naval Shipyard (PNS) that have brackish/saline groundwater and the intertidal surface water is saline. The human health screening level for groundwater and intertidal surface water that has been used previously for evaluation of lead at the PNS IRP sites is the Federal Safe Drinking Water Act (SDWA) action level of 15 ug/L. However, many of the IRP sites at PNS have brackish/saline groundwater and the intertidal surface water is saline so a screening level based on a drinking water level is not appropriate for risk screening. This technical memorandum presents alternative screening levels for two receptors hypothetically exposed to lead in aqueous media: 1) a child recreational user exposed to lead in water along the shoreline of a site (intertidal area), and 2) a construction worker exposed to lead in shallow groundwater at a site. The screening levels presented are based on the incidental ingestion route of exposure and dermal contact. Exposure to lead by dermal contact was considered in the calculations even though dermal uptake of lead is typically not considered significant for lead (USEPA, July 2004, ATSDR, online, March 2004). The screening levels presented herein were derived to facilitate human health risk assessment and risk management decisions at PNS. The screening levels were identified based on information developed using the two approaches as described below. Per USEPA guidelines, the screening levels presented in this technical memorandum incorporate exposure factor assumptions reflective of a reasonable maximum exposure (RME) case. The RME case is generally "defined as the highest exposure that is reasonably expected to occur at a site." The intent of the RME is to estimate an exposure that is well above the average but is still within the range of possible exposure possibilities.

#### **1.0 Approach No. 1: Derivation of a Screening Level for a Construction Worker Exposed to Shallow Groundwater Using the Adult Lead Model (ALM)**

A screening level for construction workers exposed to lead in water may be developed by estimating an acceptable daily intake based on the Adult Lead Model (ALM) equations. The ALM was developed to estimate blood-lead levels for adults exposed to lead in soil in non-residential exposure scenarios (i.e., industrial and recreational). An industrial soil remediation goal of 800 mg/kg based on the ALM has already been published by the USEPA. This value is expected to be protective of workers who work primarily indoors (i.e., work is not soil contact intensive) and the fetuses of workers. The 800 mg/kg value was based on an ingestion rate of 50 mg-soil per day, 219 days/year (ALM Frequently Asked Questions [FAQs] online at <http://www.epa.gov/superfund/programs/lead/almfaq.htm>; last updated April 29, 2004).

The ALM makes use of the following equation for calculating screening levels for soil:

General Adult Lead Model (ALM) Equation for Soil Exposures:

$$\text{Screening Level(soil)} = \frac{([\text{PbB}_{95\text{fetal}} / (R * (\text{GSD}_i^{1.645}))] - \text{PbB}_0) * \text{AT}_{\text{S,D}}}{\text{BKSF} * (\text{IR}_{\text{S+D}} * \text{AF}_{\text{S,D}} * \text{EF}_{\text{S,D}})}$$

where:

$\text{PbB}_{\text{fetal}, 0.95}$	95 <sup>th</sup> percentile blood lead concentration (PbB) in fetus (Goal is 10 ug/dL)
$R_{\text{fetal/maternal}}$	Fetal/maternal PbB ratio = 0.9
BKSF	Biokinetic Slope Factor = 0.4 ug/dL per ug/day
$\text{GSD}_i$	Geometric standard deviation PbB = 2
$\text{PbB}_0$	Baseline PbB = 2 ug/dL
$\text{IR}_{\text{S+D}}$	Total ingestion rate of outdoor soil and indoor dust
$\text{AF}_{\text{S,D}}$	Absorption fraction (same for soil and dust) = 0.12
$\text{EF}_{\text{S,D}}$	Exposure frequency = 150 days/yr
$\text{AT}_{\text{S,D}}$	Averaging time = 365 days/yr

The ALM approach for developing lead screening levels for soil may be used to develop a screening level for construction worker exposures to groundwater by modifying the basic equation for soil presented above, as follows:

Equation for Calculating a Construction Worker Screening Level Based on Incidental Ingestion of Lead in Water:

$$\text{Screening Level (iw)} = \frac{([\text{PbB}_{95\text{fetal}} / (R * (\text{GSD}_i^{1.645}))] - \text{PbB}_0) * \text{AT}_w}{\text{BKSF} * (\text{IR}_w * \text{AF}_w * \text{EF}_{\text{constw}})}$$

where:

$\text{PbB}_{\text{fetal}, 0.95}$	95 <sup>th</sup> percentile blood lead concentration (PbB) in fetus (Goal is 10 ug/dL)
$R_{\text{fetal/maternal}}$	Fetal/maternal PbB ratio = 0.9
BKSF	Biokinetic Slope Factor = 0.4 ug/dL per ug/day
$\text{GSD}_i$	Geometric standard deviation PbB = 2
$\text{PbB}_0$	Baseline PbB = 2 ug/dL
$\text{IR}_w$	Water ingestion rate = 0.02 L/day (0.01 L/hour x 2 hours)
$\text{AF}_w$	Absorption fraction for adults (water) = 0.60**
$\text{EF}_{\text{constw}}$	Exposure frequency for construction workers = 150 days/yr
$\text{AT}_w$	Averaging time for exposure to water = 365 days/yr

\*\* Bowers, S.B., Beck, B.D., Karam, H.S. Assessing the Relationship Between Environmental Lead Concentrations and Adult Blood Lead Levels, Risk Analysis Vol. 14, No. 2, 1994.

Some of the suggested exposure factors presented above are default values suggested in the ALM model. However, the recommended receptor exposure time (2 hours per day), exposure frequency (150 days/year), and water ingestion rate (0.01 L/hour) are based on professional judgment to a certain extent. The following items provide the rationale for the exposure factor values suggested for these parameters:

- The 2-hour per day groundwater exposure time suggested for the construction worker reflects the fact that the anticipated exposure is expected to be limited. The

recommended value is less than the 4-hour per day exposure time listed for recreational activities in Section 2 of this memorandum and in the *December 2002 Technical Memorandum titled, Human Health Risk Screening Levels for Intertidal Surface Water and Sediment* because the exposure incurred by a construction worker is likely to be sporadic and truly incidental when compared to exposure occurring during recreational activities. For example, receptors often desire/seek exposure to both surface waters and sediments during recreational activities. In contrast, the construction worker contacts the shallow groundwater in an excavation pit on an incidental basis only (e.g., while he/she is retrieving a piece of equipment out of the pit).

- The suggested ingestion rate for the construction worker exposed to groundwater in the excavation pit (0.01L per hour) is less than that suggested for recreational activities (0.05 L per hour) in Section 2 of this memorandum and in the aforementioned December 2002 Technical Memorandum because of the nature of receptor activities. Although relatively constant, direct contact with surface water (and thus incidental ingestion of surface water) while swimming is very likely; constant, direct contact with the shallow groundwater in an excavation pit is very unlikely.
- The construction worker is not anticipated to be exposed to the groundwater in the excavation pit on a daily basis. As indicated in the preceding bullets, it was assumed that exposure would occur *occasionally only* as work tasks require the construction worker to enter the excavation pit. Please note that the 150 days per year exposure frequency is the exposure frequency typically assumed for construction worker exposure to both groundwater and soils for PNS risk assessments conducted in the recent past.

The 2 ug/dL baseline adult blood level selected to compute the screening level for the construction worker is within the summary default parameter value range presented in the January 2003 version of the *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil (OSWER Directive #9285.7-54)*. More importantly, the value is in agreement with data presented for the Northeast Region of the United States in the USEPA document titled, *Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from the Phases 1 and 2 of the National Health and Nutrition Evaluation Survey (NHANES III)* (OSWER #9285.7-52, March 2002, Tables 3a and 3c).

Calculation of Construction Worker Screening Level for Incidental Ingestion of Lead in Water:

$$\text{Screening Level (iw)} = \frac{([10\text{ug/dL}/(0.9 \cdot (2.0^{1.645}))] - 2.0 \text{ ug/dL}) \cdot 365 \text{ days/yr}}{0.4 \text{ ug/dL per ug/day} \cdot (0.02\text{L/day} \cdot 0.6 \cdot 150 \text{ days/yr})}$$

$$\text{Screening Level (iw)} = 800 \text{ ug/L}$$

Equation for Calculating a Construction Worker Screening Level Based on Dermal Contact with Lead in Water:

$$\text{Screening Level (dw)} = \frac{([\text{PbB}_{95\text{fetal}}/(\text{R} \cdot (\text{GSD}_i^{1.645}))] - \text{PbB}_0) \cdot \text{AT}_w}{\text{BKSF} \cdot (\text{Kp} \cdot \text{ET} \cdot \text{CF} \cdot \text{A} \cdot \text{EF}_{\text{constw}})}$$

where:

$\text{PbB}_{\text{fetal}, 0.95}$	95 <sup>th</sup> percentile blood lead concentration (PbB) in fetus (Goal is 10 ug/dL)
$\text{R}_{\text{fetal/maternal}}$	Fetal/maternal PbB ratio = 0.9
BKSF	Biokinetic Slope Factor = 0.4 ug/dL per ug/day
$\text{GSD}_i$	Geometric standard deviation PbB = 2
$\text{PbB}_0$	Baseline PbB = 2 ug/dL
Kp	permeability coefficient = 0.0001 cm/hour
ET	Exposure Time = 2 hr/day
CF	conversion factor (0.001 L/cm <sup>3</sup> )
A	skin surface area available for contact = 3,300 cm <sup>2</sup>
$\text{EF}_{\text{constw}}$	Exposure frequency for construction workers = 150 days/yr
$\text{AT}_w$	Averaging time for exposure to water = 365 days/yr

Most of the exposure factors values presented above are default values presented in the ALM model or were defined in the preceding evaluation of the ingestion route of exposure. The skin surface available for contact (3,300 cm<sup>2</sup>) is the recommended value presented in the current version of *USEPA RAGS Part E, Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplemental Guidance for Dermal Risk Assessment*, for the evaluation of worker exposure to soils (USEPA, July 2004).

Calculation of Construction Worker Screening Level for Dermal Contact with Lead in Water:

$$\text{Screening Level (dw)} = \frac{([10\text{ug/dL}/(0.9 \cdot (2.0^{1.645}))] - 2.0 \text{ ug/dL}) \cdot 365 \text{ days/yr}}{0.4\text{ug/dL/ug/day} \cdot (0.0001\text{cm/hr} \cdot 2\text{hr/day} \cdot 0.001\text{L/cm}^3 \cdot 3,300\text{cm}^2 \cdot 150 \text{ days/yr})}$$

$$\text{Screening Level (dw)} = 14,500 \text{ ug/L}$$

The preceding calculations and screening levels suggest that receptor intake for the ingestion route of exposure is greater than receptor intake for the dermal contact route of exposure by a factor of approximately 18. A screening level derived assuming receptor contact by *both* the ingestion and dermal routes of exposure would be approximately 750 ug/L (i.e., a screening level slightly less than the 800 ug/L value derived for the ingestion route of exposure). The calculation of the combined screening level is attached.

## 2.0 Approach No. 2.0. Derivation of a Screening level for Child Recreational User Exposed to Intertidal Surface Water, Based on the USEPA Integrated Exposure Uptake Biokinetic Model (IEUBK) for Lead in Children

A lead screening level for a child recreational user can be derived using the IEUBK model by use of the Model's Alternate Source Data option. The *Alternate Source Data option* allows the user to input lead concentrations from atypical sources (i.e., *alternative lead intakes* not addressed by the Model's main menu options). Examples include the direct ingestion of lead-based paint and the use of cosmetics or home remedies. In the case of PNS, the alternate source would be exposure to lead in river water or seep water by a child recreating in the intertidal area. The child (3 to 7 years of age) is expected to be exposed 4 hours/day, 26 days/year and to incidentally ingest 0.05 L of the saline water per hour. The exposure time (4 hours per day), exposure frequency (26 days per year), and incidental surface water ingestion rate (0.05 L per hour) factors used to develop the screening level for the recreational-type of exposure are those specified in the aforementioned *December 2002 Human Health Risk Screening Levels for Intertidal Surface Water and Sediment Technical Memorandum*. The exposure time/frequency factors suggested for this analysis and the State of Maine default exposure time/frequency factors for recreational activities (2.6 hours per day and 40 days per year) yield the same overall exposure time when receptor exposure is presented in terms of exposure hours per year (i.e., both sets of time factors yield 104 exposure hours per year).

Depending on the averaging time selected (i.e., 90 days, 180 days, and 365 days) the preceding recommended exposure factors yield screening levels that range from 300 to 700 ug/L as discussed below. The averaging time is the period over which exposure is averaged. (Dermal contact is not included in these calculations because the IEUBK model does not consider dermal contact.)

The *alternate lead intake value* input into the Model is calculated as follows:

Step 1. Calculate liters of surface water ingested per year.

$$0.05 \text{ L/hour} \times 4 \text{ hours/day} \times 26 \text{ days/year} = 5.2 \text{ L/year}$$

Step 2. Calculate the amount of lead ingested per year by assuming a range of possible lead concentrations. If the concentration of lead is assumed to be 300 ug/L, the amount of lead ingested is as follows:

$$5.2 \text{ L/year} \times 300 \text{ ug/L} = 1,560 \text{ ug/year}$$

Step 3. Calculate the amount of lead ingested per day (the Model requires that the units of Alternate Source Data variable have units of ug/day). This value is calculated by dividing the amount ingested per year by an averaging time. Assumptions concerning averaging time (the period over which exposure is averaged) can vary. A typical averaging time used for lead is 365 days, as shown in Section 3. If 365 days is selected as the averaging time, the alternate lead intake value is:

$$1,560 \text{ ug/year} / 365 \text{ days/year} = 4.3 \text{ ug/day}$$

Assuming a shorter averaging time would increase the intake value. For example, if the exposure is assumed to occur during the summer months (as is assumed for the PNS recreational exposure scenario), the averaging time may be 90 days/year and the alternate lead intake value input value becomes:

$$1,560 \text{ ug/year} / 90 \text{ days/year} = 17 \text{ ug/day}$$

As demonstrated above, the shorter the averaging time, the larger the daily intake of lead, and, consequently, the smaller the screening level. The effects of averaging time on the value of the screening level are presented in Section 5.0. It should be noted that 180 and 365 days per year averaging times were included in this analysis for purposes of discussion only. As indicated in Section 6, the 90-day averaging time is the basis for the screening level recommended for the recreational user in this technical memorandum because the 90-day averaging time frame most likely reflects how exposure may occur at PNS (i.e., most recreational exposures involving direct contact with surface waters are likely to occur in the warm summer months).

The **lead screening level** for a child recreational user's exposure to intertidal surface water is calculated as follows:

Step 1. Enter the alternate lead intake value into the Model and run the Model.

Step 2. Check the Model output to see whether the projected child blood lead level is less than the USEPA goal of 10 ug/dL and the probability of exceeding 10 ug/dL is less than the USEPA goal of 5 percent. Determining the final screening level is a trial and error process which requires several repetitions of process outlined above. First, an intertidal surface water concentration must be assumed and a daily intake be derived, as shown above. The daily intake is then entered in the Alternate Source Option menu, the Model run, and the output is compared to the USEPA benchmarks. If the projected blood lead levels or probabilities are not acceptable, a different intertidal surface water concentration is assumed and the process is repeated. The repetitions are continued until acceptable blood lead levels and probabilities are predicted by the model. The intertidal surface water concentration which generates acceptable results is selected as the recommended screening level.

The intertidal surface water screening level developed by this approach has the advantage of being derived directly from the IEUBK model and site-specific assumptions. All of the model's default background levels are used. Thus, background contributions from air, soil, drinking water, diet, and maternal contributions are considered and reflected in the alternate water screening level. In addition, the screening level is not based on sources and extrapolations which may not be completely defensible.

Although the screening level is specific to the child recreational user, it would also be protective of dermal contact by a construction worker, because dermal contact with lead in water is not likely to be an important exposure route due to the low permeabilities of lead from water.

## 5.0 Uncertainty Analysis

The screening levels presented in this technical memorandum are subject various sources of uncertainty, including the following:

- *The screening level calculated for the recreational receptor did not consider exposures incurred by very young children (i.e., 0 to 3 year old children).* However, exposure to very young children is likely to be very limited because of the physical nature of much of the shoreline and intertidal areas at PNS. In many areas, the shoreline at the facility is

rocky and would be physically hazardous for very young children; very young children would rarely play unsupervised along this type of shoreline due to safety considerations. The mudflat areas of the shoreline are also not conducive to recreational activities or not safe for very young children. Consequently, exposure time and exposure frequency for the very young child are anticipated to be very limited when compared to the older-child age group (3 to 7 years old) considered for the development of the screening level for recreational user. Because of the anticipated significant differences in exposure times and frequencies, the screening level derived for the 3 to 7 year older child would be protective for the very young child who, on a rare occasion, might walk/crawl in the intertidal area of the PNS.

- *The screening levels presented in this memorandum are based on the USEPA's goal of controlling lead exposure in children/fetuses so that no more than 5 percent of receptors experience a blood lead level exceeding 10 ug/dL. However, all health-based goals, standards, or criteria are subject to change over time as new toxicity information becomes available. The toxicity of lead continues to be actively investigated by the scientific and regulatory community and is the subject of much debate. Both USEPA and State of Maine goals regarding lead exposure may change in the future as more definitive toxicity information becomes available for lead.*
- *Standard exposure factors guidelines and recommendations (e.g., recommendations for appropriate exposure frequencies) are limited for the risk evaluation/screening level development for the recreational land use scenario. A consideration of site-specific conditions and professional judgment is often necessary in the determination of appropriate exposure factors. For example, the screening levels presented in this technical memorandum for the recreational user assume that the receptor is exposed two days per week during the warm weather months (i.e., 26 days over the course of the summer [90 days]). This assumption is based on climatic conditions for the northeast region of the United States and on the fact that much of the shoreline at PNS is not attractive for recreational use. The recommended screening levels would be lower if it was assumed that exposure were to occur more frequently. However, assuming that lead concentrations in the surface water equal the recommended screening level for the recreational user (300 ug/L), lead intakes predicted for the recreational user would only exceed the lead intake associated with routine domestic use of a water supply containing 15 ug/L if it were assumed that the recreational receptor were exposed four days per week during the warm weather months.*

## **6.0 Summary and Recommendations**

This technical memorandum presents the approaches used to develop aqueous lead screening levels for recreational users and construction workers to use in assessing potential human health risks from lead at PNS IRP sites which have brackish/saline groundwater and the intertidal surface water is saline. The methods involved the use of the USEPA Adult or Child Lead Models. Screening levels developed by the approaches are presented in the following table. The Navy recommends the lead screening level based on the 90-day averaging time (300 ug/L) for the recreational user because the 90-day averaging time frame most likely reflects how exposure may occur at PNS (i.e., most recreational exposures involving direct contact with surface waters are likely to occur in the warm summer months). The aqueous lead screening level recommended for construction worker exposure is 750 ug/L.

**SUMMARY OF POTENTIAL LEAD SCREENING LEVELS**

<b>Approach 1 – Calculation of Screening Levels for Construction Workers Using Equations and Input Parameters from the Adult Lead Model (ALM)</b>		
Incidental Ingestion	Dermal Contact	Incidental Ingestion plus Dermal Contact
800 ug/L	14,500 ug/L	750 ug/L
<b>Approach 2 – Calculation of Screening Levels for Incidental Ingestion of Water by Child Recreational Users Using the Child Lead Model (IEUBK)</b>		
Averaging time of 90 days	Averaging time of 180 days	Averaging time of 365 days
300 ug/L	500 ug/L	700 ug/L

**References**

Agency for Toxic Substances and Disease Registry (ATSDR), accessed on-line March 2004. Toxicological Profile for Lead, U.S. Department of Health and Human Services, Public Health Services (<http://www.atsdr.cdc.gov/toxpro2.html>).

USEPA, July 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual ( Part E, Supplemental Guidance for Dermal Risk Assessment) Final, EPA/540/R/99/005, OSWER 9285.7-02EP, PB99-963312.

USEPA, March 2002. Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from the Phases 1 and 2 of the National Health and Nutrition Evaluation Survey (NHANES III) (OSWER #9285.7-52).

## Attachments

Check Calculation for Screening Level for Construction Worker.

Responses to Comments on the Technical Memorandum on Derivation of Aqueous Lead Screening Levels, Portsmouth Naval Shipyard (PNS), Kittery, Maine.

Conference Call Notes from the February 3, 2005 Discussion of the Technical Memorandum on Derivation of Aqueous Lead Screening Levels, Portsmouth Naval Shipyard (PNS), Kittery, Maine.

Responses to Follow-up Comments on the Technical Memorandum on Derivation of Aqueous Lead Screening Levels, Portsmouth Naval Shipyard, Kittery, Maine.

**ATTACHMENT 2**

**CALCULATION WORKSHEETS FOR CONSTRUCTION WORKER  
GROUNDWATER SCREENING LEVELS**

**SUMMARY TABLE**

**SCREENING LEVELS FOR INGESTION OF AND DERMAL CONTACT WITH GROUNDWATER  
CONSTRUCTION WORKER EXPOSURE - INORGANICS  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**

Parameter	RBC (noncancer)	RBC (cancer)	RBC (lower)	Adjusted RBC <sup>(1)</sup>	
	mg/L	mg/L	µg/L		
Aluminum	1.15E+04	NA	11500000	n	1150000 n
Antimony	1.38E+00	NA	1380	n	138 n
Arsenic	3.45E+00	5.36E-01	536	c	345 n <sup>(2)</sup>
Barium	3.57E+02	NA	357000	n	35700 n
Beryllium	9.72E-01	NA	972	n	97.2 n
Cadmium	6.54E-01	NA	654	n	65.4 n
Chromium <sup>(3)</sup>	2.71E+02	NA	271000	n	27100 n
Cobalt	4.57E+01	NA	45700	n	4570 n
Copper	4.60E+02	NA	460000	n	46000 n
Iron	8.04E+03	NA	8040000	n	804000 n
Manganese	2.55E+01	NA	25500	n	2550 n
Mercury <sup>(4)</sup>	3.57E+00	NA	3570	n	357 n
Nickel	8.71E+01	NA	87100	n	8710 n
Selenium	5.75E+01	NA	57500	n	5750 n
Silver	8.53E+00	NA	8530	n	853 n
Thallium <sup>(5)</sup>	4.60E-01	NA	460	n	46.0 n
Vanadium	7.03E+00	NA	7030	n	703 n
Zinc	4.12E+03	NA	4120000	n	412000 n
Hexavalent Chromium	2.45E+01	1.14E+00	1140	c	1140 c
Nitrate	3.11E+04	NA	31100000	n	3110000 n
Cyanide	1.17E+01	NA	11700	n	1170 n

1 - The adjusted RBC is the lower of noncarcinogenic and carcinogenic RBCs with RBCs for noncarcinogens divided by 10 to represent a hazard quotient of 0.1. RBCs for carcinogens are not adjusted and represent an incremental lifetime cancer risk of 1x10<sup>-6</sup>.

2 - One-tenth the noncarcinogenic RBC is less than the carcinogenic RBC; therefore, the noncarcinogenic RBC is presented.

3 - Values are for trivalent chromium.

4 - Values are for mercuric chloride.

5 - Toxicity criterion used is only suitable for screening and is not to be used for quantifying risks.

NA = Not applicable

RBC = Risk-based concentration

**VALUES USED FOR DAILY INTAKE CALCULATIONS**  
**INGESTION AND DERMAL EXPOSURES OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Future Medium: Groundwater Exposure Medium: Groundwater Receptor Population: Construction Worker Receptor Age: Adult
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Exposure Route	Parameter Code	Parameter Definition	Units	Values	Intake Equation/ Model Name
<b>Ingestion</b>	CGW	Chemical Concentration in Groundwater	ug/L		Ingestion Dose (mg/kg/day) = $\frac{C_{water} \times IwR \times CF \times EF \times EV \times ED}{BW \times AT}$ USEPA, December 1989
	CF	Conversion Factor	mg/ug	0.001	
	IwR	Ingestion Rate of Groundwater	L/day	0.01	
	EF	Exposure Frequency	days/year	150	
	ED	Exposure Duration	years	1	
	BW	Body Weight	kg	80	
	AT-C	Averaging Time (Cancer)	days	25550	
	AT-N	Averaging Time (Non-Cancer)	days	365	
<b>Dermal Contact</b>	Cwater	Chemical Concentration in Water	mg/L		The equations and parameters for estimating DAevent and the chemical-specific dermally absorbed dose from water (DAD) are provided in USEPA, July 2004.
	A	Skin Surface Area Available for Contact	cm <sup>2</sup>	3,470	
	DAevent	Absorbed Dose per Event	mg/cm <sup>2</sup> -event	chemical-specific	
	EV	Event Frequency	event/day	1	
	ED	Exposure Duration	years	1	
	EF	Exposure Frequency	days/year	150	
	t <sub>event</sub>	Duration of Event	hour/event	2.0	
	t*	Time to reach steady state	hour/event	chemical-specific	
	T	Lag Time	hour/event	chemical-specific	
	B	Bunge Model Constant	dimensionless	chemical-specific	
	Kp	Permeability Coefficient from Water	cm/hour	chemical-specific	
	BW	Body Weight	kg	80	
	AT-C	Averaging Time (Cancer)	days	25,550	
	AT-N	Averaging Time (Non-Cancer)	days	365	

**Daily Intake Calculations**

$$\text{Ingestion Intake} = (IwR \times CF \times EF \times ED) / (BW \times AT)$$

$$\text{Dermal Intake} = (A \times EV \times ED \times EF) / (BW \times AT)$$

$$\begin{aligned} \text{Cancer Ingestion Intake(RME)} &= 7.34\text{E-}10 \\ \text{Noncancer Ingestion Intake(RME)} &= 5.14\text{E-}08 \end{aligned}$$

$$\begin{aligned} \text{Cancer Dermal Intake(RME)} &= 2.55\text{E-}01 \\ \text{Noncancer Dermal Intake(RME)} &= 1.78\text{E+}01 \end{aligned}$$

**CALCULATION OF DAevent - EXPOSURES THROUGH DERMAL CONTACT WITH WATER  
EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

REFERENCES: USEPA, July 2004

<p><b>DERMAL CONTACT:</b>  DAD = (DAevent x EV x ED x EF x A)/(BW x AT)  WHERE:  DAD = DERMALLY ABSORBED DOSE (MG/KG/DAY)  DAevent = ABSORBED DOSE PER EVENT (MG/CM<sup>2</sup>/EVENT)  A = SKIN SURFACE AREA AVAILABLE FOR CONTACT(CM<sup>2</sup>)  EV = EVENT FREQUENCY (EVENTS/DAY)  ED = EXPOSURE DURATION (YEARS)  EF = EXPOSURE FREQUENCY (DAYS/YEAR)  BW = BODY WEIGHT(KG)  AT = AVERAGING TIME (DAYS)</p>	<p>FOR INORGANICS: DAevent = Kp x C x tevent x CF  FOR ORGANICS: IF tevent &lt; t*, DAevent = 2 x FA x Kp x C x CF x (6T x tevent/3.141592654)<sup>0.5</sup>  IF tevent &gt; t*, DAevent = FA x Kp x C x CF x ((tevent/(1 + B)) + (2T x ((1+3B+3B<sup>2</sup>)/(1 + B)<sup>3</sup>)))</p> <p>WHERE: Kp = PERMEABILITY COEFFICIENT FROM WATER (CM/HR)  Cwater = CONCENTRATION OF CHEMICAL IN WATER (MG/L)  tevent = DURATION OF EVENT (HR/EVENT)  CF = CONVERSION FACTOR (1L/1000 CM<sup>3</sup>)  t* = TIME IT TAKES TO REACH STEADY-STATE (HOUR/EVENT)  T = LAG TIME (HOUR/EVENT)  B = BUNGE MODEL CONSTANT (DIMENSIONLESS)  FA = FRACTION ABSORBED WATER (DIMENSIONLESS)</p>
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CHEMICAL	Cwater (mg/L)	ORGANIC OR INORGANIC?	t* (HR)	tevent	T (HR)	Kp (CM/HR)	B	FA	DAevent
Aluminum	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Antimony	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Arsenic	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Barium	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Beryllium	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Cadmium	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Chromium <sup>(1)</sup>	1.00E-03	i	NA	2.00E+00	NA	2.00E-03	NA	1.00E+00	4.00E-09
Cobalt	1.00E-03	i	NA	2.00E+00	NA	4.00E-04	NA	1.00E+00	8.00E-10
Copper	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Iron	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Manganese	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Mercury <sup>(2)</sup>	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Nickel	1.00E-03	i	NA	2.00E+00	NA	2.00E-04	NA	1.00E+00	4.00E-10
Selenium	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Silver	1.00E-03	i	NA	2.00E+00	NA	6.00E-04	NA	1.00E+00	1.20E-09
Thallium	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Vanadium	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09
Zinc	1.00E-03	i	NA	2.00E+00	NA	6.00E-04	NA	1.00E+00	1.20E-09
Hexavalent Chromium	1.00E-03	i	NA	2.00E+00	NA	2.00E-03	NA	1.00E+00	4.00E-09
Nitrate	1.00E-03	i	NA	2.00E+00	NA	1.00E-04	NA	1.00E+00	2.00E-10
Cyanide	1.00E-03	i	NA	2.00E+00	NA	1.00E-03	NA	1.00E+00	2.00E-09

1 - Values are for trivalent chromium.

2 - Values are for mercuric chloride.

**CALCULATION OF SCREENING LEVELS BASED ON NONCARCINOGENIC EFFECTS  
INGESTION AND DERMAL EXPOSURES OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Future Medium: Groundwater Exposure Medium: Groundwater Receptor Population: Construction Worker Receptor Age: Adult
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Exposure Route	Chemical of Potential Concern	Assumed Water Concentration	Intake (Non-Cancer) <sup>(4)</sup>	Reference Dose <sup>(5)</sup>	Hazard Quotient Based on Assumed Water Concentration	Calculated RBC (noncancer)	Calculated RBC (noncancer)
		mg/L	mg/kg-day	mg/kg-day		mg/L	µg/L
Ingestion	Aluminum	1.00E-03	5.14E-08	1.00E+00	5.1E-08	1.9E+04	1.9E+07
	Antimony	1.00E-03	5.14E-08	4.00E-04	1.3E-04	7.8E+00	7.8E+03
	Arsenic	1.00E-03	5.14E-08	3.00E-04	1.7E-04	5.8E+00	5.8E+03
	Barium	1.00E-03	5.14E-08	2.00E-01	2.6E-07	3.9E+03	3.9E+06
	Beryllium	1.00E-03	5.14E-08	5.00E-03	1.0E-05	9.7E+01	9.7E+04
	Cadmium	1.00E-03	5.14E-08	5.00E-04	1.0E-04	9.7E+00	9.7E+03
	Chromium <sup>(1)</sup>	1.00E-03	5.14E-08	1.50E+00	3.4E-08	2.9E+04	2.9E+07
	Cobalt	1.00E-03	5.14E-08	3.00E-03	1.7E-05	5.8E+01	5.8E+04
	Copper	1.00E-03	5.14E-08	4.00E-02	1.3E-06	7.8E+02	7.8E+05
	Iron	1.00E-03	5.14E-08	7.00E-01	7.3E-08	1.4E+04	1.4E+07
	Manganese	1.00E-03	5.14E-08	2.40E-02	2.1E-06	4.7E+02	4.7E+05
	Mercury <sup>(2)</sup>	1.00E-03	5.14E-08	2.00E-03	2.6E-05	3.9E+01	3.9E+04
	Nickel	1.00E-03	5.14E-08	2.00E-02	2.6E-06	3.9E+02	3.9E+05
	Selenium	1.00E-03	5.14E-08	5.00E-03	1.0E-05	9.7E+01	9.7E+04
	Silver	1.00E-03	5.14E-08	5.00E-03	1.0E-05	9.7E+01	9.7E+04
	Thallium <sup>(3)</sup>	1.00E-03	5.14E-08	4.00E-05	1.3E-03	7.8E-01	7.8E+02
	Vanadium	1.00E-03	5.14E-08	1.00E-02	5.1E-06	1.9E+02	1.9E+05
	Zinc	1.00E-03	5.14E-08	3.00E-01	1.7E-07	5.8E+03	5.8E+06
	Hexavalent Chromium	1.00E-03	5.14E-08	3.00E-03	1.7E-05	5.8E+01	5.8E+04
	Nitrate	1.00E-03	5.14E-08	1.60E+00	3.2E-08	3.1E+04	3.1E+07
Cyanide	1.00E-03	5.14E-08	6.00E-04	8.6E-05	1.2E+01	1.2E+04	
Dermal Contact	Aluminum	1.00E-03	3.6E-08	1.00E+00	3.6E-08	2.8E+04	2.8E+07
	Antimony	1.00E-03	3.6E-08	6.00E-05	5.9E-04	1.7E+00	1.7E+03
	Arsenic	1.00E-03	3.6E-08	3.00E-04	1.2E-04	8.4E+00	8.4E+03
	Barium	1.00E-03	3.6E-08	1.40E-02	2.5E-06	3.9E+02	3.9E+05
	Beryllium	1.00E-03	3.6E-08	3.50E-05	1.0E-03	9.8E-01	9.8E+02
	Cadmium	1.00E-03	3.6E-08	2.50E-05	1.4E-03	7.0E-01	7.0E+02
	Chromium <sup>(1)</sup>	1.00E-03	7.1E-08	1.95E-02	3.7E-06	2.7E+02	2.7E+05
	Cobalt	1.00E-03	1.4E-08	3.00E-03	4.8E-06	2.1E+02	2.1E+05
	Copper	1.00E-03	3.6E-08	4.00E-02	8.9E-07	1.1E+03	1.1E+06
	Iron	1.00E-03	3.6E-08	7.00E-01	5.1E-08	2.0E+04	2.0E+07
	Manganese	1.00E-03	3.6E-08	9.60E-04	3.7E-05	2.7E+01	2.7E+04
	Mercury <sup>(2)</sup>	1.00E-03	3.6E-08	1.40E-04	2.5E-04	3.9E+00	3.9E+03
	Nickel	1.00E-03	7.1E-09	8.00E-04	8.9E-06	1.1E+02	1.1E+05
	Selenium	1.00E-03	3.6E-08	5.00E-03	7.1E-06	1.4E+02	1.4E+05
	Silver	1.00E-03	2.1E-08	2.00E-04	1.1E-04	9.3E+00	9.3E+03
	Thallium <sup>(3)</sup>	1.00E-03	3.6E-08	4.00E-05	8.9E-04	1.1E+00	1.1E+03
	Vanadium	1.00E-03	3.6E-08	2.60E-04	1.4E-04	7.3E+00	7.3E+03
	Zinc	1.00E-03	2.1E-08	3.00E-01	7.1E-08	1.4E+04	1.4E+07
	Hexavalent Chromium	1.00E-03	7.1E-08	3.00E-03	2.4E-05	4.2E+01	4.2E+04
	Nitrate	1.00E-03	3.6E-09	1.60E+00	2.2E-09	4.5E+05	4.5E+08
Cyanide	1.00E-03	3.6E-08	2.00E-02	1.8E-06	5.6E+02	5.6E+05	

1 - Values are for trivalent chromium.

2 - Values are for mercuric chloride.

3 - Toxicity criterion used is only suitable for screening and is not to be used for quantifying risks.

4 - For ingestion, Intake = Ingestion Intake; for dermal contact, Intake = Dermal Intake x DAevent.

5 - Subchronic reference doses were presented if available. If no subchronic reference dose was available, the chronic reference dose is presented.

**CALCULATION OF SCREENING LEVELS BASED ON 1.0E-06 CANCER RISKS  
INGESTION AND DERMAL EXPOSURES OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value mg/L	Intake (Cancer) <sup>(3)</sup> mg/kg-day	Cancer Slope Factor (mg/kg-day) <sup>-1</sup>	Incremental Lifetime Cancer Risk Based on Assumed Water Concentration	Calculated RBC (cancer) mg/L	Calculated RBC (cancer) µg/L
Ingestion	Aluminum	1.00E-03	7.3E-10	NA	NA	NA	NA
	Antimony	1.00E-03	7.3E-10	NA	NA	NA	NA
	Arsenic	1.00E-03	7.3E-10	1.50E+00	1.10E-09	9.1E-01	9.1E+02
	Barium	1.00E-03	7.3E-10	NA	NA	NA	NA
	Beryllium	1.00E-03	7.3E-10	NA	NA	NA	NA
	Cadmium	1.00E-03	7.3E-10	NA	NA	NA	NA
	Chromium <sup>(1)</sup>	1.00E-03	7.3E-10	NA	NA	NA	NA
	Cobalt	1.00E-03	7.3E-10	NA	NA	NA	NA
	Copper	1.00E-03	7.3E-10	NA	NA	NA	NA
	Iron	1.00E-03	7.3E-10	NA	NA	NA	NA
	Manganese	1.00E-03	7.3E-10	NA	NA	NA	NA
	Mercury <sup>(2)</sup>	1.00E-03	7.3E-10	NA	NA	NA	NA
	Nickel	1.00E-03	7.3E-10	NA	NA	NA	NA
	Selenium	1.00E-03	7.3E-10	NA	NA	NA	NA
	Silver	1.00E-03	7.3E-10	NA	NA	NA	NA
	Thallium	1.00E-03	7.3E-10	NA	NA	NA	NA
	Vanadium	1.00E-03	7.3E-10	NA	NA	NA	NA
	Zinc	1.00E-03	7.3E-10	NA	NA	NA	NA
	Hexavalent Chromium	1.00E-03	7.3E-10	5.00E-01	3.67E-10	2.7E+00	2.7E+03
	Nitrate	1.00E-03	7.3E-10	NA	NA	NA	NA
Cyanide	1.00E-03	7.3E-10	NA	NA	NA	NA	
Dermal Contact	Aluminum	1.00E-03	5.1E-10	NA	NA	NA	NA
	Antimony	1.00E-03	5.1E-10	NA	NA	NA	NA
	Arsenic	1.00E-03	5.1E-10	1.50E+00	7.64E-10	1.3E+00	1.3E+03
	Barium	1.00E-03	5.1E-10	NA	NA	NA	NA
	Beryllium	1.00E-03	5.1E-10	NA	NA	NA	NA
	Cadmium	1.00E-03	5.1E-10	NA	NA	NA	NA
	Chromium <sup>(1)</sup>	1.00E-03	1.0E-09	NA	NA	NA	NA
	Cobalt	1.00E-03	2.0E-10	NA	NA	NA	NA
	Copper	1.00E-03	5.1E-10	NA	NA	NA	NA
	Iron	1.00E-03	5.1E-10	NA	NA	NA	NA
	Manganese	1.00E-03	5.1E-10	NA	NA	NA	NA
	Mercury <sup>(2)</sup>	1.00E-03	5.1E-10	NA	NA	NA	NA
	Nickel	1.00E-03	1.0E-10	NA	NA	NA	NA
	Selenium	1.00E-03	5.1E-10	NA	NA	NA	NA
	Silver	1.00E-03	3.1E-10	NA	NA	NA	NA
	Thallium	1.00E-03	5.1E-10	NA	NA	NA	NA
	Vanadium	1.00E-03	5.1E-10	NA	NA	NA	NA
	Zinc	1.00E-03	3.1E-10	NA	NA	NA	NA
	Hexavalent Chromium	1.00E-03	1.0E-09	5.00E-01	5.09E-10	2.0E+00	2.0E+03
	Nitrate	1.00E-03	5.1E-11	NA	NA	NA	NA
Cyanide	1.00E-03	5.1E-10	NA	NA	NA	NA	

1 - Values are for trivalent chromium.

2 - Values are for mercuric chloride.

3 - For ingestion, Intake = Ingestion Intake; for dermal contact, Intake = Dermal Intake x DAevent.

**SUMMARY TABLE**

**SCREENING LEVELS FOR INGESTION OF AND DERMAL CONTACT WITH GROUNDWATER  
CONSTRUCTION WORKER EXPOSURE - ORGANICS  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE  
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Parameter	RBC (noncancer)	RBC (cancer)	RBC (lower)	Adjusted RBC <sup>(1)</sup>	
	mg/L	mg/L	µg/L		
4,4'-DDD	NA <sup>(2)</sup>	9.04E-03	9.04	c	9.04 c
4,4'-DDE	NA <sup>(2)</sup>	4.01E+00	4010	c	4010 c
4,4'-DDT	9.73E+00	4.01E+00	4010	c	973 n <sup>(4)</sup>
Aldrin	7.79E-01	8.02E-02	80.2	c	77.9 n <sup>(4)</sup>
alpha-Chlordane	6.53E-02	2.61E-02	26.1	c	6.53 n <sup>(4)</sup>
Dieldrin	3.76E-02	1.65E-03	1.65	c	1.65 c
Endrin	7.53E-01	NA <sup>(3)</sup>	753	n	75.3 n
gamma-BHC (Lindane)	6.66E-03	4.24E-02	6.66	n	0.666 n
gamma-Chlordane	6.53E-02	2.61E-02	26.1	c	6.53 n <sup>(4)</sup>
Heptachlor	5.54E-02	8.61E-03	8.61	c	5.54 n <sup>(4)</sup>
PCB-hexachlorobiphenyl <sup>(5)</sup>	NA <sup>(2)</sup>	3.09E-03	3.09	c	3.09 c
1,2,4-Trichlorobenzene	1.83E+01	4.91E-01	491	c	491 c
1,2-Dichlorobenzene	2.37E+02	NA <sup>(3)</sup>	237000	n	23700 n
1,3-Dichlorobenzene	5.68E+00	3.68E+00	3680	c	568 n <sup>(4)</sup>
1,4-Dichlorobenzene	2.72E+01	5.05E+00	5050	c	2720 n <sup>(4)</sup>
2,4,6-Trichlorophenol	3.49E-01	2.22E+00	349	n	34.9 n
2,4-Dichlorophenol	1.44E+01	NA <sup>(3)</sup>	14400	n	1440 n
2,4-Dimethylphenol	7.90E+01	NA <sup>(3)</sup>	79000	n	7900 n
2,4-Dinitrophenol	1.21E+02	NA <sup>(3)</sup>	121000	n	12100 n
2,4-Dinitrotoluene	7.18E+00	8.11E-01	811	c	718 n <sup>(4)</sup>
2,6-Dinitrotoluene	1.47E+01	2.29E-01	229	c	229 c
2-Chlorophenol	1.63E+01	NA <sup>(3)</sup>	16300	n	1630 n
2-Ethoxy ethanol(Cellosolve)	1.95E+03	NA <sup>(3)</sup>	1950000	n	195000 n
2-Nitrophenol	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>		NA <sup>(2,3)</sup>
3-Nitrophenol	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>		NA <sup>(2,3)</sup>
4-Chlorophenol	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>		NA <sup>(2,3)</sup>
4-Nitrophenol	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>		NA <sup>(2,3)</sup>
Acetaldehyde	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>		NA <sup>(2,3)</sup>
BaPEQ	NA <sup>(2)</sup>	1.87E-01	187	c	187 c
Benzo(a)anthracene	NA <sup>(2)</sup>	1.87E+00	1870	c	1870 c
Benzo(a)pyrene	NA <sup>(2)</sup>	1.87E-01	187	c	187 c
Benzo(b)fluoranthene	NA <sup>(2)</sup>	1.87E+00	1870	c	1870 c
Benzoic acid	1.13E+04	NA <sup>(3)</sup>	11300000	n	1130000 n
Benzyl chloride	3.27E+00	6.74E-01	674	c	327 n <sup>(4)</sup>
Bis(2-chloroethyl)ether	NA <sup>(2)</sup>	4.04E-01	404	c	404 c
Chrysene	NA <sup>(2)</sup>	1.87E+02	187000	c	187000 c
Dibenzo(a,h)anthracene	NA <sup>(2)</sup>	1.87E-01	187	c	187 c
Dibutyl phthalate	3.33E+02	NA <sup>(3)</sup>	333000	n	33300 n
Dichlorobenzidine, 3,3'	NA <sup>(2)</sup>	1.01E-01	101	c	101 c
Diethyl phthalate	1.42E+04	NA <sup>(3)</sup>	14200000	n	1420000 n
Dioxane, 1,4-	7.45E+03	1.04E+01	10400	c	10400 c
Fluoranthene	7.79E+03	NA <sup>(3)</sup>	7790000	n	779000 n
Hexachlorobenzene	5.80E-04	2.54E-03	0.580	n	0.0580 n

**SUMMARY TABLE**

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CONSTRUCTION WORKER EXPOSURE - ORGANICS  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE  
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Parameter	RBC (noncancer)	RBC (cancer)	RBC (lower)	Adjusted RBC <sup>(1)</sup>
	mg/L	mg/L	µg/L	
Hexachlorobutadiene	1.11E-01	1.00E-01	100.0 c	11.1 n <sup>(4)</sup>
Hexachloroethane	3.12E+00	5.46E-01	546 c	312 n <sup>(4)</sup>
Indeno(1,2,3-CD)pyrene	NA <sup>(2)</sup>	1.87E+00	1870 c	1870 c
Isophorone	1.21E+04	2.97E+02	297000 c	297000 c
m-Cresol	1.13E+03	NA <sup>(3)</sup>	1130000 n	113000 n
Naphthalene	2.36E+02	NA <sup>(3)</sup>	236000 n	23600 n
o-Cresol	1.14E+03	NA <sup>(3)</sup>	1140000 n	114000 n
p-Cresol	4.57E+01	NA <sup>(3)</sup>	45700 n	4570 n
Pentachlorophenol	1.95E+01	3.41E+00	3410 c	1950 n <sup>(4)</sup>
Phenanthrene <sup>(7)</sup>	5.84E+02	NA <sup>(3)</sup>	584000 n	58400 n
Phenol	2.31E+03	NA <sup>(3)</sup>	2310000 n	231000 n
Phenol,4,6-dinitro-2-methyl-	2.61E+00	NA <sup>(3)</sup>	2610 n	261 n
TCDD	1.36E-05	1.05E-05	0.0105 c	0.00136 n <sup>(4)</sup>
1,1,1-Trichloroethane	9.20E+03	NA <sup>(3)</sup>	9200000 n	920000 n
1,1,2,2-Tetrachloroethane	9.66E+02	6.76E-01	676 c	676 c
1,1,2-Trichloroethane	9.63E+00	2.96E+00	2960 c	963 n <sup>(4)</sup>
1,1,2-Trichlorotrifluoroethane	2.22E+04	NA <sup>(3)</sup>	22200000 n	2220000 n
1,1-Dichloroethane	5.26E+03	3.23E+01	32300 c	32300 c
1,1-Dichloroethene	1.47E+01	NA <sup>(3)</sup>	14700 n	1470 n
1,2-Dichloroethane	7.79E+01	3.00E+00	3000 c	3000 c
1,2-Dichloropropane	1.55E+02	4.32E+00	4320 c	4320 c
2,2'-Oxybis(1-Chloropropane)	7.07E+01	1.77E+00	1770 c	1770 c
2,4,5-Trichlorophenol	1.03E+02	NA <sup>(3)</sup>	103000 n	10300 n
2-Butanone	2.11E+04	NA <sup>(3)</sup>	21100000 n	2110000 n
2-Chloronaphthalene	3.73E+01	NA <sup>(3)</sup>	37300 n	3730 n
2-Hexanone	2.22E+01	NA <sup>(3)</sup>	22200 n	2220 n
2-Methylnaphthalene	7.71E-01	NA <sup>(3)</sup>	771 n	77.1 n
2-Nitroaniline	3.25E+02	NA <sup>(3)</sup>	325000 n	32500 n
3-Nitroaniline	5.71E+00	NA <sup>(3)</sup>	5710 n	571 n
4-Bromophenyl Phenyl Ether	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>	NA <sup>(2,3)</sup>
4-Chloro-3-Methylphenol	5.81E+01	NA <sup>(3)</sup>	58100 n	5810 n
4-Chloroaniline	1.56E+00	1.09E+00	1090 c	156 n <sup>(4)</sup>
4-Chlorophenyl Phenyl Ether	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>	NA <sup>(2,3)</sup>
4-Methyl-2-Pentanone	4.39E+03	NA <sup>(3)</sup>	4390000 n	439000 n
4-Nitroaniline	5.59E+01	1.96E+01	19600 c	5590 n <sup>(4)</sup>
Acenaphthene	3.76E+01	NA <sup>(3)</sup>	37600 n	3760 n
Acenaphthylene <sup>(6)</sup>	3.60E+01	NA <sup>(3)</sup>	36000 n	3600 n
Acetone	2.70E+04	NA <sup>(3)</sup>	27000000 n	2700000 n
Alpha-BHC	2.65E+00	3.69E-03	3.69 c	3.69 c
Anthracene	1.01E+02	NA <sup>(3)</sup>	101000 n	10100 n
Aroclor-1016	1.36E+00	1.95E+01	1360 n	136 n
Aroclor-1221	NA <sup>(2)</sup>	3.36E-03	3.36 c	3.36 c
Aroclor-1232	NA <sup>(2)</sup>	3.36E-03	3.36 c	3.36 c

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CONSTRUCTION WORKER EXPOSURE - ORGANICS  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE  
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Parameter	RBC (noncancer)	RBC (cancer)	RBC (lower)	Adjusted RBC <sup>(1)</sup>
	mg/L	mg/L	µg/L	µg/L
Aroclor-1242	NA <sup>(2)</sup>	6.81E-01	681 c	681 c
Aroclor-1248	NA <sup>(2)</sup>	6.81E-01	681 c	681 c
Aroclor-1254	5.84E-01	6.81E-01	584 n	58.4 n
Aroclor-1260	NA <sup>(2)</sup>	6.81E-01	681 c	681 c
Benzene	1.39E+01	1.77E+00	1770 c	1390 n <sup>(4)</sup>
Benzo(g,h,i)perylene <sup>(7)</sup>	2.10E-01	NA <sup>(3)</sup>	210 n	21.0 n
Benzo(k)fluoranthene	NA <sup>(2)</sup>	1.87E+01	18700 c	18700 c
Beta-BHC	NA <sup>(2)</sup>	1.29E-02	12.9 c	12.9 c
Bis(2-Chloroethoxy)Methane	2.21E+02	NA <sup>(3)</sup>	221000 n	22100 n
Bis(2-Ethylhexyl)Phthalate	1.95E+03	9.73E+01	97300 c	97300 c
Bromodichloromethane	2.26E+01	3.19E+00	3190 c	2260 n <sup>(4)</sup>
Bromoform	9.59E+01	2.83E+01	28300 c	9590 n <sup>(4)</sup>
Bromomethane	2.65E+01	NA <sup>(3)</sup>	26500 n	2650 n
Butyl Benzyl Phthalate	3.14E+02	5.78E+00	5780 c	5780 c
Carbazole	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>	NA <sup>(2,3)</sup>
Carbon Disulfide	1.21E+02	NA <sup>(3)</sup>	121000 n	12100 n
Carbon Tetrachloride	6.50E+00	9.28E-01	928 c	650 n <sup>(4)</sup>
Chlorobenzene	4.78E+01	NA <sup>(3)</sup>	47800 n	4780 n
Chlorodibromomethane	2.10E+02	2.51E+00	2510 c	2510 c
Chloroethane	3.15E+02	NA <sup>(3)</sup>	315000 n	31500 n
Chloroform	2.42E+02	5.47E+00	5470 c	5470 c
Chloromethane	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>	NA <sup>(2,3)</sup>
Cis-1,3-Dichloropropene <sup>(8)</sup>	6.63E+01	1.55E+00	1550 c	1550 c
Delta-BHC <sup>(9)</sup>	2.65E+00	3.69E-03	3.69 c	3.69 c
Dibenzofuran	6.26E-01	NA <sup>(3)</sup>	626 n	62.6 n
Dimethyl Phthalate	NA <sup>(2)</sup>	NA <sup>(3)</sup>	NA <sup>(2,3)</sup>	NA <sup>(2,3)</sup>
Di-n-octyl Phthalate	1.56E-01	NA <sup>(3)</sup>	156 n	15.6 n
Endosulfan I <sup>(10)</sup>	9.63E+00	NA <sup>(3)</sup>	9630 n	963 n
Endosulfan II <sup>(10)</sup>	8.73E+00	NA <sup>(3)</sup>	8730 n	873 n
Endosulfan Sulfate <sup>(10)</sup>	4.54E+00	NA <sup>(3)</sup>	4540 n	454 n
Endrin Aldehyde <sup>(11)</sup>	1.78E+00	NA <sup>(3)</sup>	1780 n	178 n
Endrin Ketone <sup>(11)</sup>	4.10E-01	NA <sup>(3)</sup>	410 n	41.0 n
Ethylbenzene	4.17E+01	2.65E+00	2650 c	2650 c
Fluorene	5.65E+01	NA <sup>(3)</sup>	56500 n	5650 n
Heptachlor Epoxide	2.29E-03	1.35E-03	1.35 c	0.229 n <sup>(4)</sup>
Hexachlorocyclopentadiene	7.62E+00	NA <sup>(3)</sup>	7620 n	762 n
Methoxychlor	5.73E-01	NA <sup>(3)</sup>	573 n	57.3 n
Methylene Chloride	2.77E+02	1.61E+02	161000 c	27700 n <sup>(4)</sup>
Nitrobenzene	1.47E+01	NA <sup>(3)</sup>	14700 n	1470 n
N-Nitroso-di-n-Propylamine	NA <sup>(2)</sup>	5.50E-02	55.0 c	55.0 c
N-Nitrosodiphenylamine	NA <sup>(2)</sup>	1.15E+01	11500 c	11500 c
Pyrene	1.85E+01	NA <sup>(3)</sup>	18500 n	1850 n
Styrene	1.09E+02	NA <sup>(3)</sup>	109000 n	10900 n

**SUMMARY TABLE**

**SCREENING LEVELS FOR INGESTION OF AND DERMAL CONTACT WITH GROUNDWATER  
CONSTRUCTION WORKER EXPOSURE - ORGANICS  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE  
PAGE 4 OF 4**

Parameter	RBC (noncancer)	RBC (cancer)	RBC (lower)	Adjusted RBC <sup>(1)</sup>
	mg/L	mg/L	µg/L	
Tetrachloroethene	4.41E+01	1.47E+01	14700 c	4410 n <sup>(4)</sup>
Toluene	5.42E+02	NA <sup>(3)</sup>	542000 n	54200 n
Total 1,2-Dichloroethene	2.12E+01	NA <sup>(3)</sup>	21200 n	2120 n
Total Xylenes	1.78E+02	NA <sup>(3)</sup>	178000 n	17800 n
Toxaphene	NA <sup>(2)</sup>	2.00E-02	20.0 c	20.0 c
Trans-1,3-Dichloropropene <sup>(8)</sup>	6.63E+01	1.55E+00	1550 c	1550 c
Trichloroethene	7.15E-01	2.18E+00	715 n	71.5 n
Vinyl Chloride	1.01E+01	3.28E-01	328 c	328 c

1 - The adjusted RBC is the lower of noncarcinogenic and carcinogenic RBCs with RBCs for noncarcinogens divided by 10 to represent a hazard quotient of 0.1. RBCs for carcinogens are not adjusted and represent an incremental lifetime cancer risk of  $1 \times 10^{-6}$ .

2 - No reference dose is available.

3 - No cancer slope factor is available.

4 - One-tenth the noncarcinogenic RBC is less than the carcinogenic RBC; therefore, the noncarcinogenic RBC is presented.

5 - Toxicity values are for polychlorinated biphenyls - low risk.

6 - Toxicity values are for acenaphthene.

7 - Toxicity values are for pyrene.

8 - Toxicity values are for 1,3-dichloropropene.

9 - Toxicity values are for alpha-BHC.

10 - Toxicity values are for endosulfan.

11 - Toxicity values are for endrin.

NA = Not applicable

RBC = Risk-based concentration

**VALUES USED FOR DAILY INTAKE CALCULATIONS**  
**INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Water
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Parameter Code	Parameter Definition	Units	Values	Intake Equation/ Model Name
Ingestion	CGW	Chemical Concentration in Groundwater	ug/L		Ingestion Dose (mg/kg/day) = $\frac{C_{water} \times CF \times IwR \times EF \times ED}{BW \times AT}$ USEPA, December 1989
	CF	Conversion Factor	mg/ug	0.001	
	IwR	Ingestion Rate of Groundwater	L/day	0.01	
	EF	Exposure Frequency	days/year	150	
	ED	Exposure Duration	years	1	
	BW	Body Weight	kg	80	
	AT-C	Averaging Time (Cancer)	days	25550	
AT-N	Averaging Time (Non-Cancer)	days	365		
Dermal	Cwater	Chemical Concentration in Water	mg/L		The equations and parameters for estimating DAevent and the chemical-specific dermally absorbed dose from water (DAD) are provided in USEPA, September 2000.
	A	Skin Surface Area Available for Contact	cm <sup>2</sup>	3,470	
	DAevent	Absorbed Dose per Event	mg/cm <sup>2</sup> -event	chemical-specific	
	EV	Event Frequency	event/day	1	
	ED	Exposure Duration	years	1	
	EF	Exposure Frequency	days/year	150	
	t <sub>event</sub>	Duration of Event	hour/event	2.0	
	t*	Time to reach steady state	hour/event	chemical-specific	
	T	Lag Time	hour/event	chemical-specific	
	B	Bunge Model Constant	dimensionless	chemical-specific	
	Kp	Permeability Coefficient from Water	cm/hour	chemical-specific	
	BW	Body Weight	kg	80	
	AT-C	Averaging Time (Cancer)	days	25,550	
	AT-N	Averaging Time (Non-Cancer)	days	365	

**Daily Intake Calculations**

$$\text{Ingestion Intake} = (IwR \times CF \times EF \times ED) / (BW \times AT)$$

$$\text{Dermal Intake} = (A \times EV \times ED \times EF) / (BW \times AT)$$

$$\text{Cancer Ingestion Intake(RME)} = 7.34E-10$$

$$\text{Noncancer Ingestion Intake(RME)} = 5.14E-08$$

$$\text{Cancer Dermal Intake(RME)} = 2.55E-01$$

$$\text{Noncancer Dermal Intake(RME)} = 1.78E+01$$

**CALCULATION OF DAevent - EXPOSURES THROUGH DERMAL CONTACT WITH WATER  
EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

REFERENCES: USEPA, July 2004

**DERMAL CONTACT:**

$$DAD = (DA_{event} \times EV \times ED \times EF \times A) / (BW \times AT)$$

WHERE:

DAD = DERMALLY ABSORBED DOSE (MG/KG/DAY)

DA<sub>event</sub> = ABSORBED DOSE PER EVENT (MG/CM<sup>2</sup>/EVENT)

A = SKIN SURFACE AREA AVAILABLE FOR CONTACT(CM<sup>2</sup>)

EV = EVENT FREQUENCY (EVENTS/DAY)

ED = EXPOSURE DURATION (YEARS)

EF = EXPOSURE FREQUENCY (DAYS/YEAR)

BW = BODY WEIGHT(KG)

AT = AVERAGING TIME (DAYS)

FOR INORGANICS:

$$DA_{event} = K_p \times C \times t_{event} \times CF$$

FOR ORGANICS:

$$\text{IF } t_{event} < t^*, DA_{event} = 2 \times FA \times K_p \times C \times CF \times (6T \times t_{event} / 3.141592654)^{0.5}$$

$$\text{IF } t_{event} > t^*, DA_{event} = FA \times K_p \times C \times CF \times ((t_{event} / (1 + B)) + (2T \times ((1 + 3B + 3B^2) / (1 + B)^2)))$$

WHERE:

K<sub>p</sub> = PERMEABILITY COEFFICIENT FROM WATER (CM/HR)

C<sub>water</sub> = CONCENTRATION OF CHEMICAL IN WATER (MG/L)

t<sub>event</sub> = DURATION OF EVENT (HR/EVENT)

CF = CONVERSION FACTOR (1L/1000 CM<sup>3</sup>)

t\* = TIME IT TAKES TO REACH STEADY-STATE (HOUR/EVENT)

T = LAG TIME (HOUR/EVENT)

B = BUNGE MODEL CONSTANT (DIMENSIONLESS)

FA = FRACTION ABSORBED WATER (DIMENSIONLESS)

CHEMICAL	CAS #	C <sub>water</sub> (mg/L)	ORGANIC OR INORGANIC?	t* (HR)	t <sub>event</sub>	T (HR)	K <sub>p</sub> (CM/HR)	B	FA	DA <sub>event</sub>
4,4'-DDD	72-54-8	1.00E-03	o	2.60E+01	2.00E+00	6.65E+00	1.79E-01	1.23E+00	1.00E+00	NA <sup>(2)</sup>
4,4'-DDE	72-55-9	1.00E-03	o	2.51E+01	2.00E+00	6.48E+00	1.56E-01	1.07E+00	0.00E+00	NA <sup>(2)</sup>
4,4'-DDT	50-29-3	1.00E-03	o	4.25E+01	2.00E+00	1.04E+01	2.69E-01	1.95E+00	0.00E+00	NA <sup>(2)</sup>
Aldrin	309-00-2	1.00E-03	o	2.85E+01	2.00E+00	1.19E+01	1.40E-03	1.03E-02	0.00E+00	NA <sup>(2)</sup>
alpha-Chlordane	5103-71-9	1.00E-03	o	5.10E+01	2.00E+00	2.13E+01	3.38E-02	2.64E-01	7.00E-01	4.27E-07
Dieldrin	60-57-1	1.00E-03	o	3.51E+01	2.00E+00	1.46E+01	1.22E-02	9.18E-02	8.00E-01	1.46E-07
Endrin	72-20-8	1.00E-03	o	3.51E+01	2.00E+00	1.46E+01	1.22E-02	9.18E-02	8.00E-01	1.46E-07
gamma-BHC (Lindane)	58-89-9	1.00E-03	o	1.10E+01	2.00E+00	4.57E+00	1.08E-02	7.10E-02	9.00E-01	8.14E-08
gamma-Chlordane	5103-74-2	1.00E-03	o	5.10E+01	2.00E+00	2.13E+01	3.38E-02	2.64E-01	7.00E-01	4.27E-07
Heptachlor	76-44-8	1.00E-03	o	3.19E+01	2.00E+00	1.33E+01	8.64E-03	6.43E-02	8.00E-01	9.85E-08
PCB-hexachlorobiphenyl <sup>(1)</sup>	1336-36-3	1.00E-03	o	1.94E+01	2.00E+00	4.54E+00	5.45E-01	3.58E+00	7.00E-01	NA <sup>(2)</sup>
1,2,4-Trichlorobenzene	120-82-1	1.00E-03	o	2.66E+00	2.00E+00	1.11E+00	6.63E-02	3.43E-01	1.00E+00	2.73E-07
1,2-Dichlorobenzene	95-50-1	1.00E-03	o	1.71E+00	2.00E+00	7.11E-01	4.13E-02	1.93E-01	1.00E+00	1.39E-07
1,3-Dichlorobenzene	541-73-1	1.00E-03	o	1.71E+00	2.00E+00	7.11E-01	5.79E-02	2.70E-01	1.00E+00	1.95E-07
1,4-Dichlorobenzene	106-46-7	1.00E-03	o	1.71E+00	2.00E+00	7.11E-01	4.20E-02	1.96E-01	1.00E+00	1.41E-07
2,4,6-Trichlorophenol	88-06-2	1.00E-03	o	3.27E+00	2.00E+00	1.36E+00	3.46E-02	1.87E-01	1.00E+00	1.58E-07
2,4-Dichlorophenol	120-83-2	1.00E-03	o	2.10E+00	2.00E+00	8.74E-01	2.06E-02	1.01E-01	1.00E+00	7.53E-08
2,4-Dimethylphenol	105-67-9	1.00E-03	o	1.24E+00	2.00E+00	5.16E-01	1.09E-02	4.64E-02	1.00E+00	3.26E-08
2,4-Dinitrophenol	51-28-5	1.00E-03	o	2.76E+00	2.00E+00	1.15E+00	1.53E-03	8.00E-03	1.00E+00	6.42E-09
2,4-Dinitrotoluene	121-14-2	1.00E-03	o	2.69E+00	2.00E+00	1.12E+00	3.08E-03	1.60E-02	1.00E+00	1.27E-08
2,6-Dinitrotoluene	606-20-2	1.00E-03	o	2.69E+00	2.00E+00	1.12E+00	2.07E-03	1.07E-02	1.00E+00	8.56E-09
2-Chlorophenol	95-57-8	1.00E-03	o	1.34E+00	2.00E+00	5.60E-01	7.99E-03	3.48E-02	1.00E+00	2.47E-08
2-Ethoxy ethanol(Cellosolve)	110-80-5	1.00E-03	o	1.10E-03	2.00E+00	1.00E+00	3.00E-04	3.36E-01	3.00E-04	3.71E-13
2-Nitrophenol	88-75-5	1.00E-03	o	1.54E+00	2.00E+00	6.42E-01	4.02E-03	1.82E-02	1.00E+00	1.31E-08
3-Nitrophenol	554-84-7	1.00E-03	o	1.54E+00	2.00E+00	6.42E-01	5.54E-03	2.51E-02	1.00E+00	1.81E-08
4-Chlorophenol	106-48-9	1.00E-03	o	1.34E+00	2.00E+00	5.60E-01	1.15E-02	5.03E-02	1.00E+00	3.55E-08
4-Nitrophenol	100-02-7	1.00E-03	o	1.54E+00	2.00E+00	6.42E-01	4.83E-03	2.19E-02	1.00E+00	1.58E-08
Acetaldehyde	75-07-0	1.00E-03	o	4.51E-01	2.00E+00	1.88E-01	6.33E-04	1.62E-03	1.00E+00	1.50E-09
BaPEQ	50-32-8	1.00E-03	o	1.17E+01	2.00E+00	2.69E+00	7.01E-01	4.27E+00	0.00E+00	NA <sup>(2)</sup>

**CALCULATION OF DAevent - EXPOSURES THROUGH DERMAL CONTACT WITH WATER  
EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

REFERENCES: USEPA, July 2004

**DERMAL CONTACT:**

DAD = (DAevent x EV x ED x EF x A)/(BW x AT)

WHERE:

DAD = DERMALLY ABSORBED DOSE (MG/KG/DAY)

DAevent = ABSORBED DOSE PER EVENT (MG/CM<sup>2</sup>/EVENT)

A = SKIN SURFACE AREA AVAILABLE FOR CONTACT(CM<sup>2</sup>)

EV = EVENT FREQUENCY (EVENTS/DAY)

ED = EXPOSURE DURATION (YEARS)

EF = EXPOSURE FREQUENCY (DAYS/YEAR)

BW = BODY WEIGHT(KG)

AT = AVERAGING TIME (DAYS)

FOR INORGANICS:

DAevent = Kp x C x tevent x CF

FOR ORGANICS:

IF tevent < t\*, DAevent = 2 x FA x Kp x C x CF x (6T x tevent/3.141592654)<sup>0.5</sup>

IF tevent > t\*, DAevent = FA x Kp x C x CF x ((tevent/(1 + B)) + (2T x ((1+3B+3B<sup>2</sup>)/(1 + B)<sup>2</sup>))

WHERE:

Kp = PERMEABILITY COEFFICIENT FROM WATER (CM/HR)

Cwater = CONCENTRATION OF CHEMICAL IN WATER (MG/L)

tevent = DURATION OF EVENT (HR/EVENT)

CF = CONVERSION FACTOR (1L/1000 CM<sup>3</sup>)

t\* = TIME IT TAKES TO REACH STEADY-STATE (HOUR/EVENT)

T = LAG TIME (HOUR/EVENT)

B = BUNGE MODEL CONSTANT (DIMENSIONLESS)

FA = FRACTION ABSORBED WATER (DIMENSIONLESS)

CHEMICAL	CAS #	Cwater (mg/L)	ORGANIC OR INORGANIC?	t* (HR)	tevent	T (HR)	Kp (CM/HR)	B	FA	DAevent
Benzo(a)anthracene	56-55-3	1.00E-03	o	8.53E+00	2.00E+00	2.03E+00	4.74E-01	2.75E+00	0.00E+00	NA <sup>(2)</sup>
Benzo(a)pyrene	50-32-8	1.00E-03	o	1.17E+01	2.00E+00	2.69E+00	7.01E-01	4.27E+00	0.00E+00	NA <sup>(2)</sup>
Benzo(b)fluoranthene	205-99-2	1.00E-03	o	1.20E+01	2.00E+00	2.77E+00	7.02E-01	4.29E+00	0.00E+00	NA <sup>(2)</sup>
Benzoic acid	65-85-0	1.00E-03	o	1.24E+00	2.00E+00	5.15E-01	5.66E-03	2.41E-02	1.00E+00	1.70E-08
Benzyl chloride	100-44-7	1.00E-03	o	1.32E+00	2.00E+00	5.49E-01	1.03E-02	4.44E-02	1.00E+00	3.14E-08
Bis(2-chloroethyl)ether	111-44-4	1.00E-03	o	1.62E+00	2.00E+00	6.75E-01	1.78E-03	8.17E-03	1.00E+00	5.95E-09
Chrysene	218-01-9	1.00E-03	o	8.53E+00	2.00E+00	2.03E+00	4.74E-01	2.75E+00	0.00E+00	NA <sup>(2)</sup>
Di-2-ethylhexylphthalate	117-81-7	1.00E-03	o	3.99E+01	2.00E+00	1.66E+01	2.49E-02	1.90E-01	0.00E+00	0.00E+00
Dibenzo(a,h)anthracene	53-70-3	1.00E-03	o	1.76E+01	2.00E+00	3.88E+00	1.51E+00	9.68E+00	0.00E+00	NA <sup>(2)</sup>
Dibutyl phthalate	84-74-2	1.00E-03	o	9.27E+00	2.00E+00	3.86E+00	2.40E-02	1.54E-01	9.00E-01	1.66E-07
Dichlorobenzidine, 3,3'	91-94-1	1.00E-03	o	6.72E+00	2.00E+00	2.80E+00	1.28E-02	7.83E-02	1.00E+00	8.37E-08
Diethyl phthalate	84-66-2	1.00E-03	o	4.50E+00	2.00E+00	1.87E+00	3.90E-03	2.23E-02	1.00E+00	2.08E-08
Dioxane, 1,4-	123-91-1	1.00E-03	o	7.97E+01	2.00E+00	3.32E-01	3.32E-04	1.20E-03	1.00E+00	8.84E-10
Fluoranthene	206-44-0	1.00E-03	o	5.68E+00	2.00E+00	1.45E+00	2.24E-01	1.22E+00	0.00E+00	NA <sup>(2)</sup>
Hexachlorobenzene	118-74-1	1.00E-03	o	1.62E+01	2.00E+00	4.22E+00	1.34E-01	8.67E-01	9.00E-01	NA <sup>(2)</sup>
Hexachlorobutadiene	87-68-3	1.00E-03	o	7.42E+00	2.00E+00	3.09E+00	8.09E-02	5.03E-01	9.00E-01	5.01E-07
Hexachloroethane	67-72-1	1.00E-03	o	5.44E+00	2.00E+00	2.27E+00	3.01E-02	1.78E-01	1.00E+00	1.77E-07
Indeno(1,2,3-CD)pyrene	193-39-5	1.00E-03	o	1.68E+01	2.00E+00	3.78E+00	1.04E+00	6.65E+00	0.00E+00	NA <sup>(2)</sup>
Isophorone	78-59-1	1.00E-03	o	1.52E+00	2.00E+00	6.35E-01	3.38E-03	1.53E-02	1.00E+00	1.10E-08
m-Cresol	108-39-4	1.00E-03	o	1.03E+00	2.00E+00	4.30E-01	7.77E-03	3.11E-02	1.00E+00	2.20E-08
Naphthalene	91-20-3	1.00E-03	o	1.34E+00	2.00E+00	5.58E-01	4.66E-02	2.03E-01	1.00E+00	1.40E-07
o-Cresol	95-48-7	1.00E-03	o	1.03E+00	2.00E+00	4.30E-01	7.66E-03	3.06E-02	1.00E+00	2.16E-08
p-Cresol	106-44-5	1.00E-03	o	1.03E+00	2.00E+00	4.30E-01	7.66E-03	3.06E-02	1.00E+00	2.16E-08
Pentachlorophenol	87-86-5	1.00E-03	o	1.38E+01	2.00E+00	3.33E+00	3.93E-01	2.47E+00	0.00E+00	NA <sup>(2)</sup>
Phenanthrene	85-01-8	1.00E-03	o	4.11E+00	2.00E+00	1.06E+00	1.44E-01	7.40E-01	0.00E+00	NA <sup>(2)</sup>
Phenol	108-95-2	1.00E-03	o	8.61E-01	2.00E+00	3.59E-01	4.34E-03	1.62E-02	1.00E+00	1.17E-08
Phenol,4,6-dinitro-2-methyl-	534-52-1	1.00E-03	o	3.25E+00	2.00E+00	1.35E+00	3.15E-03	1.71E-02	1.00E+00	1.43E-08
TCDD	1746-01-6	1.00E-03	o	3.01E+01	2.00E+00	6.82E+00	8.07E-01	5.57E+00	0.00E+00	NA <sup>(2)</sup>
1,1,1-Trichloroethane	71-55-6	1.00E-03	o	1.43E+00	2.00E+00	5.96E-01	1.26E-02	5.61E-02	1.00E+00	3.98E-08

**CALCULATION OF DAevent - EXPOSURES THROUGH DERMAL CONTACT WITH WATER  
EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

REFERENCES: USEPA, July 2004

**DERMAL CONTACT:**

DAD = (DAevent x EV x ED x EF x A)/(BW x AT)

WHERE:

DAD = DERMALLY ABSORBED DOSE (MG/KG/DAY)

DAevent = ABSORBED DOSE PER EVENT (MG/CM<sup>2</sup>/EVENT)

A = SKIN SURFACE AREA AVAILABLE FOR CONTACT(CM<sup>2</sup>)

EV = EVENT FREQUENCY (EVENTS/DAY)

ED = EXPOSURE DURATION (YEARS)

EF = EXPOSURE FREQUENCY (DAYS/YEAR)

BW = BODY WEIGHT(KG)

AT = AVERAGING TIME (DAYS)

FOR INORGANICS:

DAevent = Kp x C x tevent x CF

FOR ORGANICS:

IF tevent < t\*, DAevent = 2 x FA x Kp x C x CF x (6T x tevent/3.141592654)<sup>0.5</sup>

IF tevent > t\*, DAevent = FA x Kp x C x CF x ((tevent/(1 + B)) + (2T x ((1+3B+3B<sup>2</sup>)/(1 + B)<sup>2</sup>))

WHERE:

Kp = PERMEABILITY COEFFICIENT FROM WATER (CM/HR)

Cwater = CONCENTRATION OF CHEMICAL IN WATER (MG/L)

tevent = DURATION OF EVENT (HR/EVENT)

CF = CONVERSION FACTOR (1L/1000 CM<sup>3</sup>)

t\* = TIME IT TAKES TO REACH STEADY-STATE (HOUR/EVENT)

T = LAG TIME (HOUR/EVENT)

B = BUNGE MODEL CONSTANT (DIMENSIONLESS)

FA = FRACTION ABSORBED WATER (DIMENSIONLESS)

CHEMICAL	CAS #	Cwater (mg/L)	ORGANIC OR INORGANIC?	t* (HR)	tevent	T (HR)	Kp (CM/HR)	B	FA	DAevent
1,1,2,2-Tetrachloroethane	79-34-5	1.00E-03	o	2.24E+00	2.00E+00	9.31E-01	6.94E-03	3.46E-02	1.00E+00	2.62E-08
1,1,2-Trichloroethane	79-00-5	1.00E-03	o	1.43E+00	2.00E+00	5.96E-01	6.44E-03	2.86E-02	1.00E+00	2.04E-08
1,1,2-Trichlorotrifluoroethane	76-13-1	1.00E-03	o	2.82E+00	2.00E+00	1.18E+00	1.72E-02	9.07E-02	1.00E+00	7.30E-08
1,1-Dichloroethane	75-34-3	1.00E-03	o	9.18E-01	2.00E+00	3.82E-01	6.74E-03	2.58E-02	1.00E+00	1.84E-08
1,1-Dichloroethene	75-35-4	1.00E-03	o	8.93E-01	2.00E+00	3.72E-01	1.17E-02	4.41E-02	1.00E+00	3.14E-08
1,2-Dichloroethane	107-06-2	1.00E-03	o	9.18E-01	2.00E+00	3.82E-01	4.20E-03	1.61E-02	1.00E+00	1.15E-08
1,2-Dichloropropane	78-87-5	1.00E-03	o	1.10E+00	2.00E+00	4.58E-01	7.76E-03	3.17E-02	1.00E+00	2.24E-08
2,2'-Oxybis(1-Chloropropane)	108-60-1	1.00E-03	o	2.29E+00	2.00E+00	9.53E-01	7.56E-03	3.81E-02	1.00E+00	2.89E-08
2,4,5-Trichlorophenol	95-95-4	1.00E-03	o	3.21E+00	2.00E+00	1.34E+00	3.54E-02	1.92E-01	1.00E+00	1.60E-07
2-Butanone	78-93-3	1.00E-03	o	6.47E-01	2.00E+00	2.70E-01	9.63E-04	3.14E-03	1.00E+00	2.44E-09
2-Chloronaphthalene	91-58-7	1.00E-03	o	2.05E+00	2.00E+00	8.55E-01	8.24E-02	4.04E-01	1.00E+00	2.98E-07
2-Hexanone	591-78-6	1.00E-03	o	9.17E-01	2.00E+00	3.82E-01	3.55E-03	1.37E-02	1.00E+00	9.75E-09
2-Methylnaphthalene	91-57-6	1.00E-03	o	1.58E+00	2.00E+00	6.57E-01	8.94E-02	4.10E-01	1.00E+00	2.88E-07
2-Nitroaniline	88-74-4	1.00E-03	o	1.50E+00	2.00E+00	6.23E-01	4.44E-03	2.01E-02	1.00E+00	1.44E-08
3-Nitroaniline	99-09-2	1.00E-03	o	1.50E+00	2.00E+00	6.23E-01	2.14E-03	9.68E-03	1.00E+00	6.94E-09
4-Bromophenyl Phenyl Ether	101-55-3	1.00E-03	o	1.01E+01	2.00E+00	2.61E+00	1.16E-01	7.06E-01	1.00E+00	7.34E-07
4-Chloro-3-Methylphenol	59-50-7	1.00E-03	o	1.61E+00	2.00E+00	6.71E-01	2.85E-02	1.31E-01	1.00E+00	9.37E-08
4-Chloroaniline	106-47-8	1.00E-03	o	1.31E+00	2.00E+00	5.44E-01	4.94E-03	2.14E-02	1.00E+00	1.52E-08
4-Chlorophenyl Phenyl Ether	7005-72-3	1.00E-03	o	5.72E+00	2.00E+00	1.47E+00	2.09E-01	1.15E+00	1.00E+00	9.92E-07
4-Methyl-2-Pentanone	108-10-1	1.00E-03	o	9.30E-01	2.00E+00	3.87E-01	2.66E-03	1.02E-02	1.00E+00	7.34E-09
4-Nitroaniline	100-01-6	1.00E-03	o	1.50E+00	2.00E+00	6.23E-01	2.21E-03	9.98E-03	1.00E+00	7.15E-09
Acenaphthene	83-32-9	1.00E-03	o	1.84E+00	2.00E+00	7.67E-01	8.39E-02	4.01E-01	1.00E+00	2.96E-07
Acenaphthylene	208-96-8	1.00E-03	o	1.79E+00	2.00E+00	7.47E-01	8.87E-02	4.21E-01	1.00E+00	3.08E-07
Acetone	67-64-1	1.00E-03	o	5.33E-01	2.00E+00	2.22E-01	5.20E-04	1.53E-03	1.00E+00	1.27E-09
Alpha-BHC	319-84-6	1.00E-03	o	1.07E+01	2.00E+00	4.47E+00	2.01E-02	1.32E-01	1.00E+00	1.66E-07
Anthracene	120-12-7	1.00E-03	o	4.06E+00	2.00E+00	1.05E+00	1.38E-01	7.07E-01	1.00E+00	5.50E-07
Aroclor-1016	12674-11-2	1.00E-03	o	1.17E+01	2.00E+00	2.91E+00	2.93E-01	1.81E+00	0.00E+00	NA <sup>(2)</sup>
Aroclor-1221	11104-28-2	1.00E-03	o	4.63E+00	2.00E+00	1.20E+00	1.36E-01	7.18E-01	1.00E+00	NA <sup>(2)</sup>
Aroclor-1232	11141-16-5	1.00E-03	o	4.63E+00	2.00E+00	1.20E+00	1.36E-01	7.18E-01	1.00E+00	NA <sup>(2)</sup>

**CALCULATION OF DAevent - EXPOSURES THROUGH DERMAL CONTACT WITH WATER  
EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

REFERENCES: USEPA, July 2004

**DERMAL CONTACT:**

$$DAD = (DA_{event} \times EV \times ED \times EF \times A) / (BW \times AT)$$

WHERE:

DAD = DERMALLY ABSORBED DOSE (MG/KG/DAY)

DAevent = ABSORBED DOSE PER EVENT (MG/CM<sup>2</sup>/EVENT)

A = SKIN SURFACE AREA AVAILABLE FOR CONTACT(CM<sup>2</sup>)

EV = EVENT FREQUENCY (EVENTS/DAY)

ED = EXPOSURE DURATION (YEARS)

EF = EXPOSURE FREQUENCY (DAYS/YEAR)

BW = BODY WEIGHT(KG)

AT = AVERAGING TIME (DAYS)

FOR INORGANICS:

$$DA_{event} = K_p \times C \times t_{event} \times CF$$

FOR ORGANICS:

$$IF \ t_{event} < t^*, \ DA_{event} = 2 \times FA \times K_p \times C \times CF \times (6T \times t_{event} / 3.141592654)^{0.5}$$

$$IF \ t_{event} > t^*, \ DA_{event} = FA \times K_p \times C \times CF \times ((t_{event} / (1 + B)) + (2T \times ((1 + 3B + 3B^2) / (1 + B)^2)))$$

WHERE:

Kp = PERMEABILITY COEFFICIENT FROM WATER (CM/HR)

Cwater = CONCENTRATION OF CHEMICAL IN WATER (MG/L)

t<sub>event</sub> = DURATION OF EVENT (HR/EVENT)

CF = CONVERSION FACTOR (1L/1000 CM<sup>3</sup>)

t\* = TIME IT TAKES TO REACH STEADY-STATE (HOUR/EVENT)

T = LAG TIME (HOUR/EVENT)

B = BUNGE MODEL CONSTANT (DIMENSIONLESS)

FA = FRACTION ABSORBED WATER (DIMENSIONLESS)

CHEMICAL	CAS #	Cwater (mg/L)	ORGANIC OR INORGANIC?	t* (HR)	t <sub>event</sub>	T (HR)	Kp (CM/HR)	B	FA	DAevent
Aroclor-1242	53469-21-9	1.00E-03	o	1.93E+01	2.00E+00	4.53E+00	5.20E-01	3.42E+00	0.00E+00	NA <sup>(2)</sup>
Aroclor-1248	12672-29-6	1.00E-03	o	1.95E+01	2.00E+00	4.53E+00	5.61E-01	3.69E+00	0.00E+00	NA <sup>(2)</sup>
Aroclor-1254	11097-69-1	1.00E-03	o	3.10E+01	2.00E+00	7.07E+00	7.13E-01	4.96E+00	0.00E+00	NA <sup>(2)</sup>
Aroclor-1260	11096-82-5	1.00E-03	o	7.94E+01	2.00E+00	1.72E+01	2.78E+00	2.13E+01	0.00E+00	NA <sup>(2)</sup>
Benzene	71-43-2	1.00E-03	o	7.00E-01	2.00E+00	2.92E-01	1.49E-02	5.05E-02	1.00E+00	3.74E-08
Benzo(g,h,i)perylene	191-24-2	1.00E-03	o	1.65E+01	2.00E+00	3.70E+00	1.07E+00	6.82E+00	1.00E+00	8.03E-06
Benzo(k)fluoranthene	207-08-9	1.00E-03	o	1.17E+01	2.00E+00	2.72E+00	6.60E-01	4.03E+00	0.00E+00	NA <sup>(2)</sup>
Beta-BHC	319-85-7	1.00E-03	o	1.07E+01	2.00E+00	4.47E+00	2.01E-02	1.32E-01	1.00E+00	1.66E-07
Bis(2-Chloroethoxy)Methane	111-91-1	1.00E-03	o	2.35E+00	2.00E+00	9.78E-01	1.23E-03	6.21E-03	1.00E+00	4.74E-09
Bis(2-Ethylhexyl)Phthalate	117-81-7	1.00E-03	o	3.99E+01	2.00E+00	1.66E+01	2.49E-02	1.90E-01	0.00E+00	0.00E+00
Bromodichloromethane	75-27-4	1.00E-03	o	2.12E+00	2.00E+00	8.83E-01	4.62E-03	2.27E-02	1.00E+00	1.70E-08
Bromoform	75-25-2	1.00E-03	o	6.70E+00	2.00E+00	2.79E+00	2.25E-03	1.37E-02	1.00E+00	1.47E-08
Bromomethane	74-83-9	1.00E-03	o	8.71E-01	2.00E+00	3.63E-01	2.84E-03	1.06E-02	1.00E+00	7.69E-09
Butyl Benzyl Phthalate	85-68-7	1.00E-03	o	1.41E+01	2.00E+00	5.89E+00	3.74E-02	2.54E-01	1.00E+00	3.55E-07
Carbazole	86-74-8	1.00E-03	o	2.18E+00	2.00E+00	9.07E-01	5.23E-02	2.60E-01	1.00E+00	1.95E-07
Carbon Disulfide	75-15-0	1.00E-03	o	7.18E-01	2.00E+00	2.99E-01	1.72E-02	5.91E-02	1.00E+00	4.33E-08
Carbon Tetrachloride	56-23-5	1.00E-03	o	1.86E+00	2.00E+00	7.76E-01	1.63E-02	7.78E-02	1.00E+00	5.76E-08
Chlorobenzene	108-90-7	1.00E-03	o	1.09E+00	2.00E+00	4.56E-01	2.82E-02	1.15E-01	1.00E+00	7.93E-08
Chlorodibromomethane	124-48-1	1.00E-03	o	3.77E+00	2.00E+00	1.57E+00	3.22E-03	1.79E-02	1.00E+00	1.58E-08
Chloroethane	75-00-3	1.00E-03	o	5.88E-01	2.00E+00	2.45E-01	6.07E-03	1.88E-02	1.00E+00	1.49E-08
Chloroform	67-66-3	1.00E-03	o	1.19E+00	2.00E+00	4.98E-01	6.83E-03	2.87E-02	1.00E+00	2.03E-08
Chloromethane	74-87-3	1.00E-03	o	4.90E-01	2.00E+00	2.04E-01	3.28E-03	8.97E-03	1.00E+00	7.86E-09
Cis-1,3-Dichloropropene	10061-01-5	1.00E-03	o	1.05E+00	2.00E+00	4.39E-01	7.92E-03	3.21E-02	1.00E+00	2.25E-08
Delta-BHC	319-86-8	1.00E-03	o	1.07E+01	2.00E+00	4.47E+00	2.01E-02	1.32E-01	1.00E+00	1.66E-07
Dibenzofuran	132-64-9	1.00E-03	o	2.20E+00	2.00E+00	9.19E-01	9.49E-02	4.73E-01	1.00E+00	3.56E-07
Dimethyl Phthalate	131-11-3	1.00E-03	o	3.13E+00	2.00E+00	1.30E+00	1.39E-03	7.45E-03	1.00E+00	6.21E-09
Di-n-octyl Phthalate	117-84-0	1.00E-03	o	7.44E+01	2.00E+00	1.62E+01	2.28E+00	1.74E+01	1.00E+00	3.59E-05
Endosulfan I	959-98-8	1.00E-03	o	4.79E+01	2.00E+00	1.99E+01	1.84E-03	1.43E-02	1.00E+00	3.21E-08
Endosulfan II	33213-65-9	1.00E-03	o	4.79E+01	2.00E+00	1.99E+01	2.04E-03	1.59E-02	1.00E+00	3.57E-08

**CALCULATION OF DAevent - EXPOSURES THROUGH DERMAL CONTACT WITH WATER  
EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

REFERENCES: USEPA, July 2004

**DERMAL CONTACT:**

$$DAD = (DA_{event} \times EV \times ED \times EF \times A) / (BW \times AT)$$

WHERE:

DAD = DERMALLY ABSORBED DOSE (MG/KG/DAY)

DAevent = ABSORBED DOSE PER EVENT (MG/CM<sup>2</sup>/EVENT)

A = SKIN SURFACE AREA AVAILABLE FOR CONTACT(CM<sup>2</sup>)

EV = EVENT FREQUENCY (EVENTS/DAY)

ED = EXPOSURE DURATION (YEARS)

EF = EXPOSURE FREQUENCY (DAYS/YEAR)

BW = BODY WEIGHT(KG)

AT = AVERAGING TIME (DAYS)

FOR INORGANICS:

$$DA_{event} = K_p \times C \times t_{event} \times CF$$

FOR ORGANICS:

$$\text{IF } t_{event} < t^*, \quad DA_{event} = 2 \times FA \times K_p \times C \times CF \times (6T \times t_{event} / 3.141592654)^{0.5}$$

$$\text{IF } t_{event} > t^*, \quad DA_{event} = FA \times K_p \times C \times CF \times ((t_{event} / (1 + B)) + (2T \times ((1 + 3B + 3B^2) / (1 + B))^2))$$

WHERE:

Kp = PERMEABILITY COEFFICIENT FROM WATER (CM/HR)

Cwater = CONCENTRATION OF CHEMICAL IN WATER (MG/L)

t<sub>event</sub> = DURATION OF EVENT (HR/EVENT)

CF = CONVERSION FACTOR (1L/1000 CM<sup>3</sup>)

t\* = TIME IT TAKES TO REACH STEADY-STATE (HOUR/EVENT)

T = LAG TIME (HOUR/EVENT)

B = BUNGE MODEL CONSTANT (DIMENSIONLESS)

FA = FRACTION ABSORBED WATER (DIMENSIONLESS)

CHEMICAL	CAS #	Cwater (mg/L)	ORGANIC OR INORGANIC?	t* (HR)	t <sub>event</sub>	T (HR)	Kp (CM/HR)	B	FA	DAevent
Endosulfan Sulfate	1031-07-8	1.00E-03	o	5.89E+01	2.00E+00	2.45E+01	1.77E-03	1.40E-02	1.00E+00	3.42E-08
Endrin Aldehyde	7421-93-4	1.00E-03	o	3.42E+01	2.00E+00	1.43E+01	5.09E-03	3.82E-02	8.00E-01	6.01E-08
Endrin Ketone	53494-70-5	1.00E-03	o	3.43E+01	2.00E+00	1.43E+01	2.29E-02	1.72E-01	8.00E-01	2.71E-07
Ethylbenzene	100-41-4	1.00E-03	o	1.01E+00	2.00E+00	4.20E-01	4.93E-02	1.95E-01	1.00E+00	1.32E-07
Fluorene	86-73-7	1.00E-03	o	2.15E+00	2.00E+00	8.95E-01	1.07E-01	5.29E-01	1.00E+00	3.94E-07
Heptachlor Epoxide	1024-57-3	1.00E-03	o	3.82E+01	2.00E+00	1.59E+01	2.03E-02	1.54E-01	1.00E+00	3.16E-07
Hexachlorocyclopentadiene	77-47-4	1.00E-03	o	1.40E+01	2.00E+00	3.54E+00	9.97E-02	6.34E-01	1.00E+00	7.33E-07
Methoxychlor	72-43-5	1.00E-03	o	2.17E+01	2.00E+00	9.05E+00	4.14E-02	2.96E-01	1.00E+00	4.87E-07
Methylene Chloride	75-09-2	1.00E-03	o	7.65E-01	2.00E+00	3.19E-01	3.54E-03	1.26E-02	1.00E+00	9.28E-09
Nitrobenzene	98-95-3	1.00E-03	o	1.23E+00	2.00E+00	5.14E-01	5.39E-03	2.30E-02	1.00E+00	1.62E-08
N-Nitroso-di-n-Propylamine	621-64-7	1.00E-03	o	1.37E+00	2.00E+00	5.72E-01	2.33E-03	1.02E-02	1.00E+00	7.32E-09
N-Nitrosodiphenylamine	86-30-6	1.00E-03	o	3.31E+00	2.00E+00	1.38E+00	1.45E-02	7.88E-02	1.00E+00	6.68E-08
Pyrene	129-00-0	1.00E-03	o	5.52E+00	2.00E+00	1.43E+00	1.94E-01	1.06E+00	1.00E+00	9.06E-07
Styrene	100-42-5	1.00E-03	o	9.80E-01	2.00E+00	4.08E-01	3.73E-02	1.46E-01	1.00E+00	9.98E-08
Tetrachloroethene	127-18-4	1.00E-03	o	2.18E+00	2.00E+00	9.06E-01	3.34E-02	1.66E-01	1.00E+00	1.24E-07
Toluene	108-88-3	1.00E-03	o	8.39E-01	2.00E+00	3.50E-01	3.11E-02	1.15E-01	1.00E+00	8.00E-08
Total 1,2-Dichloroethene	540-59-0	1.00E-03	o	8.93E-01	2.00E+00	3.72E-01	7.71E-03	2.92E-02	1.00E+00	2.09E-08
Total Xylenes	1330-20-7	1.00E-03	o	9.91E-01	2.00E+00	4.13E-01	4.62E-02	1.83E-01	1.00E+00	1.23E-07
Toxaphene	8001-35-2	1.00E-03	o	5.38E+01	2.00E+00	2.24E+01	1.19E-02	9.30E-02	8.00E-01	1.76E-07
Trans-1,3-Dichloropropene	10061-02-6	1.00E-03	o	1.05E+00	2.00E+00	4.39E-01	7.92E-03	3.21E-02	1.00E+00	2.25E-08
Trichloroethene	79-01-6	1.00E-03	o	1.39E+00	2.00E+00	5.81E-01	1.16E-02	5.13E-02	1.00E+00	3.64E-08
Vinyl Chloride	75-01-4	1.00E-03	o	5.73E-01	2.00E+00	2.39E-01	5.60E-03	1.70E-02	1.00E+00	1.37E-08

1 - Values are for polychlorinated biphenyls - low risk.

2 - Chemical is outside of the effective predictive domain.

**CALCULATION OF SCREENING LEVELS BASED NONCARCINOGENIC EFFECTS  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future Medium: Groundwater Exposure Medium: Water Receptor Population: Construction Worker Receptor Age: Adult
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Exposure Route	Chemical of Potential Concern	Assumed Water Concentration	Intake (Non-Cancer) <sup>(8)</sup>	Reference Dose <sup>(9)</sup>	Hazard Quotient Based on Assumed Water Concentration	RBC (noncancer)	RBC (noncancer)
		mg/L	mg/kg-day	mg/kg-day		mg/L	µg/L
Ingestion and Dermal	4,4'-DDD	1.00E-03	3.2E-05	NA	NA	NA	NA
	4,4'-DDE	1.00E-03	5.1E-08	NA	NA	NA	NA
	4,4'-DDT	1.00E-03	5.1E-08	5.00E-04	1.0E-04	9.73E+00	9.73E+03
	Aldrin	1.00E-03	5.1E-08	4.00E-05	1.3E-03	7.79E-01	7.79E+02
	alpha-Chlordane	1.00E-03	7.7E-06	5.00E-04	1.5E-02	6.53E-02	6.53E+01
	Dieldrin	1.00E-03	2.7E-06	1.00E-04	2.7E-02	3.76E-02	3.76E+01
	Endrin	1.00E-03	2.7E-06	2.00E-03	1.3E-03	7.53E-01	7.53E+02
	gamma-BHC (Lindane)	1.00E-03	1.5E-06	1.00E-05	1.5E-01	6.66E-03	6.66E+00
	gamma-Chlordane	1.00E-03	7.7E-06	5.00E-04	1.5E-02	6.53E-02	6.53E+01
	Heptachlor	1.00E-03	1.8E-06	1.00E-04	1.8E-02	5.54E-02	5.54E+01
	PCB-hexachlorobiphenyl <sup>(1)</sup>	1.00E-03	5.7E-05	NA	NA	NA	NA
	1,2,4-Trichlorobenzene	1.00E-03	4.9E-06	9.00E-02	5.5E-05	1.83E+01	1.83E+04
	1,2-Dichlorobenzene	1.00E-03	2.5E-06	6.00E-01	4.2E-06	2.37E+02	2.37E+05
	1,3-Dichlorobenzene	1.00E-03	3.5E-06	2.00E-02	1.8E-04	5.68E+00	5.68E+03
	1,4-Dichlorobenzene	1.00E-03	2.6E-06	7.00E-02	3.7E-05	2.72E+01	2.72E+04
	2,4,6-Trichlorophenol	1.00E-03	2.9E-06	1.00E-03	2.9E-03	3.49E-01	3.49E+02
	2,4-Dichlorophenol	1.00E-03	1.4E-06	2.00E-02	7.0E-05	1.44E+01	1.44E+04
	2,4-Dimethylphenol	1.00E-03	6.3E-07	5.00E-02	1.3E-05	7.90E+01	7.90E+04
	2,4-Dinitrophenol	1.00E-03	1.7E-07	2.00E-02	8.3E-06	1.21E+02	1.21E+05
	2,4-Dinitrotoluene	1.00E-03	2.8E-07	2.00E-03	1.4E-04	7.18E+00	7.18E+03
	2,6-Dinitrotoluene	1.00E-03	2.0E-07	3.00E-03	6.8E-05	1.47E+01	1.47E+04
	2-Chlorophenol	1.00E-03	4.9E-07	8.00E-03	6.1E-05	1.63E+01	1.63E+04
	2-Ethoxy ethanol(Cellosolve)	1.00E-03	5.1E-08	1.00E-01	5.1E-07	1.95E+03	1.95E+06
	2-Nitrophenol	1.00E-03	2.9E-07	NA	NA	NA	NA
	3-Nitrophenol	1.00E-03	3.7E-07	NA	NA	NA	NA
	4-Chlorophenol	1.00E-03	6.8E-07	NA	NA	NA	NA
	4-Nitrophenol	1.00E-03	3.3E-07	NA	NA	NA	NA
	Acetaldehyde	1.00E-03	7.8E-08	NA	NA	NA	NA
	BaPEQ	1.00E-03	5.1E-08	NA	NA	NA	NA
	Benzo(a)anthracene	1.00E-03	5.1E-08	NA	NA	NA	NA
	Benzo(a)pyrene	1.00E-03	5.1E-08	NA	NA	NA	NA
	Benzo(b)fluoranthene	1.00E-03	5.1E-08	NA	NA	NA	NA
	Benzoic acid	1.00E-03	3.5E-07	4.00E+00	8.9E-08	1.13E+04	1.13E+07
	Benzyl chloride	1.00E-03	6.1E-07	2.00E-03	3.1E-04	3.27E+00	3.27E+03
	Bis(2-chloroethyl)ether	1.00E-03	1.6E-07	NA	NA	NA	NA
	Chrysene	1.00E-03	5.1E-08	NA	NA	NA	NA
	Dibenzo(a,h)anthracene	1.00E-03	5.1E-08	NA	NA	NA	NA
	Dibutyl phthalate	1.00E-03	3.0E-06	1.00E+00	3.0E-06	3.33E+02	3.33E+05
	Dichlorobenzidine, 3,3'	1.00E-03	1.5E-06	NA	NA	NA	NA
	Diethyl phthalate	1.00E-03	4.2E-07	6.00E+00	7.0E-08	1.42E+04	1.42E+07
	Dioxane, 1,4-	1.00E-03	6.7E-08	5.00E-01	1.3E-07	7.45E+03	7.45E+06
	Fluoranthene	1.00E-03	5.1E-08	4.00E-01	1.3E-07	7.79E+03	7.79E+06
	Ingestion and	Hexachlorobenzene	1.00E-03	1.7E-05	1.00E-05	1.7E+00	5.80E-04

**CALCULATION OF SCREENING LEVELS BASED NONCARCINOGENIC EFFECTS  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future Medium: Groundwater Exposure Medium: Water Receptor Population: Construction Worker Receptor Age: Adult
--

Exposure Route	Chemical of Potential Concern	Assumed Water Concentration	Intake (Non-Cancer) <sup>(8)</sup>	Reference Dose <sup>(9)</sup>	Hazard Quotient Based on Assumed Water Concentration	RBC (noncancer)	RBC (noncancer)	
		mg/L	mg/kg-day	mg/kg-day		mg/L	µg/L	
Dermal	Hexachlorobutadiene	1.00E-03	9.0E-06	1.00E-03	9.0E-03	1.11E-01	1.11E+02	
	Hexachloroethane	1.00E-03	3.2E-06	1.00E-02	3.2E-04	3.12E+00	3.12E+03	
	Indeno(1,2,3-CD)pyrene	1.00E-03	5.1E-08	NA	NA	NA	NA	
	Isophorone	1.00E-03	2.5E-07	3.00E+00	8.3E-08	1.21E+04	1.21E+07	
	m-Cresol	1.00E-03	4.4E-07	5.00E-01	8.9E-07	1.13E+03	1.13E+06	
	Naphthalene	1.00E-03	2.5E-06	6.00E-01	4.2E-06	2.36E+02	2.36E+05	
	o-Cresol	1.00E-03	4.4E-07	5.00E-01	8.7E-07	1.14E+03	1.14E+06	
	p-Cresol	1.00E-03	4.4E-07	2.00E-02	2.2E-05	4.57E+01	4.57E+04	
	Pentachlorophenol	1.00E-03	5.1E-08	1.00E-03	5.1E-05	1.95E+01	1.95E+04	
	Phenanthrene <sup>(3)</sup>	1.00E-03	5.1E-08	3.00E-02	1.7E-06	5.84E+02	5.84E+05	
	Phenol	1.00E-03	2.6E-07	6.00E-01	4.3E-07	2.31E+03	2.31E+06	
	Phenol,4,6-dinitro-2-methyl-	1.00E-03	3.1E-07	8.00E-04	3.8E-04	2.61E+00	2.61E+03	
	TCDD	1.00E-03	5.1E-08	7.00E-10	7.3E+01	1.36E-05	1.36E-02	
	1,1,1-Trichloroethane	1.00E-03	7.6E-07	7.00E+00	1.1E-07	9.20E+03	9.20E+06	
	1,1,2,2-Tetrachloroethane	1.00E-03	5.2E-07	5.00E-01	1.0E-06	9.66E+02	9.66E+05	
	1,1,2-Trichloroethane	1.00E-03	4.2E-07	4.00E-03	1.0E-04	9.63E+00	9.63E+03	
	1,1,2-Trichlorotrifluoroethane	1.00E-03	1.4E-06	3.00E+01	4.5E-08	2.22E+04	2.22E+07	
	1,1-Dichloroethane	1.00E-03	3.8E-07	2.00E+00	1.9E-07	5.26E+03	5.26E+06	
	1,1-Dichloroethene	1.00E-03	6.1E-07	9.00E-03	6.8E-05	1.47E+01	1.47E+04	
	1,2-Dichloroethane	1.00E-03	2.6E-07	2.00E-02	1.3E-05	7.79E+01	7.79E+04	
	1,2-Dichloropropane	1.00E-03	4.5E-07	7.00E-02	6.4E-06	1.55E+02	1.55E+05	
	2,2'-Oxybis(1-Chloropropane)	1.00E-03	5.7E-07	4.00E-02	1.4E-05	7.07E+01	7.07E+04	
	2,4,5-Trichlorophenol	1.00E-03	2.9E-06	3.00E-01	9.7E-06	1.03E+02	1.03E+05	
	2-Butanone	1.00E-03	9.5E-08	2.00E+00	4.7E-08	2.11E+04	2.11E+07	
	2-Chloronaphthalene	1.00E-03	5.4E-06	2.00E-01	2.7E-05	3.73E+01	3.73E+04	
	2-Hexanone	1.00E-03	2.3E-07	5.00E-03	4.5E-05	2.22E+01	2.22E+04	
	2-Methylnaphthalene	1.00E-03	5.2E-06	4.00E-03	1.3E-03	7.71E-01	7.71E+02	
	2-Nitroaniline	1.00E-03	3.1E-07	1.00E-01	3.1E-06	3.25E+02	3.25E+05	
	3-Nitroaniline	1.00E-03	1.8E-07	1.00E-03	1.8E-04	5.71E+00	5.71E+03	
	4-Bromophenyl Phenyl Ether	1.00E-03	1.3E-05	NA	NA	NA	NA	
	4-Chloro-3-Methylphenol	1.00E-03	1.7E-06	1.00E-01	1.7E-05	5.81E+01	5.81E+04	
	4-Chloroaniline	1.00E-03	3.2E-07	5.00E-04	6.4E-04	1.56E+00	1.56E+03	
	4-Chlorophenyl Phenyl Ether	1.00E-03	1.8E-05	NA	NA	NA	NA	
	4-Methyl-2-Pentanone	1.00E-03	1.8E-07	8.00E-01	2.3E-07	4.39E+03	4.39E+06	
	4-Nitroaniline	1.00E-03	1.8E-07	1.00E-02	1.8E-05	5.59E+01	5.59E+04	
	Acenaphthene	1.00E-03	5.3E-06	2.00E-01	2.7E-05	3.76E+01	3.76E+04	
	Acenaphthylene <sup>(2)</sup>	1.00E-03	5.5E-06	2.00E-01	2.8E-05	3.60E+01	3.60E+04	
	Ingestion and Dermal	Acetone	1.00E-03	7.4E-08	2.00E+00	3.7E-08	2.70E+04	2.70E+07
		Alpha-BHC	1.00E-03	3.0E-06	8.00E-03	3.8E-04	2.65E+00	2.65E+03

**CALCULATION OF SCREENING LEVELS BASED NONCARCINOGENIC EFFECTS  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future Medium: Groundwater Exposure Medium: Water Receptor Population: Construction Worker Receptor Age: Adult
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Exposure Route	Chemical of Potential Concern	Assumed Water Concentration	Intake (Non-Cancer) <sup>(8)</sup>	Reference Dose <sup>(9)</sup>	Hazard Quotient Based on Assumed Water Concentration	RBC (noncancer)	RBC (noncancer)
		mg/L	mg/kg-day	mg/kg-day		mg/L	µg/L
	Anthracene	1.00E-03	9.9E-06	1.00E+00	9.9E-06	1.01E+02	1.01E+05
	Aroclor-1016	1.00E-03	5.1E-08	7.00E-05	7.3E-04	1.36E+00	1.36E+03
	Aroclor-1221	1.00E-03	1.0E-05	NA	NA	NA	NA
	Aroclor-1232	1.00E-03	1.0E-05	NA	NA	NA	NA
	Aroclor-1242	1.00E-03	5.1E-08	NA	NA	NA	NA
	Aroclor-1248	1.00E-03	5.1E-08	NA	NA	NA	NA
	Aroclor-1254	1.00E-03	5.1E-08	3.00E-05	1.7E-03	5.84E-01	5.84E+02
	Aroclor-1260	1.00E-03	5.1E-08	NA	NA	NA	NA
	Benzene	1.00E-03	7.2E-07	1.00E-02	7.2E-05	1.39E+01	1.39E+04
	Benzo(g,h,i)perylene <sup>(3)</sup>	1.00E-03	1.4E-04	3.00E-02	4.8E-03	2.10E-01	2.10E+02
	Benzo(k)fluoranthene	1.00E-03	5.1E-08	NA	NA	NA	NA
	Beta-BHC	1.00E-03	3.0E-06	NA	NA	NA	NA
	Bis(2-Chloroethoxy)Methane	1.00E-03	1.4E-07	3.00E-02	4.5E-06	2.21E+02	2.21E+05
	Bis(2-Ethylhexyl)Phthalate	1.00E-03	5.1E-08	1.00E-01	5.1E-07	1.95E+03	1.95E+06
	Bromodichloromethane	1.00E-03	3.5E-07	8.00E-03	4.4E-05	2.26E+01	2.26E+04
	Bromoform	1.00E-03	3.1E-07	3.00E-02	1.0E-05	9.59E+01	9.59E+04
	Bromomethane	1.00E-03	1.9E-07	5.00E-03	3.8E-05	2.65E+01	2.65E+04
	Butyl Benzyl Phthalate	1.00E-03	6.4E-06	2.00E+00	3.2E-06	3.14E+02	3.14E+05
	Carbazole	1.00E-03	3.5E-06	NA	NA	NA	NA
	Carbon Disulfide	1.00E-03	8.2E-07	1.00E-01	8.2E-06	1.21E+02	1.21E+05
	Carbon Tetrachloride	1.00E-03	1.1E-06	7.00E-03	1.5E-04	6.50E+00	6.50E+03
	Chlorobenzene	1.00E-03	1.5E-06	7.00E-02	2.1E-05	4.78E+01	4.78E+04
	Chlorodibromomethane	1.00E-03	3.3E-07	7.00E-02	4.8E-06	2.10E+02	2.10E+05
	Chloroethane	1.00E-03	3.2E-07	1.00E-01	3.2E-06	3.15E+02	3.15E+05
	Chloroform	1.00E-03	4.1E-07	1.00E-01	4.1E-06	2.42E+02	2.42E+05
	Chloromethane	1.00E-03	1.9E-07	NA	NA	NA	NA
	Cis-1,3-Dichloropropene <sup>(4)</sup>	1.00E-03	4.5E-07	3.00E-02	1.5E-05	6.63E+01	6.63E+04
	Delta-BHC <sup>(5)</sup>	1.00E-03	3.0E-06	8.00E-03	3.8E-04	2.65E+00	2.65E+03
	Dibenzofuran	1.00E-03	6.4E-06	4.00E-03	1.6E-03	6.26E-01	6.26E+02
	Dimethyl Phthalate	1.00E-03	1.6E-07	NA	NA	NA	NA
	Di-n-octyl Phthalate	1.00E-03	6.4E-04	1.00E-01	6.4E-03	1.56E-01	1.56E+02
	Endosulfan I <sup>(6)</sup>	1.00E-03	6.2E-07	6.00E-03	1.0E-04	9.63E+00	9.63E+03
	Endosulfan II <sup>(6)</sup>	1.00E-03	6.9E-07	6.00E-03	1.1E-04	8.73E+00	8.73E+03
	Endosulfan Sulfate <sup>(6)</sup>	1.00E-03	6.6E-07	3.00E-03	2.2E-04	4.54E+00	4.54E+03
	Endrin Aldehyde <sup>(7)</sup>	1.00E-03	1.1E-06	2.00E-03	5.6E-04	1.78E+00	1.78E+03
	Endrin Ketone <sup>(7)</sup>	1.00E-03	4.9E-06	2.00E-03	2.4E-03	4.10E-01	4.10E+02
Ingestion and Dermal	Ethylbenzene	1.00E-03	2.4E-06	1.00E-01	2.4E-05	4.17E+01	4.17E+04
	Fluorene	1.00E-03	7.1E-06	4.00E-01	1.8E-05	5.65E+01	5.65E+04
	Heptachlor Epoxide	1.00E-03	5.7E-06	1.30E-05	4.4E-01	2.29E-03	2.29E+00

CLIENT PNS		JOB NUMBER	
SUBJECT Lead Screening Level, CW Dermal Contact with GW			
BASED ON		DRAWING NUMBER	
BY L.C.	CHECKED BY MDIL	APPROVED BY	DATE

$$\text{Screening level (dw)} = \frac{(\text{PbB}_{\text{fetal}, 0.95} / (R \times (\text{GSD}_i^{1.645}))) - \text{PbB}_0 \times \text{AT}_w}{\text{BKSF} \times (\text{Kp} \times \text{ET} \times \text{CF} \times \text{A} \times \text{EF}_{\text{constw}})}$$

$$\text{PbB}_{\text{fetal}, 0.95} = 10 \text{ ug/dL}$$

$$R = 0.9$$

$$\text{BKSF} = 0.4 \text{ ug/dL per ug/day}$$

$$\text{GSD}_i = 1.8$$

$$\text{PbB}_0 = 1 \text{ ug/dL}$$

$$\text{Kp} = 0.0001 \text{ cm/hr}$$

$$\text{ET} = 8 \text{ hr/day or } 2 \text{ hr/day}$$

$$\text{CF} = 0.001 \text{ L/cm}^3$$

$$\text{EF}_{\text{constw}} = 150 \text{ days/yr.}$$

$$\text{AT}_w = 365$$

$$= \frac{([10 \text{ ug/dL} / (0.9 \times (1.8^{1.645}))]) - 1.0 \text{ ug/dL} \times 365}{0.4 \times (0.0001 \times 8 \text{ hr/day} \times 0.001 \times 3300 \times 150)}$$

$$= 7430 \text{ (assuming 8 hr. ET)}$$

$$= 29,700 \text{ (assuming 2 hr. ET)}$$

CLIENT PNS		JOB NUMBER	
SUBJECT Lead Screening level, CW Ingestion of GW			
BASED ON		DRAWING NUMBER	
BY L.C.	CHECKED BY MDK	APPROVED BY	DATE

$$\text{Screening level (iw)} = \frac{[(\text{PbB}_{\text{fetal}} / (R \times (\text{GSD}_i^{1.645}))) - \text{PbB}_0] \times \text{AT}_w}{\text{BKSF} \times (\text{IR}_w \times \text{AF}_w \times \text{EF}_{\text{constw}})}$$

$$\text{PbB}_{\text{fetal}} = 10 \text{ ug/dL}$$

$$R = 0.9$$

$$\text{BKSF} = 0.4 \text{ ug/dL per ug/day}$$

$$\text{GSD}_i = 1.8$$

$$\text{PbB}_0 = 1.0 \text{ ug/dL}$$

$$\text{IR}_w = 0.02 \text{ L/day}$$

$$\text{AF}_w = 0.60$$

$$\text{EF}_{\text{constw}} = 150 \text{ days/yr}$$

$$\text{AT}_w = 365 \text{ days/yr}$$

$$= \frac{[(10 \text{ ug/dL} / (0.9 \times (1.8^{1.645})))] - 1.0 \text{ ug/dL} \times 365 \text{ days/yr}}{(0.4 \text{ ug/dL} \times (0.02 \text{ L/day} \times 0.60 \times 150 \text{ days/yr}))}$$

$$= \frac{\text{per ug/day } 1177}{0.72} = \underline{\underline{1630 \text{ ug/L}}}$$

CLIENT PNS		JOB NUMBER	
SUBJECT Lead Screening Level, CW Inq. + Dermal w/ GW			
BASED ON		DRAWING NUMBER	
BY L.C.	CHECKED BY MDK	APPROVED BY	DATE

Screening level (combined ingestion and dermal)

$$= \frac{([10 \text{ ug/dL} / (0.9) \times (1.8^{1.645})]) - 1.0 \text{ ug/dL}}{\times 365}$$

$$\frac{(0.4 \text{ ug/dL} \cdot \underbrace{(0.024/\text{day} \times 0.6 \times 150 \text{ day/yr})}_{0.72}) + (0.4 \times \underbrace{(0.0001 \times 8 \times 0.001 \times 3300 \times 150)}_{0.1584})}{\times 150}$$

$$= 1340, (\text{assuming } 8\text{-hr ET})$$

**CALCULATION OF SCREENING LEVELS BASED NONCARCINOGENIC EFFECTS  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future Medium: Groundwater Exposure Medium: Water Receptor Population: Construction Worker Receptor Age: Adult
--

Exposure Route	Chemical of Potential Concern	Assumed Water Concentration	Intake (Non-Cancer) <sup>(8)</sup>	Reference Dose <sup>(9)</sup>	Hazard Quotient Based on Assumed Water Concentration	RBC (noncancer)	RBC (noncancer)
		mg/L	mg/kg-day	mg/kg-day		mg/L	µg/L
	Hexachlorocyclopentadiene	1.00E-03	1.3E-05	1.00E-01	1.3E-04	7.62E+00	7.62E+03
	Methoxychlor	1.00E-03	8.7E-06	5.00E-03	1.7E-03	5.73E-01	5.73E+02
	Methylene Chloride	1.00E-03	2.2E-07	6.00E-02	3.6E-06	2.77E+02	2.77E+05
	Nitrobenzene	1.00E-03	3.4E-07	5.00E-03	6.8E-05	1.47E+01	1.47E+04
	N-Nitroso-di-n-Propylamine	1.00E-03	1.8E-07	NA	NA	NA	NA
	N-Nitrosodiphenylamine	1.00E-03	1.2E-06	NA	NA	NA	NA
	Pyrene	1.00E-03	1.6E-05	3.00E-01	5.4E-05	1.85E+01	1.85E+04
	Styrene	1.00E-03	1.8E-06	2.00E-01	9.2E-06	1.09E+02	1.09E+05
	Tetrachloroethene	1.00E-03	2.3E-06	1.00E-01	2.3E-05	4.41E+01	4.41E+04
	Toluene	1.00E-03	1.5E-06	8.00E-01	1.8E-06	5.42E+02	5.42E+05
	Total 1,2-Dichloroethene	1.00E-03	4.2E-07	9.00E-03	4.7E-05	2.12E+01	2.12E+04
	Total Xylenes	1.00E-03	2.2E-06	4.00E-01	5.6E-06	1.78E+02	1.78E+05
	Toxaphene	1.00E-03	3.2E-06	NA	NA	NA	NA
	Trans-1,3-Dichloropropene <sup>(4)</sup>	1.00E-03	4.5E-07	3.00E-02	1.5E-05	6.63E+01	6.63E+04
	Trichloroethene	1.00E-03	7.0E-07	5.00E-04	1.4E-03	7.15E-01	7.15E+02
	Vinyl Chloride	1.00E-03	3.0E-07	3.00E-03	9.9E-05	1.01E+01	1.01E+04

1 - Values are for polychlorinated biphenyls - low risk.

2 - Toxicity values are for acenaphthene.

3 - Toxicity values are for pyrene.

4 - Toxicity values are for 1,3-dichloropropene.

5 - Toxicity values are for alpha-BHC.

6 - Toxicity values are for endosulfan.

7 - Toxicity values are for endrin.

8 - Intake = Ingestion Intake + (Dermal Intake x DAevent).

9 - Subchronic reference doses were presented if available. If no subchronic reference dose was available, the chronic reference dose is presented.

**CALCULATION OF SCREENING LEVELS BASED ON A TARGET CANCER RISK OF 1E-6  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Water
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value mg/L	Intake (Cancer) <sup>(6)</sup> mg/kg-day	Cancer Slope Factor (mg/kg-day) <sup>-1</sup>	Incremental Lifetime Cancer Risk	RBC (cancer) mg/L	RBC (cancer) µg/L
Ingestion and Dermal	4,4'-DDD	1.00E-03	4.6E-07	2.40E-01	1.11E-07	9.04E-03	9.04E+00
	4,4'-DDE	1.00E-03	7.3E-10	3.40E-01	2.50E-10	4.01E+00	4.01E+03
	4,4'-DDT	1.00E-03	7.3E-10	3.40E-01	2.50E-10	4.01E+00	4.01E+03
	Aldrin	1.00E-03	7.3E-10	1.70E+01	1.25E-08	8.02E-02	8.02E+01
	alpha-Chlordane	1.00E-03	1.1E-07	3.50E-01	3.83E-08	2.61E-02	2.61E+01
	Dieldrin	1.00E-03	3.8E-08	1.60E+01	6.07E-07	1.65E-03	1.65E+00
	Endrin	1.00E-03	3.8E-08	NA	NA	NA	NA
	gamma-BHC (Lindane)	1.00E-03	2.1E-08	1.10E+00	2.36E-08	4.24E-02	4.24E+01
	gamma-Chlordane	1.00E-03	1.1E-07	3.50E-01	3.83E-08	2.61E-02	2.61E+01
	Heptachlor	1.00E-03	2.6E-08	4.50E+00	1.16E-07	8.61E-03	8.61E+00
	PCB-hexachlorobiphenyl <sup>(1)</sup>	1.00E-03	8.1E-07	4.00E-01	3.24E-07	3.09E-03	3.09E+00
	1,2,4-Trichlorobenzene	1.00E-03	7.0E-08	2.90E-02	2.04E-09	4.91E-01	4.91E+02
	1,2-Dichlorobenzene	1.00E-03	3.6E-08	NA	NA	NA	NA
	1,3-Dichlorobenzene	1.00E-03	5.0E-08	5.40E-03	2.72E-10	3.68E+00	3.68E+03
	1,4-Dichlorobenzene	1.00E-03	3.7E-08	5.40E-03	1.98E-10	5.05E+00	5.05E+03
	2,4,6-Trichlorophenol	1.00E-03	4.1E-08	1.10E-02	4.51E-10	2.22E+00	2.22E+03
	2,4-Dichlorophenol	1.00E-03	2.0E-08	NA	NA	NA	NA
	2,4-Dimethylphenol	1.00E-03	9.0E-09	NA	NA	NA	NA
	2,4-Dinitrophenol	1.00E-03	2.4E-09	NA	NA	NA	NA
	2,4-Dinitrotoluene	1.00E-03	4.0E-09	3.10E-01	1.23E-09	8.11E-01	8.11E+02
	2,6-Dinitrotoluene	1.00E-03	2.9E-09	1.50E+00	4.37E-09	2.29E-01	2.29E+02
	2-Chlorophenol	1.00E-03	7.0E-09	NA	NA	NA	NA
	2-Ethoxy ethanol(Cellosolve)	1.00E-03	7.3E-10	NA	NA	NA	NA
	2-Nitrophenol	1.00E-03	4.1E-09	NA	NA	NA	NA
	3-Nitrophenol	1.00E-03	5.3E-09	NA	NA	NA	NA
	4-Chlorophenol	1.00E-03	9.8E-09	NA	NA	NA	NA
	4-Nitrophenol	1.00E-03	4.8E-09	NA	NA	NA	NA
	Acetaldehyde	1.00E-03	1.1E-09	NA	NA	NA	NA
	BaPEQ	1.00E-03	7.3E-10	7.30E+00	5.36E-09	1.87E-01	1.87E+02
	Benzo(a)anthracene	1.00E-03	7.3E-10	7.30E-01	5.36E-10	1.87E+00	1.87E+03
	Benzo(a)pyrene	1.00E-03	7.3E-10	7.30E+00	5.36E-09	1.87E-01	1.87E+02
	Benzo(b)fluoranthene	1.00E-03	7.3E-10	7.30E-01	5.36E-10	1.87E+00	1.87E+03
	Benzoic acid	1.00E-03	5.1E-09	NA	NA	NA	NA
	Benzyl chloride	1.00E-03	8.7E-09	1.70E-01	1.48E-09	6.74E-01	6.74E+02
	Bis(2-chloroethyl)ether	1.00E-03	2.2E-09	1.10E+00	2.47E-09	4.04E-01	4.04E+02
	Chrysene	1.00E-03	7.3E-10	7.30E-03	5.36E-12	1.87E+02	1.87E+05
	Dibenzo(a,h)anthracene	1.00E-03	7.3E-10	7.30E+00	5.36E-09	1.87E-01	1.87E+02

**CALCULATION OF SCREENING LEVELS BASED ON A TARGET CANCER RISK OF 1E-6  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Water
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value mg/L	Intake (Cancer) <sup>(6)</sup> mg/kg-day	Cancer Slope Factor (mg/kg-day) <sup>-1</sup>	Incremental Lifetime Cancer Risk	RBC (cancer) mg/L	RBC (cancer) µg/L
Ingestion and Dermal	Dibutyl phthalate	1.00E-03	4.3E-08	NA	NA	NA	NA
	Dichlorobenzidine, 3,3'	1.00E-03	2.2E-08	4.50E-01	9.93E-09	1.01E-01	1.01E+02
	Diethyl phthalate	1.00E-03	6.0E-09	NA	NA	NA	NA
	Dioxane, 1,4-	1.00E-03	9.6E-10	1.00E-01	9.59E-11	1.04E+01	1.04E+04
	Fluoranthene	1.00E-03	7.3E-10	NA	NA	NA	NA
	Hexachlorobenzene	1.00E-03	2.5E-07	1.60E+00	3.94E-07	2.54E-03	2.54E+00
	Hexachlorobutadiene	1.00E-03	1.3E-07	7.80E-02	1.00E-08	1.00E-01	1.00E+02
	Hexachloroethane	1.00E-03	4.6E-08	4.00E-02	1.83E-09	5.46E-01	5.46E+02
	Indeno(1,2,3-CD)pyrene	1.00E-03	7.3E-10	7.30E-01	5.36E-10	1.87E+00	1.87E+03
	Isophorone	1.00E-03	3.5E-09	9.50E-04	3.36E-12	2.97E+02	2.97E+05
	m-Cresol	1.00E-03	6.3E-09	NA	NA	NA	NA
	Naphthalene	1.00E-03	3.6E-08	NA	NA	NA	NA
	o-Cresol	1.00E-03	6.2E-09	NA	NA	NA	NA
	p-Cresol	1.00E-03	6.2E-09	NA	NA	NA	NA
	Pentachlorophenol	1.00E-03	7.3E-10	4.00E-01	2.94E-10	3.41E+00	3.41E+03
	Phenanthrene <sup>(3)</sup>	1.00E-03	7.3E-10	NA	NA	NA	NA
	Phenol	1.00E-03	3.7E-09	NA	NA	NA	NA
	Phenol,4,6-dinitro-2-methyl-	1.00E-03	4.4E-09	NA	NA	NA	NA
	TCDD	1.00E-03	7.3E-10	1.30E+05	9.54E-05	1.05E-05	1.05E-02
	1,1,1-Trichloroethane	1.00E-03	1.1E-08	NA	NA	NA	NA
	1,1,2,2-Tetrachloroethane	1.00E-03	7.4E-09	2.00E-01	1.48E-09	6.76E-01	6.76E+02
	1,1,2-Trichloroethane	1.00E-03	5.9E-09	5.70E-02	3.38E-10	2.96E+00	2.96E+03
	1,1,2-Trichlorotrifluoroethane	1.00E-03	1.9E-08	NA	NA	NA	NA
	1,1-Dichloroethane	1.00E-03	5.4E-09	5.70E-03	3.10E-11	3.23E+01	3.23E+04
	1,1-Dichloroethene	1.00E-03	8.7E-09	NA	NA	NA	NA
	1,2-Dichloroethane	1.00E-03	3.7E-09	9.10E-02	3.34E-10	3.00E+00	3.00E+03
	1,2-Dichloropropane	1.00E-03	6.4E-09	3.60E-02	2.32E-10	4.32E+00	4.32E+03
	2,2'-Oxybis(1-Chloropropane)	1.00E-03	8.1E-09	7.00E-02	5.66E-10	1.77E+00	1.77E+03
	2,4,5-Trichlorophenol	1.00E-03	4.2E-08	NA	NA	NA	NA
	2-Butanone	1.00E-03	1.4E-09	NA	NA	NA	NA
	2-Chloronaphthalene	1.00E-03	7.7E-08	NA	NA	NA	NA
	2-Hexanone	1.00E-03	3.2E-09	NA	NA	NA	NA
	Ingestion and	2-Methylnaphthalene	1.00E-03	7.4E-08	NA	NA	NA

**CALCULATION OF SCREENING LEVELS BASED ON A TARGET CANCER RISK OF 1E-6  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Water
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value mg/L	Intake (Cancer) <sup>(6)</sup> mg/kg-day	Cancer Slope Factor (mg/kg-day) <sup>-1</sup>	Incremental Lifetime Cancer Risk	RBC (cancer) mg/L	RBC (cancer) µg/L	
Dermal	2-Nitroaniline	1.00E-03	4.4E-09	NA	NA	NA	NA	
	3-Nitroaniline	1.00E-03	2.5E-09	NA	NA	NA	NA	
	4-Bromophenyl Phenyl Ether	1.00E-03	1.9E-07	NA	NA	NA	NA	
	4-Chloro-3-Methylphenol	1.00E-03	2.5E-08	NA	NA	NA	NA	
	4-Chloroaniline	1.00E-03	4.6E-09	2.00E-01	9.18E-10	1.09E+00	1.09E+03	
	4-Chlorophenyl Phenyl Ether	1.00E-03	2.5E-07	NA	NA	NA	NA	
	4-Methyl-2-Pentanone	1.00E-03	2.6E-09	NA	NA	NA	NA	
	4-Nitroaniline	1.00E-03	2.6E-09	2.00E-02	5.11E-11	1.96E+01	1.96E+04	
	Acenaphthene	1.00E-03	7.6E-08	NA	NA	NA	NA	
	Acenaphthylene <sup>(2)</sup>	1.00E-03	7.9E-08	NA	NA	NA	NA	
	Acetone	1.00E-03	1.1E-09	NA	NA	NA	NA	
	Alpha-BHC	1.00E-03	4.3E-08	6.30E+00	2.71E-07	3.69E-03	3.69E+00	
	Anthracene	1.00E-03	1.4E-07	NA	NA	NA	NA	
	Aroclor-1016	1.00E-03	7.3E-10	7.00E-02	5.14E-11	1.95E+01	1.95E+04	
	Aroclor-1221	1.00E-03	1.5E-07	2.00E+00	2.97E-07	3.36E-03	3.36E+00	
	Aroclor-1232	1.00E-03	1.5E-07	2.00E+00	2.97E-07	3.36E-03	3.36E+00	
	Aroclor-1242	1.00E-03	7.3E-10	2.00E+00	1.47E-09	6.81E-01	6.81E+02	
	Aroclor-1248	1.00E-03	7.3E-10	2.00E+00	1.47E-09	6.81E-01	6.81E+02	
	Aroclor-1254	1.00E-03	7.3E-10	2.00E+00	1.47E-09	6.81E-01	6.81E+02	
	Aroclor-1260	1.00E-03	7.3E-10	2.00E+00	1.47E-09	6.81E-01	6.81E+02	
	Benzene	1.00E-03	1.0E-08	5.50E-02	5.64E-10	1.77E+00	1.77E+03	
	Benzo(g,h,i)perylene <sup>(3)</sup>	1.00E-03	2.0E-06	NA	NA	NA	NA	
	Benzo(k)fluoranthene	1.00E-03	7.3E-10	7.30E-02	5.36E-11	1.87E+01	1.87E+04	
	Beta-BHC	1.00E-03	4.3E-08	1.80E+00	7.75E-08	1.29E-02	1.29E+01	
	Bis(2-Chloroethoxy)Methane	1.00E-03	1.9E-09	NA	NA	NA	NA	
	Bis(2-Ethylhexyl)Phthalate	1.00E-03	7.3E-10	1.40E-02	1.03E-11	9.73E+01	9.73E+04	
	Bromodichloromethane	1.00E-03	5.1E-09	6.20E-02	3.14E-10	3.19E+00	3.19E+03	
	Bromoform	1.00E-03	4.5E-09	7.90E-03	3.53E-11	2.83E+01	2.83E+04	
	Bromomethane	1.00E-03	2.7E-09	NA	NA	NA	NA	
	Butyl Benzyl Phthalate	1.00E-03	9.1E-08	1.90E-03	1.73E-10	5.78E+00	5.78E+03	
	Carbazole	1.00E-03	5.0E-08	NA	NA	NA	NA	
	Ingestion and	Carbon Disulfide	1.00E-03	1.2E-08	NA	NA	NA	NA

**CALCULATION OF SCREENING LEVELS BASED ON A TARGET CANCER RISK OF 1E-6  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Water
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value mg/L	Intake (Cancer) <sup>(6)</sup> mg/kg-day	Cancer Slope Factor (mg/kg-day) <sup>-1</sup>	Incremental Lifetime Cancer Risk	RBC (cancer) mg/L	RBC (cancer) µg/L
Dermal	Carbon Tetrachloride	1.00E-03	1.5E-08	7.00E-02	1.08E-09	9.28E-01	9.28E+02
	Chlorobenzene	1.00E-03	2.1E-08	NA	NA	NA	NA
	Chlorodibromomethane	1.00E-03	4.8E-09	8.40E-02	3.99E-10	2.51E+00	2.51E+03
	Chloroethane	1.00E-03	4.5E-09	NA	NA	NA	NA
	Chloroform	1.00E-03	5.9E-09	3.10E-02	1.83E-10	5.47E+00	5.47E+03
	Chloromethane	1.00E-03	2.7E-09	NA	NA	NA	NA
	Cis-1,3-Dichloropropene <sup>(4)</sup>	1.00E-03	6.5E-09	1.00E-01	6.47E-10	1.55E+00	1.55E+03
	Delta-BHC <sup>(5)</sup>	1.00E-03	4.3E-08	6.30E+00	2.71E-07	3.69E-03	3.69E+00
	Dibenzofuran	1.00E-03	9.1E-08	NA	NA	NA	NA
	Dimethyl Phthalate	1.00E-03	2.3E-09	NA	NA	NA	NA
	Di-n-octyl Phthalate	1.00E-03	9.1E-06	NA	NA	NA	NA
	Endosulfan I <sup>(6)</sup>	1.00E-03	8.9E-09	NA	NA	NA	NA
	Endosulfan II <sup>(6)</sup>	1.00E-03	9.8E-09	NA	NA	NA	NA
	Endosulfan Sulfate <sup>(6)</sup>	1.00E-03	9.4E-09	NA	NA	NA	NA
	Endrin Aldehyde <sup>(7)</sup>	1.00E-03	1.6E-08	NA	NA	NA	NA
	Endrin Ketone <sup>(7)</sup>	1.00E-03	7.0E-08	NA	NA	NA	NA
	Ethylbenzene	1.00E-03	3.4E-08	1.10E-02	3.77E-10	2.65E+00	2.65E+03
	Fluorene	1.00E-03	1.0E-07	NA	NA	NA	NA
	Heptachlor Epoxide	1.00E-03	8.1E-08	9.10E+00	7.38E-07	1.35E-03	1.35E+00
	Hexachlorocyclopentadiene	1.00E-03	1.9E-07	NA	NA	NA	NA
	Methoxychlor	1.00E-03	1.2E-07	NA	NA	NA	NA
	Methylene Chloride	1.00E-03	3.1E-09	2.00E-03	6.19E-12	1.61E+02	1.61E+05
	Nitrobenzene	1.00E-03	4.9E-09	NA	NA	NA	NA
	N-Nitroso-di-n-Propylamine	1.00E-03	2.6E-09	7.00E+00	1.82E-08	5.50E-02	5.50E+01
	N-Nitrosodiphenylamine	1.00E-03	1.8E-08	4.90E-03	8.69E-11	1.15E+01	1.15E+04
	Pyrene	1.00E-03	2.3E-07	NA	NA	NA	NA
	Styrene	1.00E-03	2.6E-08	NA	NA	NA	NA
	Tetrachloroethene	1.00E-03	3.2E-08	2.10E-03	6.81E-11	1.47E+01	1.47E+04
	Toluene	1.00E-03	2.1E-08	NA	NA	NA	NA
	Total 1,2-Dichloroethene	1.00E-03	6.1E-09	NA	NA	NA	NA
	Total Xylenes	1.00E-03	3.2E-08	NA	NA	NA	NA
	Ingestion and	Toxaphene	1.00E-03	4.6E-08	1.10E+00	5.01E-08	2.00E-02

**CALCULATION OF SCREENING LEVELS BASED ON A TARGET CANCER RISK OF 1E-6  
INGESTION AND DERMAL EXPOSURE OF CONSTRUCTION WORKERS TO WATER**

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Water
Receptor Population: Construction Worker
Receptor Age: Adult

Exposure Route	Chemical of Potential Concern	Medium EPC Value mg/L	Intake (Cancer) <sup>(8)</sup> mg/kg-day	Cancer Slope Factor (mg/kg-day) <sup>-1</sup>	Incremental Lifetime Cancer Risk	RBC (cancer) mg/L	RBC (cancer) µg/L
Dermal	Trans-1,3-Dichloropropene <sup>(4)</sup>	1.00E-03	6.5E-09	1.00E-01	6.47E-10	1.55E+00	1.55E+03
	Trichloroethene	1.00E-03	1.0E-08	4.60E-02	4.60E-10	2.18E+00	2.18E+03
	Vinyl Chloride	1.00E-03	4.2E-09	7.20E-01	3.04E-09	3.28E-01	3.28E+02

- 1 - Toxicity values are for polychlorinated biphenyls - low risk.
- 2 - Toxicity values are for acenaphthene.
- 3 - Toxicity values are for pyrene.
- 4 - Toxicity values are for 1,3-dichloropropene.
- 5 - Toxicity values are for alpha-BHC.
- 6 - Toxicity values are for endosulfan.
- 7 - Toxicity values are for endrin.
- 8 - Intake = Ingestion Intake + (Dermal Intake x DAevent).

**A-5 GEOTECHNICAL EVALUATIONS AND BORING LOGS**



PROJECT NAME: PORTSMOUTH NSY BORING NO.: WTB-SB01  
 PROJECT NUMBER: 6515 DATE: 7-13-98  
 DRILLING COMPANY: Maxim Tech GEOLOGIST: T. EVANS  
 DRILLING RIG: CME 75 DRILLER: J. Lear hard to

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FT.) or Screened Interval	MATERIAL DESCRIPTION			USCS	Remarks	PID/FID Reading (ppm)							
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole	Driller RZ				
	0.0																
	1.0			0-3-05			Asphalt 0-0.3		1515								
S-1		7/7	1.5/2.0		M Dense	DK Brn	Gravelly Silty Sand	GM	1515	road base							
	3.0	5/7					Silty F Sand	SM	1531	WTB-5501-002-98							
							Silt Tr-sand VF Sand	ML	1531	10.5-11.0							
	3.0							SM		(Till)							
S-2		7/10	1.8/2.0		M Dense	DK Brn	Silt some f sand	ML	1536	WTB-5801-0305-98							
	5.0	14/10					(mottled) clay	SM		(Till)							
S-3		11/20	1.2/1.2	6.7	Dense	tan Brn	F Sandy Silt Tr weathered high mag	ML	1547	Damp							
	7.0	24/100/2		III=III			(Till?) c sand	SM		1619 Drive 6" temp							
	8.0					DK Gray	Paragtzite			going to 6'							
										1625 5 7/8" AR							
	10.0									1656 10'							
							10.5-11.0 fracture										
	12.0						11.6-12.5 frac / H <sub>2</sub> O?										
	13.0			13.2 @ 1720						1715 13.5'							
	15.0									1753 continue							
										1804 15.5'							
	17.0																
	18.0									1812 17.5'							
	19.0						18.25 frac			1822 19.0							
				Base 19.0													
							#1 valve sand 7.8-19.0			1 1/2 bags							
							2" PVC 20 slot 9-19										
							Bentonite 5.6-7.8			3/8 bags							
							Grout 1.0-5.6			(neat cement)							

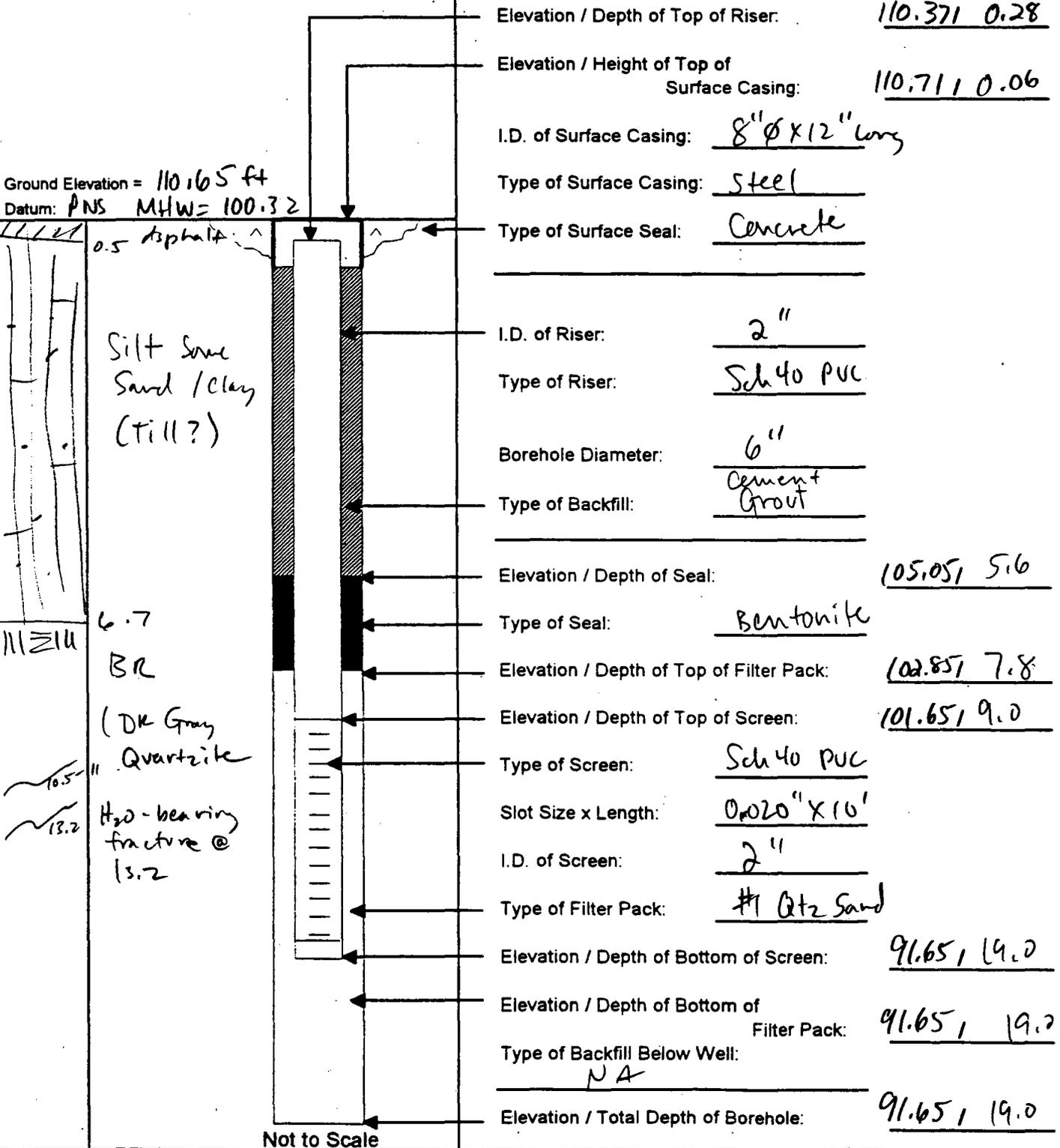
\* When rock coring, enter rock brokenness.  
 \*\* include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.  
 Remarks: 1 1/4" ID HSA, 3" SS  
 Drilling Area Background (ppm): 0.0

Converted to Well: Yes \_\_\_\_\_ No \_\_\_\_\_ Well I.D. #: \_\_\_\_\_



MONITORING WELL SHEET

PROJECT: PNS4 DRILLING Co.: MaximTech BORING No.: WTB-SB01  
 PROJECT No.: 6515 DRILLER: J. Leonhardt DATE COMPLETED: 7/15/98  
 SITE: 31 DRILLING METHOD: HSA NORTHING: 91599.33  
 GEOLOGIST: T. Evans DEV. METHOD: Bail EASTING: 346397.23





Tetra Tech NUS, Inc.

# WELL DEVELOPMENT DATA SHEET

PROJECT: PORTSMOUTH NSY  
 PROJECT No.: 6515  
 SITE: Site 31  
 PROJECT GEOLOGIST: T. Evans

WELL No.: WTRB-Mw01  
 DATE INSTALLED: 7-13-98  
 DATE DEVELOPED: 7-22-98  
 DRILLING Co.: Maxim Tech

### WELL DATA

WELL MATERIAL:  PVC  STAINLESS STEEL  OTHER: \_\_\_\_\_  
 TOTAL DEPTH: 18.51 (solid) feet (TOC bgs) CASING ID: 2" inches  
 STATIC WATER LEVEL: 7.73 feet (TOC bgs) SCREEN LENGTH: 10 feet  
 CASING VOLUME 1.75 (gal. / L) BOREHOLE DIA.: 6 inches

### PURGE DATA

START TIME: 1338 (hr.) METHOD: Bail  
 STOP TIME: 1534 (hr.) PUMP TYPE: NA

Time	Cumulative Volume (gal / L)	Pumping Rate (gpm / Lpm)	Water Level (ft. / m.)	Water Meter Type: <u>HORIBA U-10 / LaMotte 2020*</u>					Remarks (Color/Odor)
				pH	Sp. Cond. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/L)	
1350	6		17.34						Gray Brn Bail
1413	7		18.00						Gray Brn Bail / Dry
1431	-		16.00						-
1433	8		-	6.91	1.84	19.3	>999/02*	6.95	Gray Brn Bail
1437	9		18.03						Bail Dry
1451			16.38						
1458	10		18.14						Bail/Dry
1514			16.35						
1516			-	6.99	1.80	19.4	>999/02	7.64	Gray Brn Bail
1518			17.93						Bail Dry
1530	10.5		16.60	6.97	1.82	19.5	424/220	6.75	Cloudy
1534	11		17.73						Bail Dry/S

TOTAL PURGE VOLUME: 11 (gal / L) TOTAL PURGE TIME: 116 (min) hrs. )

NOTE: All depth measurements to nearest 0.01 foot.

COMMENTS/CALCULATIONS: HORIBA SIN 507012  
LaMotte 2020 SIN 0416-4457



PROJECT NAME: PORTSMOUTH NSY BORING NO.: WTB-SB02  
 PROJECT NUMBER: 6515 DATE: 7-8-98  
 DRILLING COMPANY: Maxim Tech GEOLOGIST: T. EVANS  
 DRILLING RIG: CM 75 DRILLER: J. Leonhardt

Sample No. and Type or RQD	Depth (FL) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FL) or Screened Interval	MATERIAL DESCRIPTION			USCS	Remarks	RQD ID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole*	Driller BZ**
	0.0								Time				
	1.0					Bm	Asphalt 0.0-0.35	SW	WTB-SB02-0001-98	0.0			
S-1		11/100	110.8/0.9		V Dense	Bm	Silty F Sand Tr F Gravel	SW	0.35-0.9	0.0			
	3.0						+ Gal Frag in shoe		Hard drilling 1.9-3.0				
S-2		2/3	0.7/2.0		V Loose	Black	Coal & Ash	SP	WTB-SB02-0305-98	0.0			
	5.0					White	Tr Fiber mat?						
S-3		3/2	1.4/2.0		Loose	Bm	M Sand, Coal granular, Ash	SP	0851	0.0			
	7.0					White to Rust							
S-4		2/2	1.3/2.0	2/7	V Loose	Rust	M-C Sand, Ash?	SW	WTB-SB02-0709-98	0.0			
	9.0					Bm	Some met rock frags		wet				
S-5		1/2	0.7/2.0		Loose	Rust Bm	Met Rock Frags, Some Ash	SW	0907	0.0			
	11.0					+ Black	M Sand Tr Lead shot	SW					
S-6		3/3	0.8/2.0		Loose	DK Gray	F-M Sand Tr Lead Shot	SP	0910	0.0			
	13.0						Met Rock Frags	SW					
S-7		1/1	0.8/2.0		Loose	Lt Bm	Met Rock Frags (0.5' o.i.)	GP	0917	0.0			
	15.0												
S-8		1/2	1.0/2.0		Soft	Dark Gray	Organic Silt Tr Plant stems & Shell	OL	WTB-SB02-1517-98	11.5			
	17.0									0.0			
S-9		2/3	2.0/2.0		M Stiff	Gray to Tan	Organic Silt	OL	0930	0.0			
	19.0					Gray	Clayey Silt	ML					
S-10		2/3	2.0/2.0		Soft	Tan Bm	F Sandy Silt	MH	0933	0.0			
	21.0												
S-11		well	1.8/1.8		V Soft	Bm Gray	Silt Some F Sand	MH	0938	0.0			
	23.0					Yellow Bm	F Sand & Met Rock Frags	SP/GP					
									Re Run @ 22.8'				
							Natural backfill 16-22.8' 5-15' screen		0950				

\* When rock coring, enter rock brokenness.

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

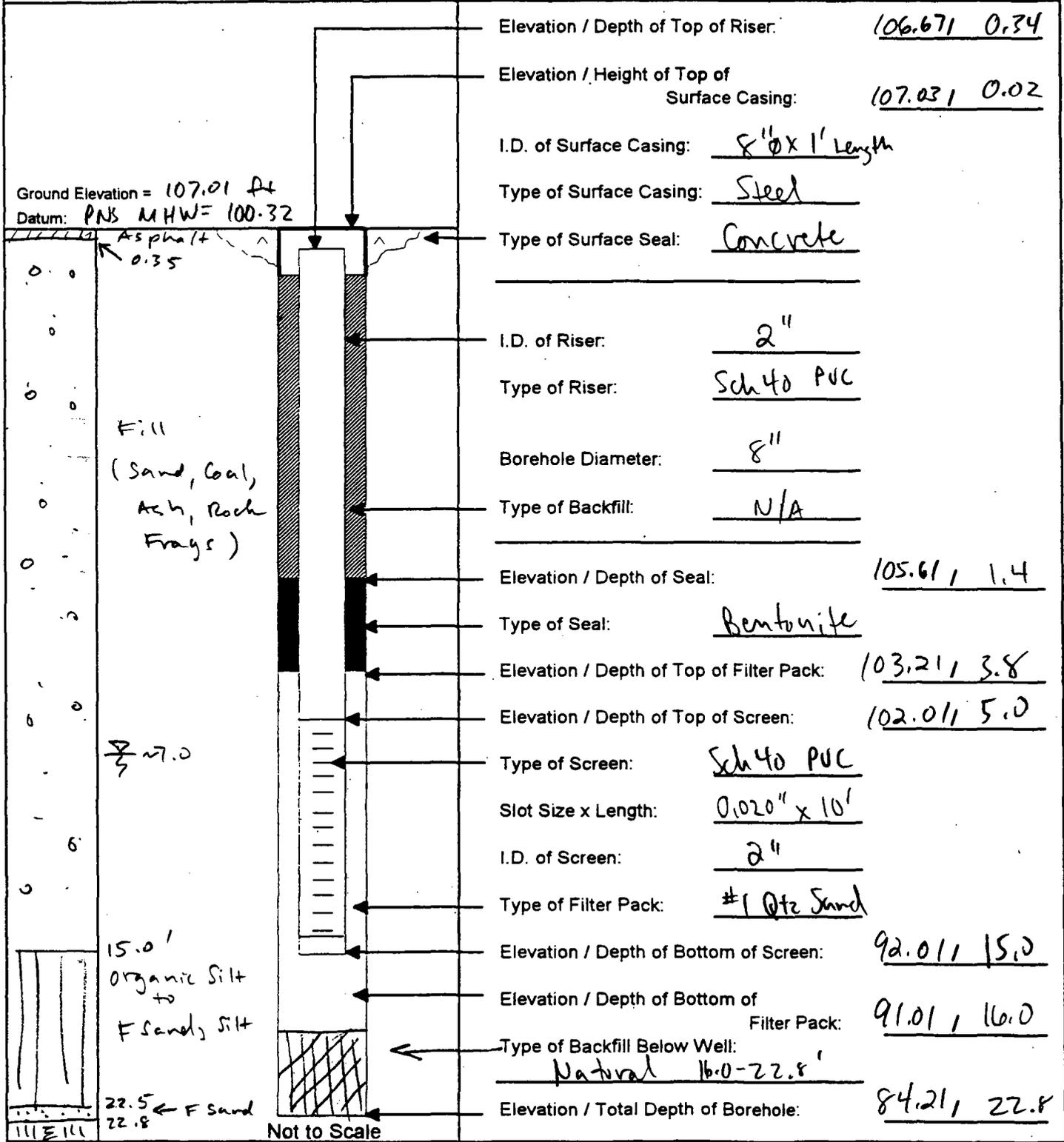
Remarks: 4 1/4" ID HSD 3" SS 0800-0930 P. Blais present Background (ppm): [C] ppm  
 • Collect MS/MSD High Tide @ 1127  
 \* Collect natural set

Converted to Well: Yes  No  Well I.D. #: WTB-MW02



MONITORING WELL SHEET

PROJECT: PNS4 DRILLING Co.: Maxim Tech BORING No.: WTB-SB02  
 PROJECT No.: 6515 DRILLER: J. Leonhardt DATE COMPLETED: 7-8-98  
 SITE: 31 DRILLING METHOD: HSA NORTHING: 91491.04  
 GEOLOGIST: T. Evans DEV. METHOD: Bail/Pump EASTING: 345996.07









PROJECT NAME:  
PROJECT NUMBER:  
DRILLING COMPANY:  
DRILLING RIG:

PORTSMOUTH NSY  
6515

BORING NO.:  
DATE:  
GEOLOGIST:  
DRILLER:

WTB-5803  
7-11-98  
T. EVANS  
J. Comhardt

Sample No. and Type or RQD	Depth (FT) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FT) or Screened Interval	MATERIAL DESCRIPTION			U S C S	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole*	Driller BZ
									Time				
	28.0												
S-9		2 2	1.0/1.0	28.3	Loose	Gray	Silt Tr F sand	MA	1138				0.0
	30.0	100/0		111E14 111E14 E03E 29.0		Yellow brn	F Sand	SP	Refusal @ 29.0'				
							Natural Backfill 25-29						
							Bentonite 17-25						
							#1 Sand 4.7-17			7 1/2 bags to 8.0' (50#) + 4 x 100 bags			
							2" screen (20-slot) 6-16						
							Bentonite 2.5-4.7			2 x 50# bags			

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

Remarks: \_\_\_\_\_

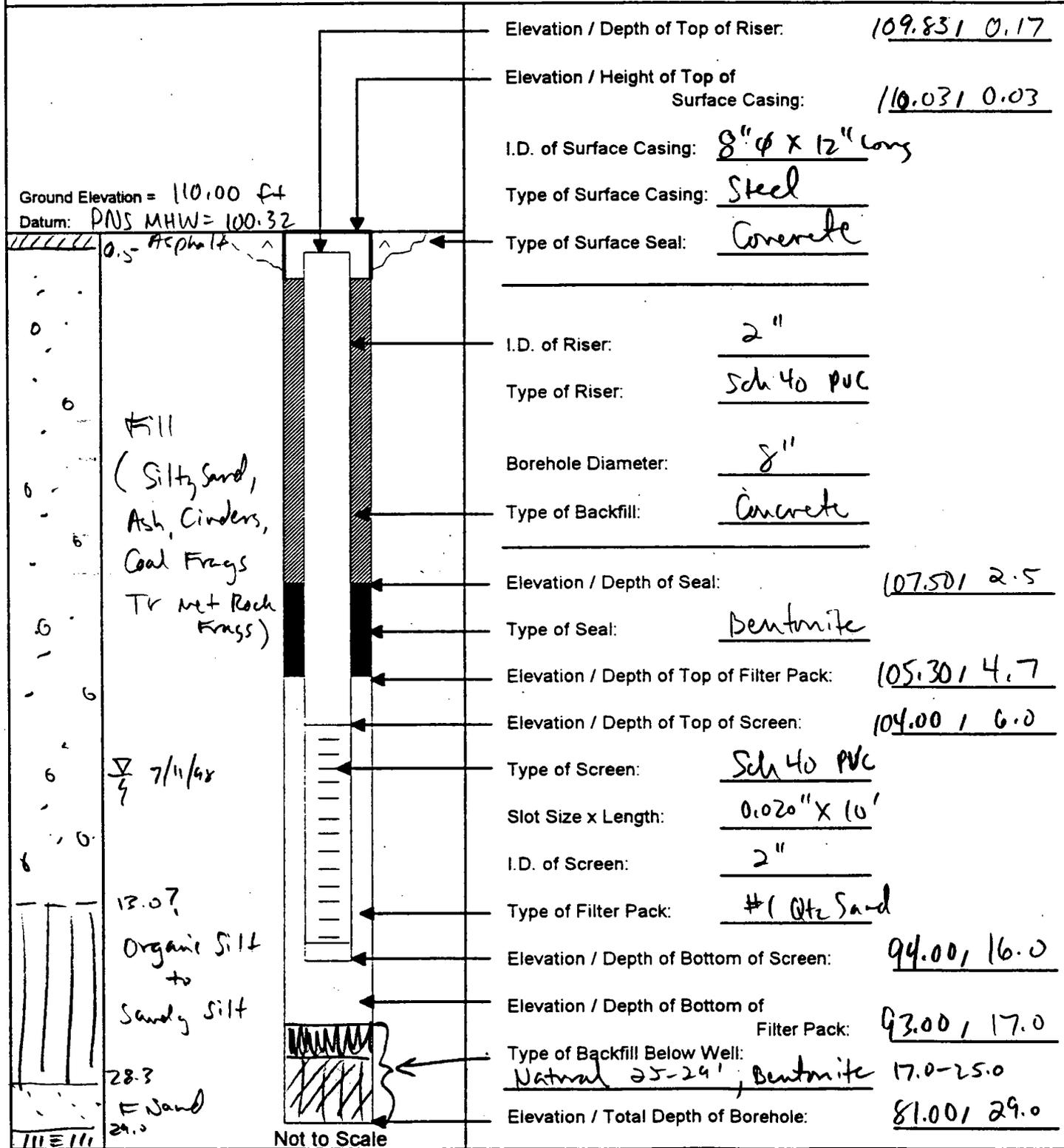
Drilling Area  
Background (ppm): 6.0

Converted to Well: Yes  No  Well I.D. #: WTB-MW03



MONITORING WELL SHEET

PROJECT: PNSY DRILLING Co.: Maxim Tech BORING No.: WTB-5803  
 PROJECT No.: 6515 DRILLER: J. Leinhardt DATE COMPLETED: 7-11-98  
 SITE: 31 DRILLING METHOD: HSA NORTHING: 91255.33  
 GEOLOGIST: T. Evans DEV. METHOD: EASTING: 346144.42





Tetra Tech NUS, Inc.

# WELL DEVELOPMENT DATA SHEET

PROJECT: PORTSMOUTH NSY  
 PROJECT No.: 6515  
 SITE: 31  
 PROJECT GEOLOGIST: T. Evans

WELL No.: WTB-MW03  
 DATE INSTALLED: 7-11-98  
 DATE DEVELOPED: 7-22-98  
 DRILLING Co.: Maxim

### WELL DATA

WELL MATERIAL:  PVC  STAINLESS STEEL  OTHER: \_\_\_\_\_

TOTAL DEPTH: 15.99 feet (TOC) bgs CASING ID: 2" inches  
 STATIC WATER LEVEL: 9.72 feet (TOC) bgs SCREEN LENGTH: 10 feet  
 CASING VOLUME 1.02 / 3.86 (gal. / L) BOREHOLE DIA.: 8 inches

### PURGE DATA

START TIME: 0945 (hr.) METHOD: Bail / Pump  
 STOP TIME: 1057 (hr.) PUMP TYPE: Grounds Redi Flo

Time	Cumulative Volume (gal./L)	Pumping Rate (gpm) / Lpm	Water Level (ft.) m.)	Water Meter Type: <u>Horiba U-10 / LaMotte 2020</u>					Remarks (Color/Odor)
				pH	Sp. Cond. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/L)	
1003	10								Gray Brn (Sil) opaque
1006	—	—	9.72			20.7			Start Pump
1012	20	1.7	9.78	7.40	.547	20.7	7999/02	0.80	gray (sil)
1018	30	1.7	9.80	7.21	.525	20.5	954/800	0.61	tan
1023	40	2.0	9.81	7.19	.522	20.4	7999/02	0.47	tan
1028	50	2.0	9.74	7.21	.516	20.6	82/70	0.69	clear
1032	60	2.5	9.79	7.22	.515	20.5	39/28	0.48	clear
1037	70	2.0	9.81	7.20	.511	20.5	14/13	0.59	clear
1042	80	2.0	9.79	7.21	.509	20.5	7/9.1	0.88	clear
1047	90	2.0	9.81	7.23	.509	20.6	12/6.3	0.46	clear
1052	100	2.0	9.81	7.21	.509	20.6	5/5.2	0.58	clear
1057	109	1.8	9.81	7.22	.510	20.6	0/4.5	0.67	clear/gray

TOTAL PURGE VOLUME: 109 (gal) / L) TOTAL PURGE TIME: 72 (min) / hrs. )

NOTE: All depth measurements to nearest 0.01 foot

COMMENTS/CALCULATIONS:  
Bail 1st 10 gal to remove fines  
Horiba S/N 507012  
LaMotte 2020 S/N  
0416 - 4467



PROJECT NAME: PORTSMOUTH NSY
PROJECT NUMBER: 6515
DRILLING COMPANY: Maxin Tech
DRILLING RIG: CME 75

BORING NO.: WTB-SB24
DATE: 7-8-98
GEOLOGIST: T. EVANS
DRILLER: J Leunhardt

Table with columns: 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, U S C S, Remarks, and PID Reading (ppm).

\* When rock coring, enter rock brokenness.
\*\* Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.
Remarks: 4 1/4" ID HPA, 3" SS. 1310-1415 Paula (rad) e WTB Background (ppm): 0.0
Low Tide @ 1713 High Tide @ 1127

Converted to Well: Yes [checked] No
Well I.D. #: WTB-MW04



PROJECT NAME: PORTSMOUTH NSY BORING NO.: WTB-5B04  
 PROJECT NUMBER: 6515 DATE: 7-8-94  
 DRILLING COMPANY: Max Tech GEOLOGIST: T. EVANS  
 DRILLING RIG: CME 75 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			U S C S *	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole**	Driller BZ**
	25.0								Time				
S-13		2/3	1.8/2.0		M Stiff	Brown Gray	Silt Some F Sand Some Clay Tr Rust spots	ML	1445				
	27.0	5/3											
	28.0												
S-14		1/2	2.0/2.0		M Stiff	Brown Gray	Clayey Silt (mottled)	ML	1455				
	30.0	2/3						TO MH					
	33.0												
S-15		3/6	1.6/2.0	-7-7- 31.5	Dense	Tan Brown	Sandy Silt / Silty F Sand	ML/SM	1505				
	35.0	12/19			34.0 34.65		to lt Brown	F Sand Some wet rock fraggs	SP				
	38.0									1515 Auger refusal @ 37.4'			
	40.0			≡    EUB@ 37.4						1530 Pull augers to 20' Natural backfill to 23.0'			
										1537 Convert boring to WTB-MW04			
										Bentonite 18'-23'			
										2" PVC screen 7'-17'			
										#1 Sand 6 - 18.0			
										Bentonite 1.5-6			

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

Remarks: \_\_\_\_\_

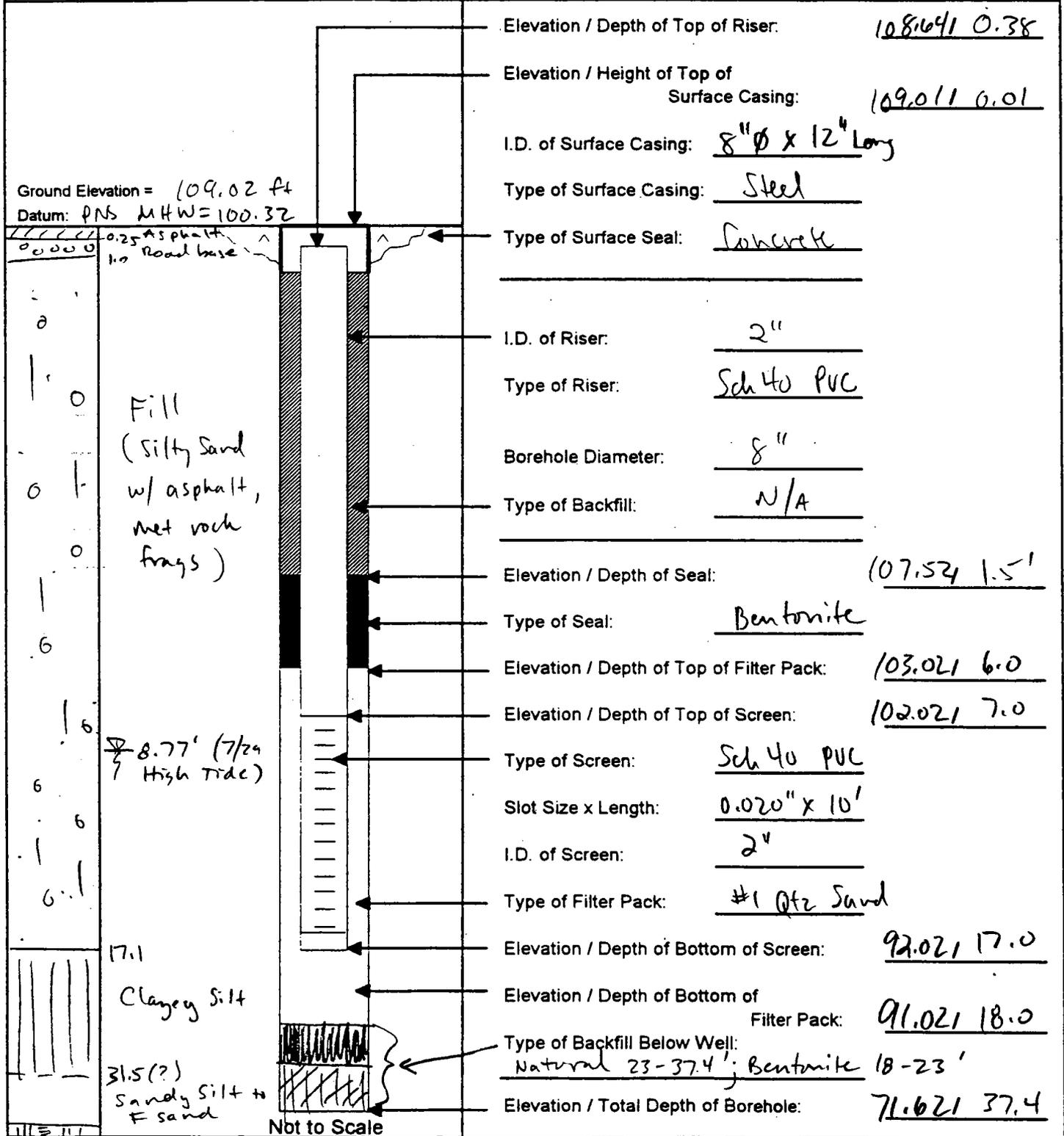
Drilling Area Background (ppm): [ ]

Converted to Well: Yes  No  Well I.D. #: WTB-MW04



MONITORING WELL SHEET

PROJECT:	<u>PNSY</u>	DRILLING Co.:	<u>Maxim Tech</u>	BORING No.:	<u>WTB-SB04</u>
PROJECT No.:	<u>6515</u>	DRILLER:	<u>J. Leinhardt</u>	DATE COMPLETED:	<u>7/8/98</u>
SITE:	<u>31</u>	DRILLING METHOD:	<u>HSA</u>	NORTHING:	<u>91049.46</u>
GEOLOGIST:	<u>T. Evans</u>	DEV. METHOD:	<u>Bail/Pump</u>	EASTING:	<u>346200.53</u>





Tetra Tech NUS, Inc.

WELL DEVELOPMENT DATA SHEET

PROJECT: PORTSMOUTH NSY
PROJECT No.: 6515
SITE: Site 31
PROJECT GEOLOGIST: T. Evans

WELL No.: WTB - MW04
DATE INSTALLED: 7-8-98
DATE DEVELOPED: 7-22-98
DRILLING Co.: Maxim Tech

WELL DATA

WELL MATERIAL: [X] PVC [ ] STAINLESS STEEL [ ] OTHER:
TOTAL DEPTH: 17.13 feet (TOC / bgs) CASING ID: 2" inches
STATIC WATER LEVEL: 8.53 feet (TOC) bgs) SCREEN LENGTH: 10 feet
CASING VOLUME (gal. / L) BOREHOLE DIA.: 8" inches

PURGE DATA

START TIME: 0800 (hr.) METHOD: Bail / Pump
STOP TIME: 0924 (hr.) PUMP TYPE: Ground Air Rediflow
BML / T&E

Table with columns: Time, Cumulative Volume (gal./L), Pumping Rate (gpm./Lpm), Water Level (ft./m.), Water Meter Type, pH, Sp. Cond. (mS/cm), Temp. (°C), Turbidity (NTU), DO (mg/L), Remarks (Color/Odor). Rows show data from 0813 to 0924.

TOTAL PURGE VOLUME: 87.5 (gal.) L ) TOTAL PURGE TIME: 84 (min.) / hrs. )

NOTE: All depth measurements to nearest 0.01 foot.

COMMENTS/CALCULATIONS:
Bail 1st 10 gal to remove fines.
0822 Switch to pump
HORIBA u-10 S/N 507012
La Motte 2020 S/N 0416-4497



PROJECT NAME: PORTSMOUTH NSY BORING NO.: WTB-5805  
 PROJECT NUMBER: 6515 DATE: 7-7-98  
 DRILLING COMPANY: Maxim Tech GEOLOGIST: T. EVANS  
 DRILLING RIG: CME 75 DRILLER: J. Leunhardt

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FL) or Screened Interval	MATERIAL DESCRIPTION			U S C S *	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole**	Driller BZ**
	0.0								Time				
	1.0						Asphalt 0-0.5'						
S-1	1.0	14	1.8	1.8	Dense	Brown	F Sand Tr F Gravel	SW	1340	WTB-5805-0701-98 @ 0.5-1.0	0.0	0.0	
	3.0	14	1.8	1.8		yellow brown	F Sand Tr F Gravel	SP	1352	Dry	0.0	0.0	0.0
S-2	3.0	8	0.6	2.0	Dense	Brown	F Silty F Sand Tr Gravel	SM					
	5.0	19	1.4	2.0			F Silty Silt Tr F Gravel	SM	1402	WTB-5805-0705-98 Dry	0.0		
S-3	5.0	6	1.4	2.0	M Dense	Tan Brown	F.M Sand VTR F Gravel	SP	1408	moist	0.0		
	7.0	6	0.8	2.0			Silt / sandy silt	ML					
S-4	7.0	4	0.8	2.0	Stiff				1418		0.0		
	9.0	9	1.3	2.0			Met Rock Frags			Rust Stained			
S-5	9.0	4	1.3	2.0	M Dense	Rust Brown	Same F Sand	GM	1423	Saturated @ 8.5	0.0		
	11.0	5											
	13.0												
S-6	13.0	1	1.5	2.0	Loose	Black Gray	F Silty Silt / Tr Shell & wood	SM/ML	1442	Natural (marine mud) H2S odor	3.1		
	15.0	3											
	17.0												
2" SS S-7	18.0	100								Refered @ 17.7'			
				EOS									
				17.7									
							Backfill bentonite 15-17.7		1515				
							2" PVC Screen 4-14						
							#1 Sand 2.9-15			← 2 3/4 bags			
							Bentonite 1.3-2.9						

\* When rock coring, enter rock brokenness.

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

Remarks: 4 1/4" ID HSA, 3" SS 1330 P. Blaise @ WTB (1510) Drilling Area P, Background (ppm): 0.

1622 Low Tide 1402 MN @ WTB (1510) 1 jar - metals, Cr<sup>6</sup>, TOC, pH, CN; 1 jar SUOC / P/P; 1 jar Tel UOC; 2-GRO; 1 jar

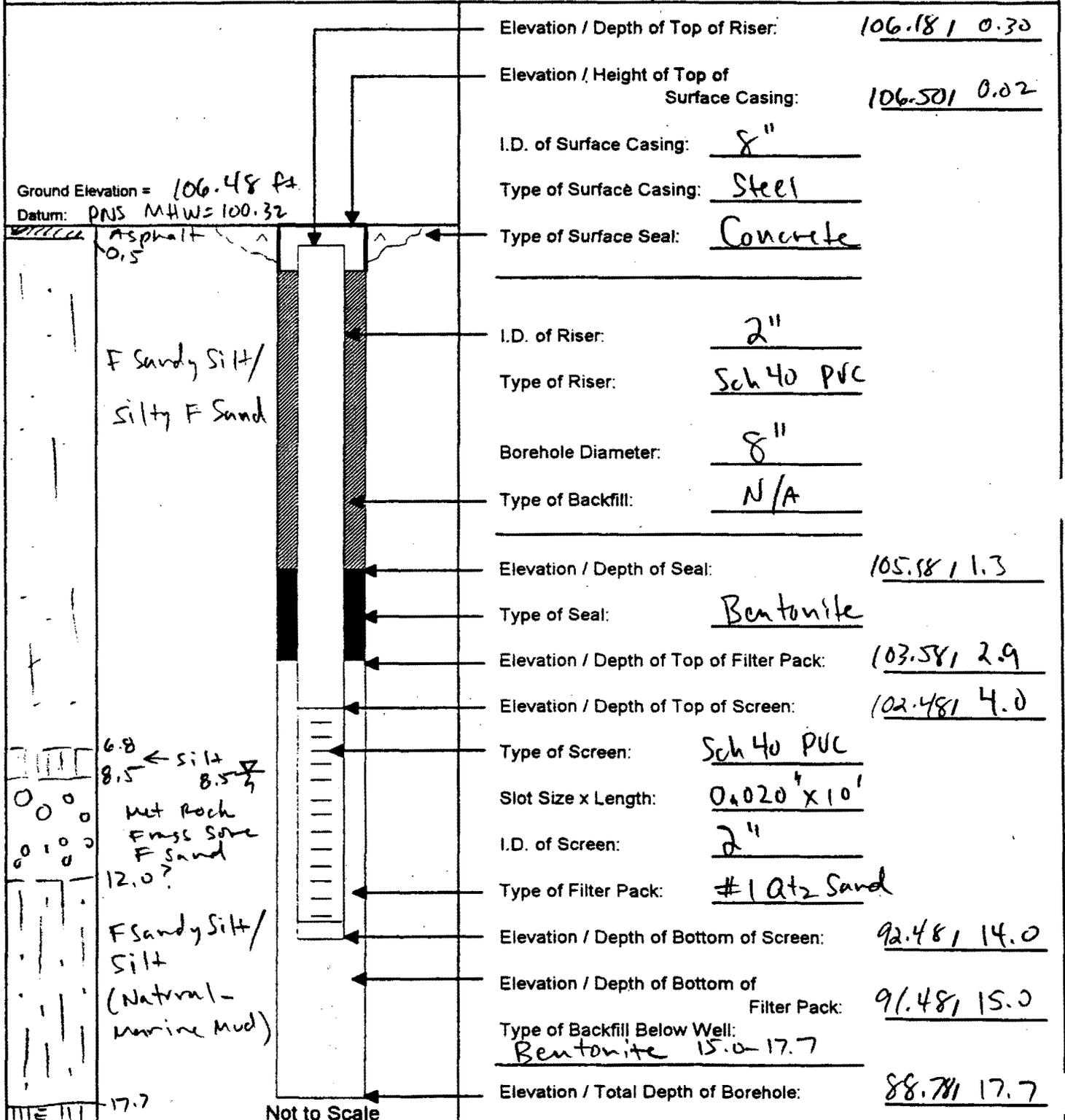
Converted to Well: Yes [X] No Well I.D. #: WTB-MW05

000 1 jar - metals + TOC; 1 jar SUOC + P/P; others normal sets  
0 Normal



MONITORING WELL SHEET

PROJECT: PNSY DRILLING Co.: Maxim Tech BORING No.: WTB-5B05  
 PROJECT No.: 6515 DRILLER: J. Leonhardt DATE COMPLETED: 7-7-98  
 SITE: 31 DRILLING METHOD: HSA NORTHING: 91134.30  
 GEOLOGIST: T. Evans DEV. METHOD: Pump EASTING: 345990.68





Tetra Tech NUS, Inc.

# WELL DEVELOPMENT DATA SHEET

PROJECT: PORTSMOUTH NSY  
 PROJECT No.: 6515  
 SITE: Site 31 - West Timber Basin  
 PROJECT GEOLOGIST: St. Evans

WELL No.: WTB-MW05  
 DATE INSTALLED: 7-7-98  
 DATE DEVELOPED: 7-21-98  
 DRILLING Co.: Maxim Tech

### WELL DATA

WELL MATERIAL:  PVC  STAINLESS STEEL  OTHER: \_\_\_\_\_  
 TOTAL DEPTH: 14.36' (solid) feet (TOC) bgs) CASING ID: 2" inches  
 STATIC WATER LEVEL: 7.45' feet (TOC) bgs) SCREEN LENGTH: 10 feet  
 CASING VOLUME: 1.13 / 4.2c (gal. / L) BOREHOLE DIA.: 8 inches

### PURGE DATA

START TIME: 1414 (hr.) METHOD: Pump  
 STOP TIME: 1614 (hr.) PUMP TYPE: Grundfos RediFlo (RTI/MP1)

Time	Cumulative Volume (gal / L)	Pumping Rate (gpm / Lpm)	Water Level (ft. / m.)	Water Meter Type: <u>HOV USA V-10 / La Motte 2025*</u>					Remarks (Color/Odor)
				pH	Sp. Cond. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/L)	
1420	5.0	0.83	10.76						DK Gray opaque
1427	10.0	0.71	11.35						Gray Brn / opaque
1437	15.0	1.0	10.45	7.49	37.1	17.0	999/0.2*	1.34	Gray Brn / cloudy
1451	20.0	0.71	11.25	7.53	37.4	16.2	470/300	1.97	Lt Gray Brn / cloudy
1505	30.0	0.71	11.53	7.50	37.5	15.7	141/70	0.68	Tan / clear
1513	35.0	0.63	12.02	7.50	38.0	15.4	70/33	0.62	Tan / clear
1519	40.0	0.81	12.02	7.51	38.1	15.2	73/45	0.69	Clear
1527	45.0	0.63	12.00	7.50	38.0	15.2	28/20	0.46	clear
1534	50.0	0.71	11.82	7.50	38.0	15.2	25/16	0.50	clear
1541	55.0	0.71	PM	7.50	38.0	15.2	14/11	0.41	clear
1547	60.0	0.83	11.79	7.51	38.1	15.2	16/7.9	0.59	clear
1602	70.0	0.67	11.81	7.52	38.1	15.0	14/10	0.92	clear
1609	75.0	0.71	11.84	7.51	38.0	15.2	5/6.0	0.66	clear
1614	79.0								clear / stop

TOTAL PURGE VOLUME: 79 (gal / L) TOTAL PURGE TIME: 120 (min.) hrs. )

NOTE: All depth measurements to nearest 0.01 foot.

COMMENTS/CALCULATIONS: High Tide @ 1025  
Low Tide @ 1614



PROJECT NAME: PORTSMOUTH NSY BORING NO.: WTB-SB06  
 PROJECT NUMBER: 6515 DATE: 7-15-48  
 DRILLING COMPANY: Maxim Tech GEOLOGIST: T. EVANS  
 DRILLING RIG: CME 75 DRILLER: J. Leonardt

Sample No. and Type or RGD	Depth (Ft) or Run No.	Blows / 6" or RGD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft) or Screened Interval	MATERIAL DESCRIPTION			U S C S	Remarks	PID ID Reading (ppm)							
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole	Driller BZ				
	0.0																
	1.0			22221			Asphalt 0-0.3 Gravel BASE 0.3-0.65		1430								
S-1		100/11				Bm	M-C Sand Tr F Gravel (2nd specimen Met rock frags)	SW	0165-10 Re-sample S/N N=12/40/18/10								
	3.0																
S-2		3/3	1.4/2.0		4.5	Loose	F-C Sand Tr F Gravel	SW	1457								
	5.0																
S-3		31/16	1.5/2.0			M Dense	Cinders & Coal frags Cinders (Ash 40-62)	SW	1458								
	7.0																
S-4		7/5	1.4/2.0			Loose	Silty F Sand Tr Rock Silt some C Sand & Ash (from water?)	SW	1505								
	9.0																
	13.0																
S-5		4/3	0.7/2.0			Dense	Black Met rock frags		1515								
	15.0						- Poor Recovery -										
	15.0																
S-6		3/0	2.0/2.0			M Dense	F Sandy Silt to Clayey Silt	MH	1525 + SBFD - 071598								
	20.0																
	23.0																
S-7		3/4	1.8/2.0			Stiff	Clayey Silt	MH	1531								
	25.0																

\* When rock coring, enter rock brokenness.

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

Remarks: 4 1/4" 10 HSA 3" SS 1415-1530 P Blais @ WTB Drilling Area Background (ppm):           
1415 plate yard closes @ 1500 hrs - talk to worker - will stay open to 1600

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





PROJECT NAME: PORTSMOUTH NSY
PROJECT NUMBER: 6515
DRILLING COMPANY: Maxim Tech
DRILLING RIG: CME 75

BORING NO.: WTB-5B07
DATE: 7-11-98
GEOLOGIST: T. EVANS
DRILLER: J. Leonhardt

Table with columns: 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, U S C S, Remarks, and PDI/D Reading (ppm).

\* When rock coring, enter rock brokenness.

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

Remarks: 4 1/4" ID HDA, 3" SS 1435-1510 P. Beauvoir @ WTB
Normal sed

Converted to Well: Yes No X Well I.D. #:
VOC, SVOC, P/P; Metals, Cr+6; TPC, CN, PH; DRD; GPO

Drilling Area
Background (ppm):



PROJECT NAME: PORTSMOUTH NSY  
PROJECT NUMBER: 6515  
DRILLING COMPANY: Maxin Tech  
DRILLING RIG: CME 75

PORTSMOUTH NSY  
6515  
Maxin Tech  
CME 75

BORING NO.: TP-5801  
DATE: 6-22-98  
GEOLOGIST: T. EVANS  
DRILLER: J. Leavelle

TP-5801  
6-22-98  
T. EVANS  
J. Leavelle

Sample No. and Type or RQD	Depth (FT) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FL) or Screened Interval	MATERIAL DESCRIPTION			U S C S	Remarks	Pb, FID Reading (ppm)							
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole*	Driller BZ**				
	0.0																
	1.0					Brn	F Sand Tr Silt & Frag	SN	1345 0.5-1.0	0.0							
S-1		7/9	1.4/2.0	2.5	M Dense	Brn	Silt & wet rock Frag	GM	1351								
	3.0	9/7		2.9		Brn Red	Silt Some Clay Beat (wood chips)	ML PL		0.0							
S-2		3/6	1.4/2.0	3.0	Stiff	Brn	Silt Tr to Sand (Clay mottled)	ML to MH	1401 Moist @ tip Damp								
	5.0	6/8		5.2													
S-3		2/5	2.0/2.0	6.7	M Stiff to Stiff				1409								
	7.0	8/16		6.7		Brn	F.M sand	SP									
	8.0			6.7													
S-4		18/19	1.5/2.0		Dense	Brn	F Sand Tr (sand)	SP	1419 Saturated	0.0							
	10.0	22/25				Brn	Silty F Sand Some Frag	SW	Till(?)								
S-5		24/27	1.0/2.0		M Dense	Gray	Silty F Sand Some Frag	SW	1430								
	12.0	9/9				Brn											
S-6		20/12	0.8/1.5	13.5	M Dense to Dense	Gray	Silty F Sand Tr Frag	SM	1443								
	14.0	7/10		13.5					Refusal @ 13.5								
				13.5		DK Gray	Relict wet rock		1515 Drive 6" @ Casin	to 13.5							
	16.0					DK Gray	wet siltstone		1550 5 7/8" rollerbit								
							-H2O zone @ 16' - @ 1728		13.5' - 16.5'								
	18.0			EOB 16.5'					14.0' @ 1439								
									15.0' @ 1700								
									16.5' @ 1737								
									6/23 SWL = 5.21' @ 95								
									Set 2" PVC screen 6.5-16.5	(20-56)							
									#1 Sand 5.6-16.5								
									Reamite 3.0-5.6								

\* When rock coring, enter rock brokenness.

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

Remarks: 4 1/4" ID HSA 3" SS

TP-5801-0001-98  
TP-5801-0305-98

TP-5801-0910-98  
TP-5801-1214-98

Converted to Well: Yes

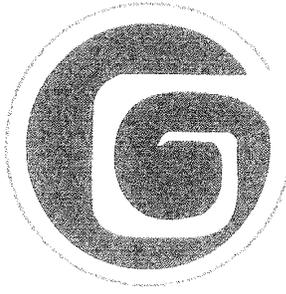
Yes

No

Well I.D. #:

TP- MW01

Drilling Area PID  
Background (ppm): 0.0



## R. W. Gillespie & Associates, Inc.

Geotechnical Engineering • Geohydrology • Materials Testing Services

12 June 2009

05 January 2010 (Revised)

Steven J. Towne, P.E.  
Oak Point Associates  
73 Court Street  
Portsmouth, NH 03801

Subject: Geotechnical Evaluation  
Waterfront Support Facility - Portsmouth Naval Shipyard  
Kittery, Maine  
RWG&A Project No. 767-42

Dear Mr. Towne:

R. W. Gillespie & Associates, Inc., (RWG&A) is pleased to present the results of our geotechnical evaluation for the Waterfront Support Facility at the Portsmouth Naval Shipyard in Kittery, Maine. This work was performed in general accordance with RWG&A's proposal to you dated 20 January 2009 (revised) (note: RWG&A Proposal No. P-6354GI). The purpose of the evaluation was to obtain information regarding subsurface conditions and soil/rock properties on which to base recommendations for design and construction of foundations and floor slabs. RWG&A prepared a draft Geotechnical Evaluation dated 12 June 2009. This report incorporates recent field work and recommendations for an addition to Building 175 and rack storage in the high bay area of Building 174, and supercedes the draft report in it's entirety.

The attached report presents the results of RWG&A's subsurface explorations, laboratory testing, and engineering evaluations, and provides geotechnical design recommendations. In summary, subsurface conditions consist of bituminous pavement over fill underlain by naturally deposited stiff to very soft silty clay underlain by silty sand with gravel extending to bedrock. Fill extended to depths of 12.5 to 23 feet below local ground surface and consisted of silty sand, sandy silt, and/or gravelly sand mixed with varying amounts of shot rock, brick, organics, and other debris. Organic silt was encountered in four explorations between the fill and silty clay. Explorations were terminated on refusal surfaces at depths of 16 to 76 feet below current ground surface. Boring B-103 encountered refusal on an obstruction in the fill at a depth of 16 feet below current ground surface. Two explorations were extended below refusal surfaces using rock coring

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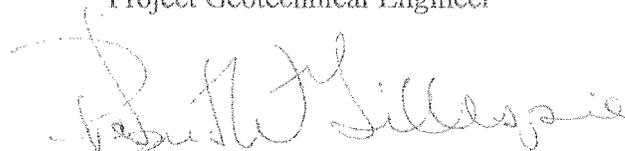
techniques, and two explorations were extended below refusal using roller-cone drilling techniques. Free water was observed in each of the explorations at depths of about 5 to 8.5 feet below local ground surface. Crosshole testing was performed in two boreholes to measure shear wave velocity of on-site soils.

The fill and organic silt encountered are not suitable to support the proposed additions or rack storage areas on conventional shallow foundations. Removal of these materials and replacement with structural fill is not considered practicable due to depth, groundwater levels, and potential environmental issues; it is recommended the proposed addition to Building 174 and rack storage area be supported on a deep foundation system consisting of driven steel H-piles. The addition to Building 175 could be supported on a mat foundation, but the magnitude of total and differential settlement is greater than tolerable limits and should be supported on driven H-piles. The floor slab of pile supported areas should be designed as a structural slab. The on-site fill soils are not suitable for reuse as structural fill or pavement base or subbase, but might be suitable to be used as fill beneath pile supported areas and as backfill around pile caps and grade beams. On-site materials should be stockpiled and tested during construction.

We have enjoyed working with Oak Point Associates on this project. If you have any questions or if we may be of further service, please contact us.

Very truly yours,  
R. W. GILLESPIE & ASSOCIATES, INC.

Marc R. Grenier, P.E.  
Project Geotechnical Engineer



Robert W. Gillespie, P.E.  
Principal Geotechnical Engineer

MRG/RWG:md  
In quadruplicate

Report  
of  
GEOTECHNICAL EVALUATION  
for  
WATERFRONT SUPPORT FACILITY - PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE

Prepared  
for  
OAK POINT ASSOCIATES  
PORTSMOUTH, NEW HAMPSHIRE

Prepared  
by  
R. W. GILLESPIE & ASSOCIATES, INC.  
PORTSMOUTH, NEW HAMPSHIRE



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Robert W. Gillespie  
Maine PE No. 4975

# R. W. Gillespie & Associates, Inc.

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### FIGURES:

- Figure 1. Locus Map
- Figure 2. Exploration Location Plan

### APPENDICES:

- Appendix A. Test Boring Logs
- Appendix B. Test Pit and Trench Excavation Logs
- Appendix C. Hager-Richter Geoscience, Inc. Report
- Appendix D. Laboratory Testing

# R. W. Gillespie & Associates, Inc.

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## 1.0 INTRODUCTION

### 1.1 Background

The project consists of an addition to the east side of Building 174, an addition to the north side of Building 175, and rack storage in the high bay area of Building 174 at the Portsmouth Naval Shipyard in Kittery, Maine, as illustrated on Figure 1, *Locus Map*. Currently, the project area is covered with bituminous pavement, occupied temporary structures, and dumpsters. Topography is relatively flat, but slopes down slightly from north to south.

R.W. Gillespie & Associates, Inc.'s (RWG&A's) understanding of site conditions and proposed construction is based on review of the current plans and record drawings provided, as follows:

#### Current Project Plans

- Sheet CX-101, *Existing Conditions Site Plan*, dated 25 November 2009, prepared by Oak Point Associates.
- Sheet C-101, *Site Plan*, dated 25 November 2009, prepared by Oak Point Associates.

#### Record Drawings

- *Building 174 Utility Building Foundation Plan and Details*, dated June 5, 1942, prepared by Chas T. Main Inc. Engineers.
- *Polaris Overhaul Facility, East and West Additions to Building 174, Location Plan and Boring Logs*, dated November 2, 1960, prepared by the Department of the Navy.
- *Addition for Polaris Launch System Overhaul, Borings*, dated March 14, 1963, prepared by the Department of the Navy.
- *Addition for Polaris Launch System Overhaul, Foundation and 1<sup>st</sup> Floor Plan*, dated March 14, 1963, prepared by the Department of the Navy.
- *Addition to Building 174, Foundation Plan and Sections*, dated December 4, 1978, prepared by Lev Zetlin Associates, Inc.

## 1.2 Scope

This evaluation was performed to develop site-specific soil conditions, and to make geotechnical evaluations for the proposed construction. As performed, our scope of work included the following items:

1. Prepared a program of subsurface explorations to obtain information for foundation and earthwork design.
2. Arranged to have the subsurface explorations performed by a local contractor. Provided technical monitoring of the exploration activities so that depths, locations, and sampling methods could be modified in response to the subsurface conditions encountered. As part of the exploration activities, installed PVC casing in two bore holes to facilitate crosshole shear wave testing. Coordinated with Hager-Richter Geoscience, Inc., to perform crosshole shear wave testing in order to evaluate seismic design parameters.
3. Performed laboratory tests on selected soil samples recovered from the subsurface explorations to aid in soil description and for determination of engineering properties needed for foundation design and site development evaluations.
4. Conducted engineering evaluations of the geotechnical aspects of foundation and slab design, and evaluated construction and site development issues. The engineering evaluations emphasized building foundations and slabs, and site design criteria.
5. Prepared this report presenting the findings, conclusions, and recommendations of the geotechnical evaluation.

RWG&A's scope of services on this project did not include an environmental site assessment for the presence or impact of oil or hazardous materials on the proposed construction or worker safety. The Government should provide RWG&A's reports and all other information related to subsurface and environmental site conditions that might be encountered or affect construction activities or worker safety to project contractors for informal purposes.

## 2.0 SUBSURFACE EXPLORATION

The subsurface exploration program consisted of seventeen test borings advanced to depths ranging from 16 to 76 feet below local ground surface. Explorations were drilled between 27 April and 08 May 2009 and 09 to 11 November 2009 by Great Works Pump & Test Boring, Inc., of

Rollinsford, New Hampshire, using a truck-mounted drill rig. Split-barrel sampling with standard penetration testing (*ASTM D1586, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*) was performed at about 5-foot intervals in most of the explorations. Relatively continuous sampling of the existing fill was performed in boring B-7. The explorations were advanced with driven casing and washed boring techniques. Borings B-9 and B-15 were extended 7.5 feet and 5.5 feet, respectively, below refusal surfaces with rock coring techniques, and borings B-101 and B-104 were extended 16.5 feet and 17.5 feet, respectively, with roller cone drilling techniques. Thin-wall tube samples of soft silty clay were recovered from boring B-5. Borings B-3, B-4, and B-11 were not drilled in the initial phase of drilling due to access problems and issues with underground utilities. Borings B-101 and B-104 were drilled as replacements for B-4 and B-3, respectively. PVC casing (3-inch ID) was grouted in borings B-101 and B-104 to allow verticality measurements by Hager-Richter Geoscience, Inc. as part of their seismic survey analysis. Field vane tests (*ASTM D2573, Standard Test Method for Field Vane Shear Test in Cohesive Soil*) were conducted with an Acker field vane in silty clay deposits in boring B-104 in lieu of standard penetration tests.

A total of 11 test pits (designated TP) and 12 trench excavations (designated Q) were also made at the site in order to obtain samples for environmental testing or to determine the location of a historic quay wall. The logs of test pits and trench excavations are included in Appendix B and excavation locations are shown on the *Exploration Location Plan* for informational purposes only. Results of analytic testing will be provided to Oak Point Associates by RWG&A under separate cover.

Exploration activities were coordinated and monitored by RWG&A personnel who prepared the exploration logs. The soils were described in general accordance with *ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*. Logs of the explorations are included in Appendix A. Stratification lines shown on the exploration logs represent the estimated boundaries between the different soil types encountered and approximate refusal depths; the actual transitions will be more gradual and vary over short distances.

Figure 2, *Exploration Location Plan*, shows the locations of the explorations. Exploration locations shown were located in the field by Oak Point Associates using GPS and other survey techniques. Elevations of the borings were measured during the survey operations. Locations and elevations should be considered accurate only to the degree implied by the methodology used to determine them.

## 3.0 LABORATORY TESTING

Laboratory testing was performed to assist in description and estimation of engineering properties of the soils. The laboratory testing program consisted of six (6) sieve analyses and fourteen (14) natural moisture content determinations. The tests were performed in general accordance with the following methods and procedures:

- *ASTM D2216, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.*
- *ASTM D422, Standard Test Method for Particle-Size Analysis of Soils.*

Moisture content test results are presented on the test boring logs. Results of the other laboratory tests are presented in Appendix D, *Laboratory Test Results*. All tests were conducted at the RWG&A soil and materials testing laboratory in Saco, Maine, which is accredited by the American Association of State Highway and Transportation Officials (AASHTO) for the tests performed.

## 4.0 SUBSURFACE CONDITIONS

### 4.1 Subsurface Soils

Six different units were encountered in the explorations: concrete, bituminous pavement, fill, organic silt, silty clay, and silty sand with gravel. In general, the conditions encountered consisted of concrete or bituminous pavement over fill underlain by stiff to very soft silty clay underlain by silty sand with gravel extending to refusal. Fill extended to depths of 12.5 to 23 feet below local ground surface and consisted of silty sand, sandy silt, silty clay, and/or gravelly sand mixed with varying amounts of shot rock, brick, organic material, and other debris. An organic silt layer 4.5 to 5 feet thick was encountered between fill and silty clay in borings B-6, B-13, B-14, and B-16.

Explorations were advanced to depths of 16 to 76 feet below local ground surface and were terminated on refusal surfaces. Boring B-103 encountered refusal on an obstruction at a depth of 16 feet below ground surface. Borings B-9 and B-15 were extended 7.5 feet and 5.5 feet, respectively, below top of bedrock using rock coring techniques. Borings B-101 and B-104 were extended 16.5 feet and 17.5 feet, respectively, below top of bedrock using roller cone drilling techniques. Please refer to the exploration logs in Appendix A for detailed descriptions at specific locations.

## 4.2 Groundwater

Free water was observed in the explorations at depths of about 5 to 8.5 feet below local ground surface. Water levels observed during the subsurface exploration program were influenced by the exploration methods (e.g., introduction of wash water and slow groundwater response due to low soil permeability) and are not considered representative of stabilized groundwater levels. Groundwater levels at the site will fluctuate due to tide, season, temperature, rainfall and construction activity in the area; therefore, water levels during and following construction will vary from those observed in the explorations.

## 4.3 Bedrock

Based on the results of the rock coring, refusals encountered in the explorations are interpreted to represent bedrock. Bedrock recovered during coring in borings B-9 and B-15 was described as medium hard, moderately weathered, light gray, fine grained Argillaceous Slate, with very close to close fracture spacing. The bedrock encountered is part of the Kittery Formation and is highly fractured, especially near the top of bedrock surface.

## 4.4 Concrete

Concrete slabs inside Building 174 and in existing and demolished buildings within the proposed building area were cored to determine thickness. Core C-4 was performed in an area of asphalt pavement. Core C-8 consisted of 7.5 inches of concrete underlain by 3 inches of asphalt. The following table shows the results of the concrete coring. Locations are provided on Figure 2.

Location	Thickness (in)	Location	Thickness (in)
B-5	5	C-4	4**
B-16	7	C-5	7
C-1	8.5	C-6	7
C-2	6.5	C-7	4.25
C-3	9.5	C-8	10.5*

\* 7.5 inches of concrete underlain by 3 inches of asphalt.

\*\* 4 inches of asphalt only.

## 4.5 Seismic Design Parameters

Hager-Richter Geoscience, Inc., performed crosshole seismic testing in a two borehole array (comprised of borings B-101 and B-104 with 3-inch ID PVC casing installed) on 19 November 2009. The testing was conducted in accordance with applicable portions of *ASTM D4428/D4428 M-00 Standard Test Methods for Crosshole Seismic Testing* and was performed to confirm the UBC site seismic designation. Hager-Richter's report is provided in its entirety in Appendix C.

## 5.0 EVALUATION OF GEOTECHNICAL DATA

### 5.1 General

Engineering evaluations for this project are based on the subsurface explorations, laboratory testing data, and the conceptual construction information currently available to RWG&A. Proposed site grades were not finalized when this report was written. This report addresses geotechnical issues with addition finished floors matching the existing buildings and site layout as illustrated on *Site Plan*, dated 25 November 2009, prepared by Oak Point Associates.

This report is suitable for planning and design but not for construction. The engineering evaluations that follow should be reviewed by RWG&A to confirm their continued applicability after proposed finished floor elevations, site layout, and site grading have been finalized. It is recommended foundation design and construction be in compliance with the requirements of all applicable ordinances, regulations, and codes.

### 5.2 Proposed Construction

The proposed project consists of a new building addition to the east side of Building 174, an addition to the north side of Building 175, and rack storage in the high bay of Building 174. Construction of the addition to Building 174 is anticipated to be steel frame with metal cladding and pitched roofs. Overall building dimensions would be approximately 120 feet by 150 feet, and finished floor would match Building 174. Structural information provided by Oak Point Associates indicates maximum allowable column loads (note: dead plus snow plus live) of about 284 kips, and maximum allowable post-construction settlement of ½ inch.

Review of record drawings indicates Building 174 was constructed *circa* 1942 and is supported on 30-foot timber piles with a 12-inch butt diameter. The portion of Building 174 adjacent to the currently proposed addition was constructed around 1963, and appears to be supported on steel H-piles. Information related to the H-piles indicates 12BP74 ( $F_y=36$ ksi) driven

to approximately 60 feet with an allowable capacity of 40 tons. The existing timber pile report was not available at the time of preparation of this report.

The addition to Building 175 would be one-story in height with a footprint of about 11 feet by 14 feet. It is understood the finished floor would match Building 175. The addition would house compressed air tanks, and piping would connect to Building 175. Structural information provided by Oak Point Associates indicates the building would have an overall ground pressure of about 1,000 pounds per square foot, including dead, live, and snow loading. It is understood the maximum allowable post-construction settlement would need to be determined by the Navy. It is also understood that the existing portion of Building 175 is supported on a pile foundation system.

Construction of the high bay rack storage system proposed for the interior of Building 174 would include removing the existing ground floor slab-on-grade and pile caps, and replacing it with new piles and a structural slab to support the storage rack system. Structural loading in the new rack area would about 1,500 pounds per square foot under the racks and 250 pounds per square foot in the rows between the racks.

## 5.3 Foundation Considerations

### 5.3.1 Addition to Building 174 and Rack Storage

The fill, which was likely placed in an uncontrolled manner, underlying organic silt, and silty clay will settle under the new foundation loads. These materials are not considered suitable for support of the proposed construction, and removal and replacement will not be practicable. Consequently, the addition and rack storage will require support on a deep foundation system.

Several alternatives were considered, including precast concrete piles, drilled shafts, and steel H-piles. Precast concrete piles are not considered readily available in the area, especially in a small quantity lot, and driving could be difficult. In addition, precast concrete is usually considered as a friction pile rather than end-bearing. Drilled shafts would require disposal of soils (environmental issues), casing and dewatering, and the use of Type V portland cement to resist sulfate attack from the salt water environment. Steel H-piles driven to, or into, bedrock offer a high capacity capable of being installed with locally available equipment.

Several sizes were considered in our evaluations, including HP10x42, HP10x57, HP12x53, and HP12x74. A sacrificial layer was assumed to account for corrosion losses in the organic and salt water zones, and hammer energy was limited to 20,000 foot-pounds to reflect local equipment. By wave equation analysis, working capacities range from 40 to 65 tons for a geotechnical factor of safety of 2.5.

An old quay wall transects the new building from south to north about 30 feet west of the eastern building wall (See Figure 2). Observations made during test pit excavation show wall construction is granite quarry blocks augmented (chinked) with smaller, randomly sized stones. A pile plan provided to Independent Archeological Consulting (IAC) indicates that the quay wall will be physically impacted at five locations related to pile caps, grade beams, or trenches. The vertical and horizontal impacts presented below are derived from the IAC *End-of-Field Report* dated 27 December 2009.

Location	Arch. Exposure	Length (m)	Length (ft)	Vertical Impact (ft)
South Wall of building addition	Trench 1	4.9	16	4
Eastern portion of bldg – internal pile	not exposed	3.7	12	2
Eastern portion of bldg-- internal pile	not exposed	3.7	12	2
Eastern portion of bldg-- internal pile	Trench 2	2.4	8	2
Northeast corner of building	Trench 3	9.8	32	6

Once lowering of the wall is completed at those pile cap locations, the balance of the wall is still restrained horizontally even with a pile cap excavation. It follows that pile driving will have little if any effect on the wall. It should be noted that the wall expands laterally somewhat with depth, and pile locations might require modifications in the field.

### 5.3.2 Addition to Building 175

The existing fill is variable in nature and not suitable to support the addition on conventional shallow foundations. However, the addition could be supported on a mat foundation. Mat foundations have a rigidity which tends to equalize applied loads over its area, thereby reducing the likelihood of abrupt differential settlement.

Settlement estimates suggest that post-construction total and differential settlement will be on the order of about 2 inches and 1 inch, respectively. Most of the settlement is expected to occur in the first 6 months after construction; the balance may take an additional 2 to 5 years. If settlements of this magnitude are not acceptable, the addition should be supported on deep foundations consisting of driven piles, similar to the addition to Building 174 and rack storage area. For purposes of this report and based on our discussions with Oak Point Associates, the estimated total and differential settlements exceed tolerable limit and a mat foundation has been removed from further consideration.

## 5.4 Construction Considerations

Construction Dewatering: The on-site soils are very sensitive to disturbance when wet. To reduce disturbance of exposed subgrade soils, it will be important to divert runoff, provide positive grading to shed seepage and runoff from flat areas, and compact exposed soils to reduce rutting, ponding, and surface water infiltration.

Groundwater levels observed in the explorations were below anticipated finished floor elevations. RWG&A anticipates that groundwater control can be accomplished through the use of ditches, sumps, and open pumping to depths of about 1 to 2 feet below free water levels encountered during construction. Temporary detention ponds, trenches, ditches, and dewatering sumps should not be made within or near areas to be filled.

Use of On-site Soils: The subsurface soils from foundation and site work excavations will generally consist of gravelly sand (pavement base/subbase), and mixtures of silt, sand, and clay with varying amounts of gravel, brick, concrete fragments, shot rock, and debris. In a broad sense, the existing fills can be reused as fill under structural slabs, and around pile caps and grade beams. The more granular materials can be used to establish pavement subgrade but will require observation when segregation is underway. Silt, clay, and other fine-grained soils should not be used as fill beneath the proposed additions. If on-site soil is proposed for use other than common fill, the soil should be stockpiled separately and tested to determine if it meets specification requirements for its intended use.

**The on-site soils are moisture sensitive due to their high fines content and will be difficult to place and compact when they are wet.** Moisture-density relationships should be established during construction to provide guidance for appropriate working moisture contents. Working moisture content for moisture sensitive soils typically ranges from about minus three to plus one percent of optimum moisture content.

## 5.5 Pavement Section

The typical CIA area pavement section consists of 2 inches of bituminous concrete wearing surface (MeDOT 703.09, Type 12.5mm), an inch of bituminous concrete base (MeDOT 703.09, Type 19mm), and 6 inch of subbase (MeDOT 703.06, Type D). No traffic data are available as of this writing, so assumptions were made in order to evaluate the proposed pavement section. They are as follows:

Subgrade:	CBR of 5%; Resilient Modulus of 3,000 PSI
Max Axle Load:	20 Kips
Max Vehicle Weight:	60 Kips

Using the foregoing, our evaluation worked backwards through the design process to estimate the number of design vehicles per day and the design life. Both Asphalt Institute and AASHTO methods were used with similar results from each. The results are summarized below.

<u>Method</u>	<u>No. Of Design Vehicles</u>	<u>Design Life, years</u>
AI	30 to 40 per day	10±
AASHTO	40 to 50 per day	10±

The service life might be extended with a maintenance program and possibly an overlay.

Observations of the other pavements in the paved areas surrounding the project site show signs of rutting and indentations from pallets, blocks supporting (temporarily) equipment, and trailer pads. A portland cement concrete pavement would eliminate the foregoing, and possibly provide a longer service life.

## 6.0 RECOMMENDATIONS

### 6.1 Site Preparation

1. Site preparation should include demolition and removal of existing structures, associated foundations and utilities, and backfilling. All topsoil, loose soils, organic material, fill materials, demolition debris, active and abandoned utilities, and bituminous pavement should be removed from the area of new construction. The ends of underground pipes and utility conduits outside the proposed addition footprints that will be abandoned in-place should be filled with concrete and capped to reduce the likelihood of erosion of material into the conduit or pipe.
2. Obstructions to pile installation which might be encountered at the site include, but are not limited to rubble fill, concrete foundations, piles that supported previous structures, the quay wall, and abandoned utilities. It is anticipated that obstruction removal will be accomplished by excavation and that other methods, such as spudding, might be needed. It might be necessary to relocate or increase the number of piles where obstructions are encountered which cannot be removed or otherwise overcome.
3. All excavation and filling, including excavation and filling associated with removal of obstructions, should be completed before pile driving. Excavations to remove obstructions should be backfilled with compacted sand or gravel fill free of organics, silty clay, ice, loam, organic and other deleterious materials.

4. Site grading should provide positive drainage away from constructed facilities both during and after construction.
5. It should be practicable to dewater excavations extending to 1-foot below groundwater by open pumping methods. Excavations deeper than 1-foot below groundwater may require the use of side trenches within or adjacent to excavations, or other dewatering methods. Surface runoff and infiltration of groundwater should be controlled so that excavation, filling, and foundation construction can be completed in-the-dry.

Dewatering of contaminated soils is a possibility and will require testing of groundwater before evacuation begins to determine type(s) of treatment, and to establish suitable discharge points.

Recent projects close to the river which required dewatering experienced high flow rates in areas of coarse fill such as shot rock and concrete rubble. Construction documents should provide for dewatering flow rates of 300 gallons per minute (GPM) or more.

## 6.2 Site Filling

6. Structural fill should be a well-graded sand and gravel mixture meeting the following gradation requirements:

Screen Number or Sieve Size	Percent Passing
6 inches	100
3 inches	70 - 100
Number 4	35 - 70
Number 40	5 - 35
Number 200	0 to 5

Note: Maximum particle size limited to 3 inches within 3 feet of foundation walls, pile caps, and floor slabs or if compacted by hand-guided equipment.

Gradations performed on fill encountered in the upper five feet indicate that it is not suitable for use as structural fill, but can be used as fill to raise grade below the addition to Building 174, the rack storage area, paved areas, and utility trench backfill. However, RWG&A's experience at PNSY is that soil conditions can vary greatly across construction areas. Therefore, the on-site inorganic soils should be stockpiled separately after excavation and evaluated for reuse in the project.

7. In open areas, fill should be placed in level, uniform lifts not exceeding 9 inches in uncompacted thickness and be compacted with self-propelled compaction equipment. In confined areas and within 4 feet of mat foundations, pile caps, and/or grade beams, fill should be placed in lifts not exceeding 6 inches in uncompacted thickness and be compacted with hand-operated compaction equipment. All fill placed should be structural fill compacted to at least 95 percent of the maximum dry density as determined by ASTM Standard D1557 *Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort* (56,000 ft-lbf/ft<sup>3</sup> (2,700 kN-m/m<sup>3</sup>)).

### 6.3 Foundations - General

8. The additions and rack storage area should be designed to withstand lateral, uplift, and overturning forces due to earthquake. Fill materials encountered in the explorations are not considered susceptible to liquefaction. In accordance with the 2006 *International Building Code*<sup>®</sup>, the soil profile at the site is classified as Site Class D.
9. If the addition to building 175 is unheated, the fill should be removed to a depth of at least 4 feet below adjacent exterior finished grade and replaced with a non-frost susceptible material such as 3/4 inch crushed stone. The stone should extend laterally 3 feet beyond addition limits and be densified with a small self propelled vibratory roller.
10. Excavation of foundation bearing surfaces in soil or fill should be performed by earthwork equipment fitted with smooth-edged buckets. Final subgrade preparation should include recompaction of subgrades with hand-guided, vibratory compaction equipment. Following recompaction and prior to placement of concrete, care should be taken to limit disturbance of the bearing surfaces. Any loose, softened, or disturbed material due to construction traffic should be removed prior to placement of concrete.
11. The integrity of subgrade soils must be maintained during cold weather conditions. Foundation subgrades should not be allowed to freeze. Freezing of subgrade soils beneath foundations might result in frost heaving and post-construction settlement. The Contractor should make every effort to prevent freezing of subgrade soils. In the event frost penetration occurs, granular fill or naturally deposited soils should be removed and replaced to the depth of the frozen soils. At no time should frozen material be placed as fill.
12. Lateral loads from wind and earthquake may be resisted by friction between the bottom of foundation and supporting subgrades. A friction coefficient of 0.25 should be used in design of foundations.

## 6.3.1 Pile Foundations

13. The proposed additions, rack storage area, and addition to Building 175 should be supported on a deep foundation system that will transmit the relatively high foundation loads through the in-place fill, organic silt, and soft silty clay to the underlying glacial till or bedrock. Review of the exploration logs yields estimated pile lengths on the order of 35 to 70 feet. In some locations, the bedrock is highly fractured, and piles may extend below boring refusal elevations. The following pile sections and design capacities are technically feasible and locally available:

Pile Section	Design Capacity (Tons)
HP 10 x 42	40
HP 10 x 57	45
HP 12 x 53	60
HP 12 x 74	65

14. The above driving criteria assumes the piles are driven to refusal with a single or double acting hammer delivering about 20,000 to 30,000 foot-pounds of energy. The design capacity at the end of driving should include a geotechnical safety factor of 2.5. A wave equation analysis should be submitted by the contractor to demonstrate that his proposed pile hammer can drive the piles to the required minimum ultimate capacity and depth without over stressing or damaging the piles.
15. The building code requires a pile load test for design capacities greater than 40 tons.
16. Driving stresses should be limited to a maximum compressive stress of 45 kips per square inch for the steel H-piles with a yield stress,  $F_y$ , of 50 ksi. Splices should not be allowed in the upper 10 feet of the embedded portion of the pile. Cast steel points should be provided to reduce damage while driving through debris in the fill. The pile points should be "Hard-Bite" pile points manufactured by American Pile Fittings of Clifton, New Jersey, or equivalent.
17. Each pile should be driven plumb at the prescribed location. A pile should be considered out of plumb if the inclination is greater than 2 inches in 10 feet from its design alignment.
18. Center-to-center pile spacing should be not less than 30 inches for groups of two or more piles. Recommended minimum design eccentricity between the columns and centroid of the supporting piles is 3 inches.

19. It is recommended design bottom of exterior pile cap level be a minimum of 4 feet below lowest adjacent ground surface exposed to freezing. At heated interior locations, pile caps may be designed to bear a minimum of 24 inches below top of ground floor slab. If exposure to freezing is anticipated either during or following construction, then interior pile caps should be lowered in accordance with the recommendations for exterior pile caps.
20. Lateral loads from wind and earthquake may be counteracted by earth pressure against below grade structures. An earth pressure equivalent fluid unit weight of 125 pounds per cubic foot ( $K_p = 1.0$ ) may be used against pile cap faces. Piles can be battered to achieve additional lateral resistance; batter should not be steeper than 1 horizontal to 12 vertical.

## 6.4 Ground Floor Slabs

21. Due to the potential for post-construction settlement, a pile supported structural slab is recommended for ground floors.

## 6.5 Utilities

22. Utilities within the site and beneath paved areas may be earth supported. Bedding placed between the utility and subgrade should meet the utility and manufacturer requirements for the type of conduit or pipe being installed.

## 6.6 Temporary Excavations

23. Soils at this site, encountered within the anticipated depths of excavations, consist of concrete, bituminous pavement, fill, and naturally deposited organic silt, silty clay, and silty sand with gravel. We anticipate that foundation and utility excavations can be accomplished using sloped, open-cut techniques. It is also anticipated that dewatering can be accomplished using sumps and open pumping methods. Refer to Recommendation 5 for additional information.

The Contractor should be aware that slope height, slope inclination, and excavation depths (including utility trench excavations) should in no case exceed those specified in local, state, or federal safety regulations (e.g., OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926, or successor regulations). Such regulations are strictly enforced and, if they are not followed, the Owner, Contractor, and/or earthwork and utility subcontractors could be liable for substantial penalties.

As a safety measure, it is recommended all vehicles and spoil piles be kept a minimum lateral distance from the top of excavations equal to no less than 100 percent of the slope height. Exposed slope faces should be protected against the elements.

## 6.7 Geotechnical Observation

The geotechnical recommendations provided as the basis for design of this project were developed using limited numbers of observations and tests. The Owner should be sensitive to the potential need for adjustment in the field. We recommend that the Owner retain RWG&A to observe geotechnical construction aspects of the project. These services should include observing general compliance with the design concepts, specifications and recommendations, and assisting in development of design changes should subsurface conditions differ from those anticipated prior to the start of construction. Observation improves the likelihood that the design intent will be carried out during construction. In addition, it allows RWG&A to confirm its design recommendations.

In addition to geotechnical observation, RWG&A can also provide full service construction inspection and materials testing. This would include soils, portland cement and asphaltic concrete, structural steel and welding inspections, destructive and non-destructive testing, and special inspection services in fulfillment of building code requirements.

## 7.0 CLOSURE

This report has been prepared for specific application to the proposed Waterfront Support Facility at the Portsmouth Naval Shipyard in Kittery, Maine, for the exclusive use of Oak Point Associates. This work has been completed in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made. In the event any changes are made in the nature, design, or location of the proposed construction, the conclusions and recommendations of this report should be reviewed by RWG&A.

The recommendations presented are based on the results of widely spaced explorations. The nature of variations between the explorations may not become evident until construction has begun. If variations are encountered, it will be necessary for RWG&A to re-evaluate the recommendations presented in this report. RWG&A requests an opportunity for a general review of the final design and specifications in order to determine that earthwork and foundation recommendations have been interpreted in the manner in which they were intended.



## R. W. Gillespie & Associates, Inc.

Geotechnical Engineering • Geohydrology • Materials Testing Services

22 June 2009

Stephen Towne, P.E.  
Oak Point Associates  
73 Court Street  
Portsmouth, New Hampshire 03801

Subject: Building 307 Air Compressor and Piping System  
Portsmouth Naval Shipyard  
Kittery, Maine  
Project No. 767-42

Dear Mr. Towne:

This letter is in response to recent email communications concerning Building 307 and the compressed air pipelines which exist beneath the proposed addition to Building 174 at the Portsmouth Naval Shipyard in Kittery, Maine. It is understood the Navy does not want the building or the pipelines relocated outside of the proposed addition area. Oak Point Associates (OPA) asked RWG&A to evaluate potential affects of foundation and earthwork construction activities on the pipelines. Our evaluation is presented in the following paragraphs.

RWG&A completed a Geotechnical Evaluation for the proposed addition to Building 174 and provided a draft of the report to OPA on 12 June 2009. In the report, RWG&A recommended supporting the addition on driven steel H-piles and a structural slab. Building 307 is located adjacent to Building 174 in the southwest quadrant of the proposed addition. The compressed air pipelines run north-south, approximately along the centerline of the proposed addition. It is understood the pipelines are encased in concrete, buried at a relatively shallow depth (although the depth is not known), and the air is at a pressure of approximately 4,500 pounds per square inch.

RWG&A's evaluation focused on the impact of construction on the pipelines, if they are not relocated. RWG&A evaluated alternate pile types because of concerns that vibrations from driven pile installation could damage the pipelines. It is our recommendation that the compressed air pipelines be relocated outside of the proposed addition area or that a minimum horizontal separation of 50 to 75 feet be maintained between the placement of steel H-piles and the pipeline. To reduce horizontal separation, alternative piles could be considered, but do not seem practicable

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Augusta, ME 04344  
207-623-4914 • Fax 207-623-3429

for the following reasons. Drilled shafts would cause less ground vibration and horizontal separation to the pipeline could be reduced when compared to driven piles, but their installation would require disposal of soils (environmental issues), casing and dewatering, and would require the use of Type V portland cement to resist sulfate attack from the salt water environment; augered, cast-in-place piles would also require significant expense for disposal of soils when compared to driven piles. One other option would be augered, cast-in-place displacement piles, which require less disposal of soils, although some disposal would still likely be required. Because of poor subsoil conditions, augered helical piles would not satisfy seismic requirements for this project. Also, all alternate pile systems likely would require a contractor from outside the local area which would result in higher costs for foundation installation. Driven steel H-Piles have low displacement during driving, probably less expensive than the aforementioned alternatives, and can be installed by local contractors.

Another issue, if the pipelines remain under the proposed construction area, is construction equipment trafficking over the pipelines. Heavily loaded equipment or equipment with high ground pressure could cause damage to the pipelines, depending on the depth to the top of pipe, age of the pipe, and type of pipe and joints. Equipment used at the project would probably be subject to weight or ground pressure restrictions but detailed geotechnical evaluations would be required to develop vehicle weight and ground pressure limitations. Higher costs associated with specialty equipment or limitations during construction should be anticipated at this time. The Navy and/or their consultant would need to provide any requirements for construction traffic over the pipelines.

In summary, it is our opinion that foundation construction could be accomplished if the building and pipelines remain in their current location, but with higher to significantly higher costs and the risk to damage of the pipelines, and potential collateral damage. If you have any questions or if we may be of further service, please contact us.

Very truly yours,  
R. W. GILLESPIE & ASSOCIATES, INC.

Marc R. Grenier, P.E.  
Project Geotechnical Engineer

Robert W. Gillespie, P.E.  
Principal Geotechnical Engineer

MRG/RWG:md

G:\PROJECTS\0700\0767\0767-042\Corresp\2009-06-19 Build up 307 Air Compressor and Piping System.wpd

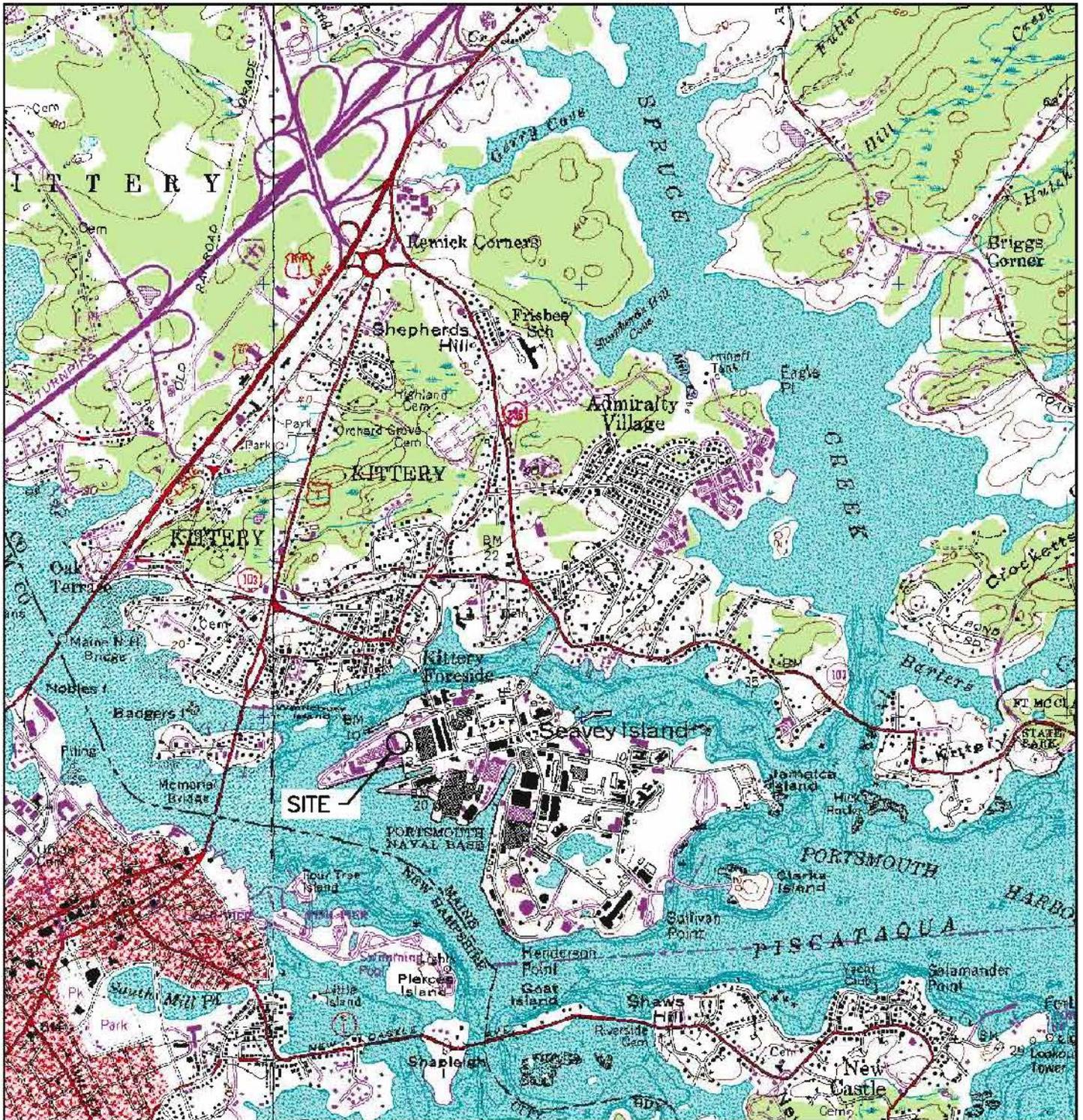


FIGURE 1  
LOCUS MAP  
WATERFRONT SUPPORT FACILITY  
KITTERY, MAINE

JUNE 2009

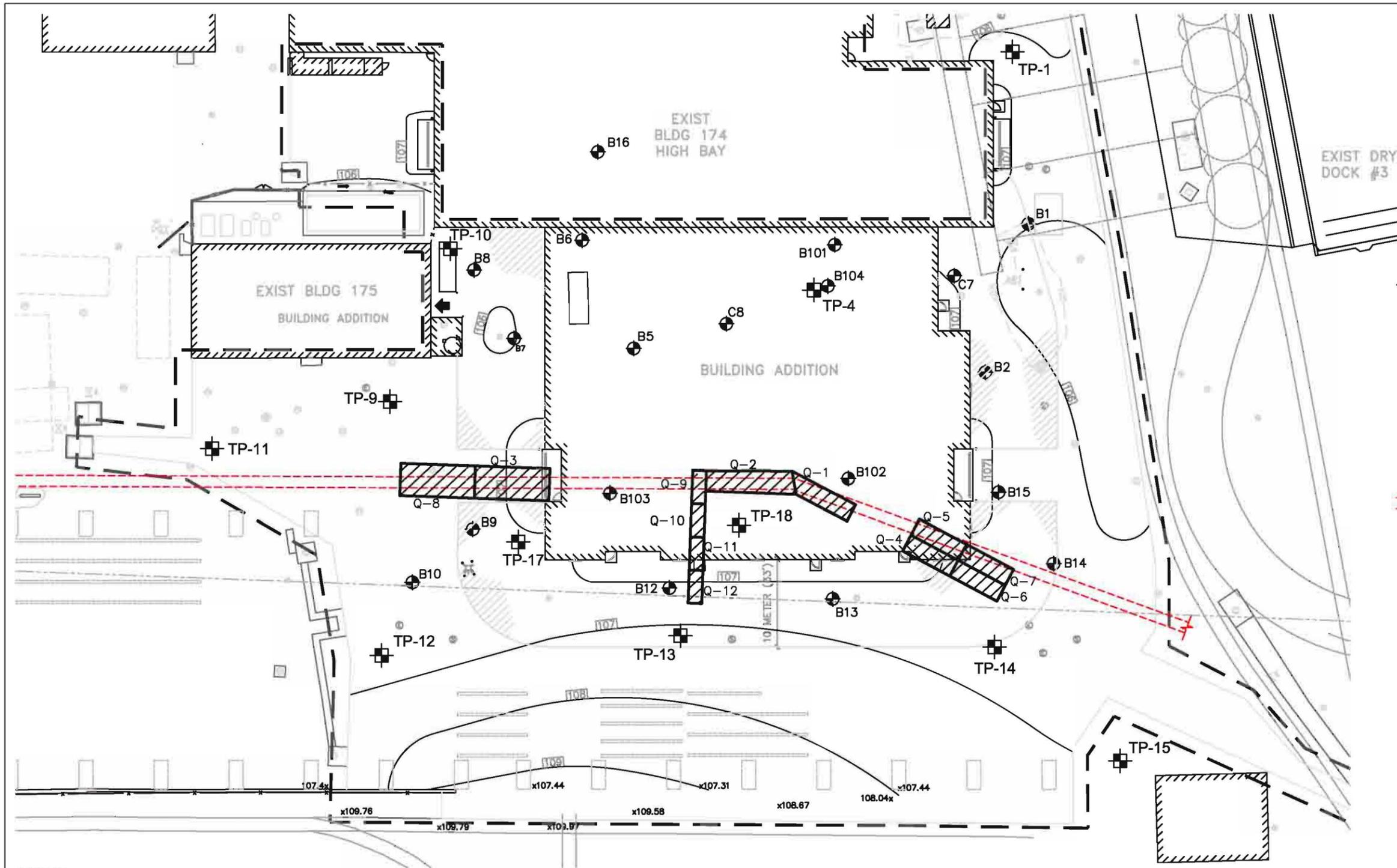
PROJECT NO. 787-42



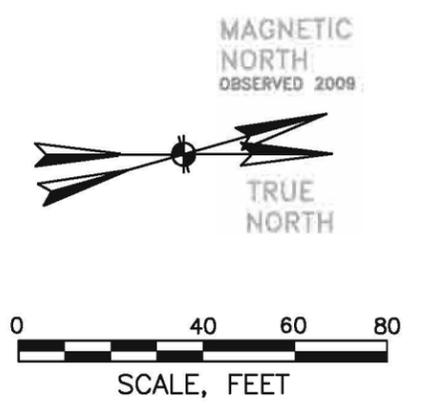
**R.W. Gillespie & Associates, Inc.**  
CONSULTING GEOTECHNICAL & ENVIRONMENTAL SPECIALISTS

**SOURCE:**  
USGS 7.5-MINUTE TOPOGRAPHIC QUADRANGLES  
OF KITTERY, MAINE AND PORTSMOUTH, NH,  
DATED 1990 AND 1993 RESPECTIVELY.

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- LEGEND:**
- B1 GEOTECHNICAL BORING PERFORMED BY RWG&A BETWEEN APRIL AND MAY 2009
  - B101 GEOTECHNICAL BORING PERFORMED BY RWG&A IN NOVEMBER 2009
  - TP-1 TEST PIT AND SOIL SAMPLING LOCATION
  - C7 ENVIRONMENTAL SAMPLING CORE HOLE BY RWG&A IN NOVEMBER 2009
  - Q-1 QUAY WALL EXCAVATION (BY INDEPENDENT ARCHAEOLOGICAL CONSULTANTS)
  - APPROXIMATE LOCATION OF QUAY WALL



SOURCE:  
SHEET C101 TITLED "SITE PLAN" BY OAK POINT ASSOCIATES,  
DATED 25 NOVEMBER 2009

- NOTE:**
- BORING AND TEST PIT LOCATIONS SHOWN WERE DETERMINED BY OAK POINT ASSOCIATES, INC., USING GPS AND OTHER SURVEY TECHNIQUES.
  - BORINGS B-3, B-4 AND B-11 WERE NOT DRILLED DUE TO SURFACE OBSTRUCTIONS OR UTILITY CONFLICTS AND ARE NOT SHOWN. TEST PITS TP-2, TP-3, TP-5 THROUGH TP-8 AND TP-16 WERE NOT EXCAVATED AND ARE NOT SHOWN.

FIGURE 2  
EXPLORATION LOCATION PLAN  
WATERFRONT SUPPORT FACILITY  
KITTERY, MAINE

JANUARY 2010 PROJECT NO. 767-42

**R.W. Gillespie & Associates, Inc.**  
CONSULTING GEOTECHNICAL & ENVIRONMENTAL SPECIALISTS

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**APPENDIX A**  
**TEST BORING LOGS**

Geotechnical Evaluation  
Waterfront Support Facility - Portsmouth Naval Shipyard  
Kittery, Maine



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 04/29/09  
 Date Completed: 04/29/09  
 Surface Elevation: 105 ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
0 - 4.5		S-1	SILTY SAND (FILL); Dense to medium dense, moist to wet, fine to medium sand, little silt, few fine gravel, brown.	18	10 20 21 14	41	6	GS
4.5 - 5.5		S-2		2	5 5 4	9	11	
5.5 - 10.5		S-3		6	4 8 12 7 8	19	13	
10.5 - 15.5			SAND (FILL); Dense, wet, fine to medium sand, trace shotrock fill, brown. grades coarser with depth.					
15.5 - 20.5		S-4		10	20 20 12 15	32	19	
20.5 - 25.5		S-5		6	7 22 17 5	39	10	
25.5 - 30.5		S-6	SILTY CLAY (CL); Stiff, wet, silt and clay, blue gray. trace fine sand seams.  Pocket Penetrometer: Undrained Shear Strength, Su = 1.25ksf	10	8 10 13 10	23		

Notes:



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Boring Log: B-1

Total Depth: 64

Sheet 2 of 3

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42

Surface Elevation: 105 ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-7		18	2 2 1 2	3		
35								
40		S-8		22	WOH WOH WOH WOH	WOH		
45								
50								
55								
60								

Notes:



**R.W. Gillespie & Associates, Inc.**  
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Boring Log: B-1

Total Depth: 64

Sheet 3 of 3

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42

Surface Elevation: 105 ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
60		S-9	SILTY SAND WITH GRAVEL (SM); Very dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.	6	24 25 40 40	65		
65			Bottom of exploration at 64 ft; rollercone refusal, probable bedrock.					
70								
75								
80								
85								
90								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 04/29/09  
 Date Completed: 04/29/09  
 Surface Elevation: 105 ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
			SILTY SAND (FILL); Medium dense to very loose, moist to wet, fine to medium sand, little silt, few fine gravel and shotrock fill, brown.					
5		S-1		7	5 8 8 6	16	10	GS
10		S-2		3	16 11 7 8	18		
15		S-3		0	1 1 0 0	1		
20		S-4	SILTY CLAY (CL); Stiff, wet, silt and clay, blue gray. trace fine sand seams.  Pocket Penetrometer: Undrained Shear Strength, Su = 2.0ksf	17	.4 5 6 6	11		
25		S-5	  Pocket Penetrometer: Undrained Shear Strength, Su = 1.75ksf	19	2 3 6 7	9		
30								

Notes:



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Boring Log: B-2  
 Total Depth: 52.5  
 Sheet 2 of 2

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: 105 ( )  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-6		24	WOH WOH WOH WOH	0		
35								
40								
45								
50		S-7	SILTY SAND WITH GRAVEL (SM); Very dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.		50/0	100+		
55			Bottom of exploration at 52.5 ft; rollercone refusal, probable bedrock.					
60								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Expl. Loc. Plan-Offset 8 ft toward B-7  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 05/06/09  
 Date Completed: 05/06/09  
 Surface Elevation: 106 ()  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			SILTY SAND (FILL); Loose, moist to wet, fine sand, few to some silt, trace medium sand, light brown.					
5		S-1		5	3 3 2 3	5	22	GS
10		S-2	SILTY SAND (FILL); Very dense, wet, fine sand, little silt, trace fine gravel, organic odor, black gray.	9	9 22 30 14	52		
15		S-3	wood fragments	2	1 1 2 50	3		
20		S-4	SILTY CLAY (CL); Stiff, wet, silty clay, trace fine sand, blue gray.  Pocket Penetrometer: Undrained Shear Strength, $S_u = 3.25\text{ksf}$	19	6 12 7 11	19		
25								
30								

Notes:



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Boring Log: B-5

Total Depth: 57

Sheet 2 of 2

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42

Surface Elevation: 106 ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30	[Hatched pattern]	U-1		23				
35								
40	[Hatched pattern]	U-2		24				
45								
50	[Dotted pattern]	S-5	SILTY SAND WITH GRAVEL (SM); wet, fine sand, little fine gravel, few silt, blue gray.	3	3 8 60 30	68		
55								
60			Bottom of exploration at 57ft; rollercone refusal, probable bedrock.					

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Expl. Loc. Plan-Offset 10 ft toward B-7  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 5 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 05/06/09  
 Date Completed: 05/06/09  
 Surface Elevation: 106 ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven, 3 inch telescope

DEPTH, FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT(2 inches).					
0 - 5			SILTY SAND (FILL); moist to wet, fine to medium sand, little silt, few fine gravel and shotrock fill, brown.					
5								
10								
15		S-1	SILTY SAND (FILL); Dense, wet, fine sand, little silt, trace fine gravel, black gray. Hard drilling from 11 ft to 15 ft, possible boulder.	3	12 33 15 7	48		
20		S-2	ORGANIC SILT (OL); Stiff, wet, clayey silt, few fine sand, trace organics, organic odor, black and gray.	6	2 8 6 7	14		
25		S-3	SILTY CLAY (CL); Medium stiff, wet, silty clay, trace fine sand, blue gray.	20	4 3 5 7	8		
30								

Notes:





Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 04/29/09  
 Date Completed: 04/28/09  
 Surface Elevation: 106 (  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
		S-1	SANDY SILT (FILL); Medium dense, moist, silt, little fine sand, trace coarse sand, dark brown.	6	11 13 11 7	24	8	
5		S-2		4	12 23 15	38	17	
		S-3	GRAVELLY SAND (FILL); Loose to dense, wet, medium to coarse sand, little gravel, few silt, organic odor, gray.	3	8 12 8 4	12	14	
10		S-4		3	5 6 27 23	50	21	
		S-5		1	5 8 6 6	12	8	
15		S-6		2	6 11 12	18	16	
		S-7		3	6 6 4 4 3	7		
20		S-8	SILTY CLAY (CL); Medium stiff to very soft, wet, silty clay, trace fine sand, blue gray. shell fragments in spoon sample Pocket Penetrometer: Undrained Shear Strength, Su = 4.0ksf	16	4 6 13 12 21	25		
25		S-9		2	7 8 10 12	18		
30								

Notes:



**R.W. Gillespie & Associates, Inc.**  
 Geotechnical Engineering • Geohydrology • Materials Testing Services

Boring Log: B-7

Total Depth: 55

Sheet 2 of 2

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42

Surface Elevation: 106 ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-10		20	WOH WOH WOH WOH	0		
35								
40								
45								
50			SILTY SAND WITH GRAVEL (SM); wet, fine sand, little silt and clay, few fine gravel, blue gray.					
55			Bottom of exploration at 55 ft; rollercone refusal, probable bedrock beginning at 54 ft.					
60								

Notes:



Project Name: Waterfront Support Facility

RWG&A Project No. 767-42

Location: Kittery, Maine

Client: Oak Point Associates

RWG&A Representative: C. Morrell

Boring Location: See Exploration Location Plan

Boring Abandonment Method: Backfilled with cuttings

Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring

Drill Rig: B 59 Truck

Driller Rep.: Pete Michaud

Date Started: 04/29/09

Date Completed: 04/28/09

Surface Elevation: 106 ( )

Drilling Method: 4-inch Tri-Cone

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (3 inches).					
0 - 4.5		S-1	SILTY SAND (FILL); Medium dense, moist to wet, fine to medium sand, little silt, few fine gravel and shotrock, brown.	14	11 11 8 8	19	10	GS
4.5 - 5.5		S-2		4	5 5 5	10		
5.5 - 9.5		S-3	increased shotrock fraction	3	4 3 4 10 12	14		
9.5 - 14.5		S-4	drilling resistance increased from 12 ft to 14 ft, probable boulder. (12' to 14')	2	50/4"	100+		
14.5 - 19.5		S-5	SILTY CLAY (CL); Very stiff to very soft, wet, silty clay, trace fine sand, dark gray.	16	10 12 12 11	24		
19.5 - 24.5		S-6		2	3 4 10 9	14		
24.5 - 29.5		S-7	Pocket Penetrometer: Undrained Shear Strength, Su = 1.25ksf	12	12 12 9 12	21		

Notes:



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Boring Log: B-8

Total Depth: 58

Sheet 2 of 2

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: 106 ()  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-8		20	WOH WOH WOH WOH	0		
35								
40								
45								
50								
55								
60			Bottom of exploration at 58 ft; rod probe refusal, probable bedrock.					

Notes:



Project Name: Waterfront Support Facility

RWG&A Project No. 767-42

Location: Kittery, Maine

Client: Oak Point Associates

RWG&A Representative: C. Morrell

Boring Location: See Exploration Location Plan

Boring Abandonment Method: Backfilled with cuttings

Observed Water Depth: 8.5 (feet)

Drilling Contractor: Great Works Test Boring

Drill Rig: B 59 Truck

Driller Rep.: Pete Michaud

Date Started:

Date Completed:

Surface Elevation: 106 ( )

Drilling Method: 4-inch Tri-Cone

Casing Type:

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
			SILTY SAND (FILL); Medium dense, moist to wet, fine to medium sand, few to little silt, few to some fine gravel and shotrock fill, brown.					
5		S-1		4	8 5 6 4	11	11	GS
10		S-2		2	3 8 9 5	17		
			SILTY CLAY (FILL); Medium, wet, silt and clay, trace fine sand, with wood fragments, organic odor, black gray.					
15		S-3		20	1 1 4 4	5		
			SILTY CLAY (CL); Very stiff to soft, wet, silt and clay, blue gray. Trace fine sand seams.					
20		S-4		2	12 10 18 21	28		
			Pocket Penetrometer: Undrained Shear Strength, $S_u = 1.0ksf$					
25		S-5		20	8 7 9 10	16		
30								

Notes:



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Boring Log: B-9  
 Total Depth: 50  
 Sheet 2 of 2

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 8.5 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: 106 ()  
 Casing Type:

DEPTH, FT.	SYMBOL SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30	G-6		24	WOH 2 2	2		
35	S-7	SILTY SAND WITH GRAVEL (SM); Very dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.	11	30 29 33 16	62		
40		Top of bedrock at 42.5 feet, Rollerbit to 45 feet and begin rock core					
45	R-1	(45' To 50'); Medium, moderately weathered, light gray, fine grained, ARGILLACEOUS SLATE; very close to close fracture spacing, wet; (Argillaceous interbedding within Kittery Formation). Recovery = 30"/60.0" = 50% RQD = 16"/60.0" = 27%					
50		Bottom of exploration at 50 ft; terminated boring 7.5 ft into bedrock.					
55							
60							

Notes:



Project Name: Waterfront Support Facility

RWG&A Project No. 767-42

Location: Kittery, Maine

Client: Oak Point Associates

RWG&A Representative: C. Morrell

Boring Location: See Exploration Location Plan-Off set 5 ft from Surface Elevation: ( )

Boring Abandonment Method: Backfilled with cuttings

Observed Water Depth: Not Obs.

Drilling Contractor: Great Works Test Boring

Drill Rig: B 59 Truck

Driller Rep.: Pete Michaud

Date Started: 04/30/09

Date Completed: 04/30/09 09:10

Surface Elevation: ( )

Drilling Method: 4-inch Tri-Cone

Casing Type:

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches). SANDY SILT (FILL); moist, silt, little fine sand, trace coarse sand, dark brown. Drilled through concrete from 3 ft to 7 ft, abandoned boring and offset 5 ft.					
5 10 15 20 25 30			Bottom of exploration at 7 ft; auger refusal on concrete, offset 5 ft and redrilled.					

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 05/04/09  
 Date Completed: 05/04/09  
 Surface Elevation: 106 ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0		ASPHALTIC PAVEMENT (2 inches).					
0 - 5		SILTY SAND (FILL); Medium dense, moist to wet, fine to medium sand, little silt, few fine gravel and shotrock, brown.					
5	S-1		6	4 4 7 6	11		
10	S-2		4	7 8 8 10	16		
10 - 15		SILTY CLAY (CL); Medium to very soft, wet, silt and clay, trace fine sand, black gray.					
15	S-3		2	2 3 4 3	7		
20	S-4		13	2 6 8 12	14		
20 - 25		Pocket Penetrometer: Undrained Shear Strength, $S_u = 3.5\text{ksf}$					
25	S-5		22	4 5 7 9	12		
25 - 30		Pocket Penetrometer: Undrained Shear Strength, $S_u = 1.5\text{ksf}$					
30							

Notes:



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Boring Log: B-10  
 Total Depth: 40.5  
 Sheet 2 of 2

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: 106 ( )  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-6		10	WOH WOH WOH WOH	WOH		
35								
40		S-7	SILTY SAND WITH GRAVEL (SM); Very dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.		75	100+		
			Bottom of exploration at 40.5 ft; rollercone refusal, probable bedrock.					
45								
50								
55								
60								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 6 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 05/04/09  
 Date Completed: 05/04/09  
 Surface Elevation: 106 ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
			SILTY SAND (FILL); Loose, moist to wet, fine to medium sand, little silt, few fine gravel and shotrock fill, brown.					
5		S-1		4	2 4 6 6	10	35	
10		S-2		1	2 1 1 1	2	37	
			SILTY CLAY (FILL); Soft, wet, silt and clay, trace fine sand, with wood fragments, organic odor, black gray.					
15		S-3		8	2 2 1	3	64	
		S-4		1	2 2 2 2 2	4	31	
20		S-5	SILTY CLAY (CL); Stiff to very soft, wet, silt and clay, blue gray. trace fine sand seams. Pocket Penetrometer: Undrained Shear Strength, $S_u = 1.75\text{ksf}$	16	2 2 3 5 7 6	12		
25		S-6		12	WOH WOH WOH WOH	WOH		
30			SILTY SAND WITH GRAVEL (SM); Medium dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.					

Notes:



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Boring Log: B-12

Total Depth: 35

Sheet 2 of 2

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 6 (feet)

RWG&A Project No. 767-42

Surface Elevation: 106 ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-7		10	7 6 5 11	11		
35			Bottom of exploration at 35 ft; rollercone refusal, probable bedrock beginning at 34 ft.					
40								
45								
50								
55								
60								

Notes:



Project Name: Waterfront Support Facility

RWG&A Project No. 767-42

Location: Kittery, Maine

Client: Oak Point Associates

RWG&A Representative: C. Morrell

Boring Location: See Exploration Location Plan

Boring Abandonment Method: Backfilled with cuttings

Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring

Drill Rig: B 59 Truck

Driller Rep.: Pete Michaud

Date Started: 05/05/09

Date Completed: 05/05/09

Surface Elevation: 106 ( )

Drilling Method: 4-inch Tri-Cone

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
0			SAND WITH GRAVEL (FILL); Loose to medium dense, moist to wet, fine to medium sand, few fine gravel, trace silt, brown. with brick fragments.					
5		S-1		10	7 6 4 3	10	34	GS
10		S-2		3	2 3 1 2	4		
10			ORGANIC SILT (OL); Soft, wet, silt and clay, few fine sand, with shells, organic odor, black gray.					
15		S-3		4	3 2 2 1	4		
15			SILTY CLAY (CL); Stiff to soft, wet, silt and clay, blue gray.					
20		S-4		22	3 4 5 4	9		
20			Pocket Penetrometer: Undrained Shear Strength, $S_u = 1.5 \text{ksf}$					
25		S-5		15	2 2 1 1	3		
30			SILTY SAND WITH GRAVEL (SM); Very dense, wet, fine sand, little silt					

Notes:



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Boring Log: B-13  
 Total Depth: 32.5  
 Sheet 2 of 2

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: 106 ()  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-6	and clay, few fine gravel, blue gray.	1	50	50/4"		
			Bottom of exploration at 32.5 ft; rollercone refusal, probable bedrock.					
35								
40								
45								
50								
55								
60								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Expl. Loc. Plan-Offset 3 ft north  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 8 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 05/05/09  
 Date Completed: 05/05/09  
 Surface Elevation: ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
			SAND WITH GRAVEL (FILL); Loose, moist to wet, fine to medium sand, few fine gravel, trace silt, brown.					
5		S-1		10	4 4 5 4	9		
10		S-2		4	11 10 11 7	21		
			ORGANIC SILT (OL); Medium, wet, silt and clay, few fine sand, with shells, organic odor, black gray.					
15		S-3		5	4 5 4 4	9		
			SILTY CLAY (CL); Stiff to very stiff, wet, silt and clay, blue gray. trace fine sand seams at 25 ft.					
20		S-4		11	4 6 7 8	13		
25		S-5		8	WOH WOH WOH WOH	0		
30								

Notes:



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Boring Log: B-14

Total Depth: 42

Sheet 2 of 2

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 8 (feet)

RWG&A Project No. 767-42

Surface Elevation: ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-6		4	WOR WOR WOR WOR	WOR		
35		S-7	SILTY SAND WITH GRAVEL (SM); Very dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.	7	20 29 50/3"	79+		
40								
45								
50								
55								
60			Bottom of exploration at 42 ft; rollercone refusal, probable bedrock.					

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Expl. Loc. Plan-Offset 5ft west  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 8 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 04/27/09  
 Date Completed: 04/27/09  
 Surface Elevation: 106 ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0		S-1	ASPHALTIC PAVEMENT (3 inches).	15	14	33		
		S-2	SAND WITH GRAVEL (FILL); Dense, moist to wet, fine to medium sand, few fine gravel, trace silt, brown.	6	11	10		
5		S-3		5	5	11		
		S-4		2	6	11		
10		S-5		1	6	29		
		S-6		2	12	30		
15		S-7		2	6	14		
		S-8	SILTY CLAY (CL); Stiff to very soft, wet, silt and clay, blue gray. trace fine sand seams at 25 ft.	1	6	15		
25		S-9	Pocket Penetrometer: Undrained Shear Strength, Su = 1.25ksf.	20	3	6		
30					3			
					3			
					4			

Notes:



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Boring Log: B-15

Total Depth: 53

Sheet 2 of 2

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 8 (feet)

RWG&A Project No. 767-42

Surface Elevation: 106 ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30	[Hatched pattern]	S-10	SILTY SAND WITH GRAVEL (SM); Medium dense, wet, fine sand, little silt and clay, few fine gravel, blue gray.	24	WOH WOH WOH WOH	WOH		
35								
40								
45	[Dotted pattern]	S-11		3	9 10 15 13	25		
50	[Cross-hatched pattern]	R-1	Top of bedrock at 47.5 feet, Rollerbit to 48 feet and begin rock core. (48' To 53'); Medium, moderately weathered, light gray, fine grained, ARGILLACEOUS SLATE; very close to close fracture spacing, wet; (Argillaceous interbedding within Kittery Formation). Recovery = 36"/60.0" = 60% RQD = 11"/60.0" = 18%					
55			Bottom of exploration at 53 ft, terminated boring 5.5 ft into rock.					
60								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 05/08/09  
 Date Completed: 05/08/09  
 Surface Elevation: ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0		S-1	CONCRETE (6 inches).	10	20	51		
			GRAVELLY SAND (FILL); Very dense, moist to wet, fine to coarse sand, little fine gravel, trace silt, brown.		25			
					26			
					22			
5		S-2	GRAVELLY SILT WITH CLAY (FILL); Medium dense to very loose, silt and clay, little fine gravel, trace sand, organic odor, brown gray.	9	12	19		
					12			
					7			
					5			
10		S-3		16	1	3		
					2			
					1			
					2			
15		S-4		20	2	5		
					3			
					2			
					4			
20		S-5	ORGANIC SILT (OL); Medium, wet, clayey silt, few fine sand, trace shells, organic odor, black and gray.	19	2	7		
					4			
					3			
					4			
25		S-6	SILTY CLAY (CL); Stiff to very soft, wet, silty clay, trace fine sand, gray.	22	6	14		
					7			
					7			
					8			
30								

Notes:



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Boring Log: B-16

Total Depth: 66

Sheet 2 of 3

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42

Surface Elevation: ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30	[Hatched pattern]	S-7		20	3	6		
					3			
					3			
35	[Hatched pattern]	S-8		16	WOR	WOR		
					WOR			
					WOR			
40	[Hatched pattern]				WOR			
45	[Hatched pattern]							
50	[Hatched pattern]							
55	[Hatched pattern]							
60	[Hatched pattern]							

Notes:



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Boring Log: B-16

Total Depth: 66

Sheet 3 of 3

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 7 (feet)

RWG&A Project No. 767-42

Surface Elevation: ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
60								
65			SILTY SAND WITH GRAVEL (SM); Wet. Soil change logged based on change in drilling resistance. Bottom of exploration at 66 ft; rollercone refusal, probable bedrock.					
70								
75								
80								
85								
90								

Notes:

**APPENDIX B**

**TEST PIT AND TRENCH EXCAVATION LOGS**

Geotechnical Evaluation  
Waterfront Support Facility - Portsmouth Naval Shipyard  
Kittery, Maine



Project Name: Waterfront Support Facility

RWG&A Project No. 767-42

Location: Kittery, Maine

Client: Oak Point Associates

RWG&A Representative: C. Morrell

Boring Location: See Exploration Location Plan

Boring Abandonment Method: Backfilled with cuttings

Observed Water Depth: 6 (feet)

Drilling Contractor: Great Works Test Boring

Drill Rig: B 59 Truck

Driller Rep.: Pete Michaud

Date Started: 11/10/09

Date Completed: 11/10/09

Surface Elevation: ( )

Drilling Method: 4-inch Tri-Cone

Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (3 inches).					
0 - 5			SAND (FILL); Loose, moist to wet, fine to medium sand, few silt, trace gravel and coarse sand, brown.					
5		S-1		8	4 5 3 4	8		
10		S-2	CLAYEY SILT WITH SAND (FILL); Medium dense, wet, silt and clay, few fine sand, with shell fragments, organic odor, black and gray.	4	6 12 10 8	22		
15		S-3	GRAVELLY SAND (FILL); Medium dense, wet, fine to medium sand, little gravel, with rock fill, organic odor, dark gray.	6	7 17 7 10	24		
20		S-4	SILTY CLAY (CL); Very stiff, wet, silty clay, with occasional fine sand seams, brown and gray.	0	4 5 5 9	10		
25		S-5		4	7 11 7 5	18		
30								

Notes: Installed 3-inch PVC casing for cross-hole seismic testing.



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Boring Log: B-101

Total Depth: 76

Sheet 2 of 3

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 6 (feet)

RWG&A Project No. 767-42

Surface Elevation: ( )

Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-6		20	WOR WOR WOR WOR	WOR		
35								
40								
45								
50								
55		S-7	SILTY SAND WITH GRAVEL (SM); Medium dense, wet, fine sand, little silt, few fine gravel, gray.	21	8 17 3 20	20		
60								

Notes: Installed 3-inch PVC casing for cross-hole seismic testing.





Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 8 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 11/09/09  
 Date Completed: 11/09/09  
 Surface Elevation: ( )  
 Drilling Method: Rotary Wash  
 Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (3 inches).					
			GRAVELLY SAND (FILL); Medium dense, moist, fine to medium sand, little gravel, trace silt, brown.					
5		S-1		6	9 8 4 4	12		
10		S-2	SILTY SAND WITH GRAVEL (FILL); Loose, wet, fine to medium sand, little silt, few gravel, organic odor, brown and black gray.	4	3 4 3 6	7		
15								
20			SILTY CLAY (CL); wet, gray.					
25								
30								

Notes: Logged strata changes below 12ft based on drilling resistance.



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Boring Log: B-102

Total Depth: 46

Sheet 2 of 2

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 8 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: ()  
 Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30								
35								
40				SILTY SAND WITH GRAVEL (SM).				
45			Bottom of exploration at 46ft; Refusal, probable bedrock.					
50								
55								
60								

Notes: Logged strata changes below 12ft based on drilling resistance.



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 8 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 11/09/09  
 Date Completed: 11/09/09  
 Surface Elevation: ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0		S-1	ASPHALTIC PAVEMENT (3 inches). GRAVELLY SAND (FILL); Very dense, moist, fine to medium sand, with rock fill and brick fragments, little fine gravel, trace silt, dark brown.	5	7 9 50/0"	100+		
5		S-2		5	6 7 17 11	24		
10		S-3	GRAVELLY SILT WITH CLAY (FILL); Very stiff, wet, clayey silt, little fine gravel, few fine sand, organic odor, black and gray.	2	3 50/3"	100+		
15		S-4		13	8 6 6 12	12		
			Bottom of Exploration at 16'; Refusal due to obstruction.					

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 6 (feet)

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 11/10/09  
 Date Completed: 11/11/09  
 Surface Elevation: ( )  
 Drilling Method: Rotary Wash  
 Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (2 inches).					
0 - 14			SAND (FILL); Loose, moist to wet, fine to medium sand, few silt, trace gravel and coarse sand, brown.					
10 - 15			GRAVEL AND SILT (FILL); wet, gravel, with rock fill, few silt and clay, gray.					
15		S-1		6	16 10 13 4	23		
20 - 22			Drilling resistance increased, possible boulder or cobble. (20' to 22')					
22 - 25		S-2	SILTY CLAY (CL); Very stiff to very soft, wet, silty clay, gray.	19	5 10 14 15	24		
25 - 30		S-3		12	4 6 6 7	12		

Notes:



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Boring Log: B-104

Total Depth: 70.5

Sheet 2 of 3

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 6 (feet)

RWG&A Project No. 767-42  
 Surface Elevation: ()  
 Casing Type: 4-inch Driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		FV	Field Vane: Undrained Shear Strength: $S_u=0.87$ ksf, Residual=0.11 ksf.					
35		S-4		24	WOR WOR WOR WOR	0		
40		FV	Field Vane: Undrained Shear Strength: $S_u=0.71$ ksf, Residual=0.22 ksf.					
		FV	Field Vane: Undrained Shear Strength: $S_u=0.69$ ksf, Residual=0.22 ksf.					
45		FV	Field Vane: Undrained Shear Strength: $S_u=0.76$ ksf, Residual=0.22 ksf.					
		FV	Field Vane: Undrained Shear Strength: $S_u=0.76$ ksf, Residual=0.22 ksf.					
50		S-5	Occasional fine sand seams.	19	WOH WOH 10 10	10		
			SILTY SAND WITH GRAVEL (SM); Medium dense, wet, fine sand, little silt, few fine gravel, gray.					
			Top of bedrock at 53', begin rollercone drilling.					
55								
60								

Notes:





Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: N/A  
 Drill Rig: N/A  
 Driller Rep.: N/A  
 Date Started: 11/11/09  
 Date Completed: 11/11/09  
 Surface Elevation: ()  
 Drilling Method: Hand Auger  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			CONCRETE (7.5 inches).					
			SAND (FILL); moist, fine to medium sand, trace coarse sand, trace silt, light brown.					
			Bottom of exploration at 1.8'; Hand auger refusal, possible cobble.					
5								
10								
15								
20								
25								
30								

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-1

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/11/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (3.5 inches). SAND (FILL); moist, fine to coarse sand, few silt, brown.		
5				Bottom of exploration at 2.3 ft; hand auger refusal, possible cobble.		
10						
15						
20						
25						

Notes: *Sawcut pavement and used hand auger for sampling.*



**TEST PIT LOG**  
 Test Pit No. TP-4

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	12/01/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: 5.8 (feet) When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (4.5 inches).		
5				SILTY SAND WITH GRAVEL (FILL); moist, fine to medium sand, little silt, few coarse sand and gravel, grayish brown.		
				GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, orangish brown. brick fragments.		
				SAND (FILL); moist, fine to medium sand, trace silt, yellowish brown.		
				SILTY SAND WITH GRAVEL (FILL); moist, fine to medium sand, little silt, few gravel, gray. Occasional boulder sized fill. (4' to 6')		
10				Bottom of exploration at 6 ft; not refusal.		
15						
20						
25						

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-9

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/19/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (4 inches).		
				SAND (FILL); moist, fine to medium sand, trace coarse sand, light brown.		
				GRAVEL WITH SILT (FILL); moist, gravel and shotrock fill, few silt, gray and black.		
5				GRAVELLY SILT (FILL); moist, silt and clay, little gravel, with shotrock fill, brownish gray.		
				Bottom of exploration at 2.7 ft; bucket refusal on granite boulder (possible displaced quay wall block).		
10						
15						
20						
25						

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-10

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	12/01/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (4 inches).		
5				SILTY SAND WITH GRAVEL (FILL); moist, fine to medium sand, little silt, few gravel, brown, with brick and metal fragments. Shotrock and boulder sized fill. (1' to 6')		
10				Bottom of exploration at 6.5 ft; terminated due to caving of test pit.		
15						
20						
25						

Notes:



**TEST PIT LOG**  
**Test Pit No. TP-11**

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/23/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (6 inches).		
				SANDY GRAVEL AND SILT (FILL); moist, gravel and shotrock fill, little fine sand, little silt, brownish gray, some wood and ceramic fragments.		
5				GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, brown.		
				Intact metal utility pipe (likely abandoned) (3.5' to 3.6')		
				Bottom of exploration at 3.6 ft; terminated excavation due to unidentified utility pipe.		
10						
15						
20						
25						

Notes:



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**TEST PIT LOG**  
**Test Pit No. TP-12**

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/23/09 14:19
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0	XXXX			ASPHALTIC PAVEMENT (3.5 inches). GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel, few coarse sand, light brown and dark brown. Bottom of exploration at 0.9 ft; refusal on concrete surface.		
5						
10						
15						
20						
25						

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-13

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/24/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: 6.8 (feet) When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (3 inches).		
				GRAVELLY SAND (FILL); moist, fine to coarse sand, little gravel, with brick fragments, dark brown.		
				SILTY SAND (FILL); moist, fine sand, little silt, trace shotrock fill, yellowish brown, with brick fragments.		
5				GRAVELLY SAND (FILL); moist to wet, medium to coarse sand, few gravel, few fine sand, black, with brick, wood and charcoal fragments.		
6.8				Bottom of exploration at 7.2 ft; not refusal.		
10						
15						
20						
25						

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-14

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/24/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (3.5 inches).		
				SANDY GRAVEL (FILL); moist, gravel and shotrock fill, little fine to medium sand, dark grayish brown, with wood and brick fragments.		
				SILTY SAND WITH GRAVEL (FILL); moist, fine to medium sand, little silt, few gravel, grayish brown and dark brown.		
5				SILTY SAND (FILL); moist, fine sand, little silt, trace fine gravel, yellowish brown.		
				GRAVELLY SAND (FILL); moist, medium to coarse sand, few gravel, few fine sand, black, with brick, wood and charcoal fragments.		
10				SILTY SAND (FILL); moist, fine to medium sand, few silt, brick fragments, light brown.		
				Bottom of exploration at 7.2 ft; bucket refusal on possible boulder or brick fill.		
15						
20						
25						

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-15

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/25/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (3 inches).		
				GRAVELLY SAND (FILL); moist, fine to medium sand, little fine gravel, trace coarse sand, light brown.		
				GRAVELLY SAND (FILL); moist, fine to medium sand, few gravel, trace silt, dark brown, with metal fragments.		
5				Bottom of exploration at 1.5 ft; bucket refusal on concrete pad.		
10						
15						
20						
25						

Notes:



**TEST PIT LOG**  
 Test Pit No. TP-17

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/23/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: 7.5 (feet) When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (3.5 inches).		
				GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel, trace coarse sand and silt, dark brown, with brick and concrete fragments.		
5				SAND (FILL); moist, fine to medium sand, few coarse sand and gravel, trace silt, orangish brown. Observed yellow, brittle material on west side of test pit.		
7.5				SAND (FILL); moist, fine to medium sand, little coarse sand, few silt, black, with charcoal and brick fragments, metal wire. Terminated excavation due to caving of test pit.		
10						
15						
20						
25						

Notes:



**TEST PIT LOG**  
**Test Pit No. TP-18**

PROJECT	Waterfront Support Facility	PROJECT NO.	767-42
CLIENT	Oak Point Associates	DATE	11/24/09
LOCATION	Kittery Maine	ELEV.	
EXCAVATION METHOD	Volvo ECR 88 Excavator	LOGGER	C. Morrell
DEPTH TO - Water: Not Obs. When checked:		Caving:	

DEPTH	SYMBOL	SAMPLES	SAMPLE NUMBER	DESCRIPTION	LAB TESTS	MOISTURE %
0				ASPHALTIC PAVEMENT (4 inches).		
				GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, dark brown, with shotrock fill, metal, brick, and wood fragments.		
				SAND (FILL); moist, fine to medium sand, few coarse sand and gravel, trace silt, light brown.		
5				Bottom of exploration at 3 ft; bucket refusal on concrete pad.		
10						
15						
20						
25						

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7.5 (feet)

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/13/09  
 Date Completed: 11/13/09  
 Surface Elevation: ()  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (4.5 inches).					
5			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, orangish brown, occasional brick fragments. Quay Wall encountered.					
7.5			BOE-terminated excavation at 7.5' due to groundwater and slope stability concerns.					
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/16/09  
 Date Completed: 11/16/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (6 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, orangish brown. occasional brick, metal pipe, and ceramic fragments.					
			BOE-terminated excavation at 1.8ft, top of quay wall.					
5								
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7.5 (feet)

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/16/09  
 Date Completed: 11/16/09  
 Surface Elevation: ( )  
 Drilling Method:  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (5 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, brown, with brick, shotrock, and metal fragments.					
5			SAND (FILL); moist, fine to medium sand, some shotrock fill/brick fragments, dark brown and black, with occasional green colored substances (oxidized copper). Quay Wall encountered					
			GRAVELLY SAND (FILL); moist to wet, fine to medium sand, little gravel and cobble sized fill, trace silt, brown.					
			BOE-terminated excavation at 7.5ft due to groundwater and slope stability concerns.					
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/17/09  
 Date Completed: 11/17/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (6 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, dark brown and grayish black, with concrete, brick, shotrock, wood, and metal fragments.					
			SILTY SAND (FILL); moist, fine sand, little silt, few coarse sand, light brown.					
5			SAND (FILL); moist, medium to coarse sand, black, with charcoal-like, porous material in coarse sand to fine gravel sized particles, possibly burn/boiler slag.					
			Bottom of exploration at 4.2 ft; not refusal.					
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/17/09  
 Date Completed: 11/17/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (6 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, dark brown, with wood and metal fragments, occasional oxidation.					
5			SAND (FILL); moist, medium to coarse sand, black, with charcoal-like, porous material in coarse sand to fine gravel sized particles, possibly burn/boiler slag.					
			Bottom of exploration at 4 ft; terminated excavation 1.8 ft below top of quay wall.					
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/18/09  
 Date Completed: 11/18/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (4.5 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, dark brown and orangish brown, with brick, shotrock, and asphaltic pavement fragments.					
5			SAND (FILL); moist, medium to coarse sand, black, with charcoal-like, porous material in coarse sand to fine gravel sized particles. Encountered utility duct bank.  Bottom of exploration at 5 ft; not refusal, terminated due to potential for undermining adjacent utility duct bank.					
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7 (feet)

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/19/09  
 Date Completed: 11/19/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (4.5 inches).					
0			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, dark brown and orangish brown. with brick, wood, and shotrock fragments, styrofoam pieces. Encountered top of quay wall (southern-most block)					
5			SAND (FILL); moist, medium to coarse sand, few shotrock fill, trace silt, black, with charcoal-like, porous material in coarse sand to fine gravel sized particles, electrical wires.					
5			SAND WITH SILT (FILL); moist to wet, fine to medium sand, few fine gravel, few silt, reddish brown and black, shotrock and porous metal fill, wood, brittle yellow brick material. Encountered top of quay wall (all subsequent blocks north of southern-most block)					
10			Bottom of exploration at 7 ft; not refusal.					
15								
20								
25								
30								

Notes: Water caused cave in, unable to sample below 6 ft (would have been outside of trenchbox, causing a safety issue)



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/19/09  
 Date Completed: 11/19/09  
 Surface Elevation: ()  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (4.5 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, brown, with brick and shotrock fragments.					
			Bottom of exploration at 1.8 ft; terminated excavation at top of quay wall.					
5								
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 7.5 (feet)

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/25/09  
 Date Completed: 11/25/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (9 inches).					
0			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel and cobble sized fill, trace silt, light brown, with brick fragments.					
5								
7.8			Bottom of exploration at 7.8 ft; not refusal.					
10								
15								
20								
25								
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/25/09  
 Date Completed: 11/25/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (6 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel, dark brown, with brick and metal fragments.					
			SILTY SAND WITH GRAVEL (FILL); moist, fine sand, little silt, trace gravel, yellowish brown.					
5			Encountered top of utility duct bank in west side of pit. Bottom of exploration at 2.7 ft; refusal on top of concrete structure associated with former plate racks.					
10								
15								
20								
25								
30								

Notes:



**R.W. Gillespie & Associates, Inc.**  
 Geotechnical Engineering • Geohydrology • Materials Testing Services

Boring Log: Q-11  
 Total Depth (ft): 2.7  
 Sheet 1 of 1

Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: Not Obs.

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/25/09  
 Date Completed: 11/25/09  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (4 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel, dark brown, with brick, wood and metal fragments.					
			SILTY SAND WITH GRAVEL (FILL); moist, fine sand, little silt, trace gravel, yellowish brown.					
5			Encountered top of utility duct bank in west side of pit. Bottom of exploration at 2.7 ft; refusal on top of concrete duct bank.					
30								

Notes:



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: See Exploration Location Plan  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 6.8 (feet)

Drilling Contractor: W.M. Shapleigh Construction  
 Drill Rig: Volvo ECR 88 Excavator  
 Driller Rep.: See Remarks  
 Date Started: 11/25/09 15:00  
 Date Completed: 11/25/09 15:03  
 Surface Elevation: ( )  
 Drilling Method: N/A  
 Casing Type: N/A

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT (4 inches).					
			GRAVELLY SAND (FILL); moist, fine to medium sand, little gravel, brick and metal fragments, wood fragments, dark brown.					
			SILTY SAND WITH GRAVEL (FILL); moist, fine sand, little silt, trace gravel, yellowish brown.					
5			Encountered top of two concrete structures associated with former plate racks in east and west sides of pit.					
			GRAVELLY SAND (FILL); moist to wet, medium to coarse sand, little gravel, few fine sand, black, with brick, wood, charcoal and metal fragments.					
			Bottom of exploration at 6.8 ft; terminated due to groundwater and fill cave-in.					
10								
15								
20								
25								
30								

Notes:

**APPENDIX C**

**HAGER-RICHTER GEOSCIENCE, INC. REPORT**

Geotechnical Evaluation  
Waterfront Support Facility - Portsmouth Naval Shipyard  
Kittery, Maine

**CROSSHOLE SEISMIC TESTING  
BUILDING 174  
PORTSMOUTH NAVAL SHIPYARD  
KITTERY, MAINE**

*Prepared for:*

R.W. Gillespie & Associates, Inc.  
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File 09VD28  
December, 2009

## 0. EXECUTIVE SUMMARY

Hager-Richter Geoscience, Inc. (Hager-Richter) performed crosshole seismic testing in one two-borehole array at the Portsmouth Naval Shipyard in Kittery, Maine for R. W. Gillespie & Associates, Inc. of Saco, Maine as part of the seismic design for proposed construction at the Site. The testing was conducted on November 19, 2009 in accordance with the applicable portions of ASTM D4428/D4428 M-07 "Standard Test Methods for Crosshole Seismic Testing."

The site is an active naval facility. The crosshole seismic testing was conducted in a two-borehole array. The borings were located adjacent to Building 174 and designated by Gillespie as Borings B-101 and B-104. The depth of the borings available for the crosshole seismic measurements was 67.5 ft.

The boring logs report the soils penetrated by the borings as 20 ft of fill over about 30 ft of clay over a few feet of sand and gravel. The depths of bedrock are reported as 59.5 ft and 53 ft for Borings B-101 and B-104, respectively.

The objective of the crosshole seismic testing program was to determine the velocity of shear waves as a function of depth at the specified location.

The velocity of shear waves  $V_s$  vary with depth  $Z$  as follows:

$\Delta Z$ (feet)	VELOCITY (feet/second)
5 to 14.7	500
14.7 to 22.9	$V_s = 23.192 * Z + 158.3$
22.9 to 27.5	700
27.5 to 58	550
58 to 100	7350

The average shear wave velocity to a depth of 100 ft determined in accordance with the procedures specified in the building code is 968 fps and the Site Class is D.

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### APPENDICES

- 1 ASTM D4428/D4428M - 07, Standard Test Methods for Crosshole Seismic Testing
- 2 Boring Logs
- 3 Deviation Data

## 1. INTRODUCTION

Hager-Richter Geoscience, Inc. (Hager-Richter) performed crosshole seismic testing in a two-borehole array at the Portsmouth Naval Shipyard in Kittery, Maine for R. W. Gillespie & Associates, Inc. of Saco, Maine as part of the seismic design for proposed construction at the Site. The testing was conducted November 19, 2009 in accordance with the applicable portions of ASTM D4428/D4428 M-07 "Standard Test Methods for Crosshole Seismic Testing," copy reproduced in Appendix 1.

The site is an active naval facility. The general project location is shown in Figure 1. The crosshole seismic testing was conducted in a two-borehole array. The borings were located adjacent to Building 174 and were designated by Gillespie as Borings B-101 and B-104. The locations of the borings are shown in Figure 2. The depth of the borings available for the crosshole seismic measurements was 67.5 ft.

The boring logs, reproduced in Appendix 2, report the soils penetrated by the borings as 20 ft of fill over about 30 ft of clay over a few feet of sand and gravel. The depths of bedrock are reported as 59.5 ft and 53 ft for Borings B-101 and B-104, respectively.

The objective of the crosshole seismic testing program was to determine the velocity of shear waves as a function of depth at the specified location.

The field work was performed November 19, 2009 by Jeffrey Reid, P.G., and Eric Rickert of Hager-Richter. The project was coordinated with Marc R. Grenier, P.E., Project Geotechnical Engineer, of Gillespie. Mr. Christopher Morrell, also of Gillespie, was onsite during the field work. The field work and subsequent data processing were performed in accordance with the ASTM document referenced above and included in the Appendix. The project records will be kept for at least 3 years.

## 2. CROSSHOLE SEISMIC TESTING

### 2.1 General

As noted in the Introduction, the testing was performed in substantial conformance with ASTM D4428/D4428 M-07 "Standard Test Methods for Crosshole Seismic Testing." The document is reproduced in Appendix 1.

### 2.2 Field Procedures

The two borehole method was used. The ASTM document specifies the construction details of the boreholes, including a requirement for grouting the casing from bottom to top. The grout provides a path for the elastic signals from the source to the borehole wall in one borehole and from the borehole wall to the geophone in one or more other boreholes.

The geometry of the measuring system is shown in Figure 3. The source and geophones are positioned at the same elevation. The source generates a seismic signal that travels as an elastic wave to the geophones, where it is converted to an electric signal, sent to the seismograph via cable, and amplified, filtered, and recorded by the seismograph.

The seismograph is a 24-channel seismograph (Geometrics Geode), coupled to a downhole geophone assembly. The downhole geophone assembly includes a Mark Products triaxial geophone and an electrically controlled spring to secure the assembly to the inside of the casing. The source is a downhole sparker that produces a shear wave. The seismograph records data digitally and the records are available immediately to verify the quality of the data. The stored digital data are transferred to a laptop computer at the end of the field day for storage, backup, and future data processing.

The seismograph is coupled to the three-component triaxial geophones with electrical cables. The geophones are positioned at the same elevation as the source, and are clamped to the PVC casing. The vertical axis of the geophones is oriented vertically (because it is constrained by the borehole), but the horizontal axes are not oriented.

Seismic energy is provided by a downhole source, Geotomographie Borehole Sparker S-Wave Probe SH-66 and Impulse Generator. The Impulse Generator delivers short electrical impulses of energy up to about 1000 J at a voltage up to 5 kV through a rugged high voltage coaxial cable to an electrode enclosed in a metallic tube filled with water and having a single long narrow window. The discharge of the electrical energy through the electrode creates a pressure pulse that travels along the axis of the metallic tube and is converted at the window into a horizontal directed pressure pulse that generates a horizontal shear motion in the adjacent material. The SH-66 Probe is clamped to the casing and the shear motion is transmitted through the casing

and grout in the casing/borehole annulus to the material outside the borehole. Before the Probe is clamped, it is oriented so that the horizontally polarized shear wave propagates toward the receiver(s). The direction of first motion of the shear wave can be reversed, thereby facilitating recognition of the onset of the shear waves at the geophone(s). The downhole source also creates a compressional wave. The number of stacks per shot depth/direction is variable, and the quality of the stacked seismic signal for each shot depth/direction is verified in the field.

The deviation probe is a Mount Sopris downhole tool 2DVA-1000 that is operated with a Mount Sopris portable logger MGX2. The downhole tool includes a 3-axis magnetometer and three accelerometers. The manufacturer's stated accuracy is Azimuth  $\pm 1^\circ$  and Inclination  $\pm 0.3^\circ$ . Additional specifications and the manual for the deviation probe are available on the website [www.mountsopris.com](http://www.mountsopris.com).

### 2.3 Data Analysis

The seismic data are analyzed using the digital data and commercially available software. The arrival times for the shear and compressional waves at each geophone are determined from the digital seismic data. The *apparent*<sup>1</sup> velocities are calculated for each depth from the arrival times and the distances between the three pairs of boreholes as follows:

$$V_s (S-R_1) = L (S-R_1) / \bar{\Delta}T_s (S-R_1) \quad (1)$$

$$V_p (S-R_1) = L (S-R_1) / \bar{\Delta}T_p (S-R_1) \quad (2)$$

where

V is the velocity, with subscripts S and P indicating shear and compressional waves, respectively,

L (S-R<sub>1</sub>) is the distance between borings containing the source and Receiver R<sub>1</sub>;

$\bar{\Delta}T$  (S-R<sub>1</sub>) is the time of transit of elastic energy from the source to Receiver R<sub>1</sub>, averaged for source up and down, and with subscripts and superscripts as defined for V.

Similar equations are used for the times and distances of source to Receiver R<sub>2</sub> and R<sub>1</sub> to R<sub>2</sub> for the case of testing with a three hole array.

---

<sup>1</sup>Apparent velocity is the ratio of distance between source and Receiver 1, between source and Receiver 2, or between Receivers 1 and 2 divided by the time required for the seismic signal to travel from source to Receiver 1, source to Receiver 2, or from Receiver 1 to Receiver 2, respectively.

The assumptions inherent in Equations 1 and 2 are that the medium is isotropic and homogeneous within layers, the interface between layers is horizontal, and the displacements are small.

The velocities determined with Equations 1 and 2 are *apparent* velocities. The actual velocities would be determined by correcting for the effects of refraction, if refraction is present, using Snell's Law, which for any two layers is given by

$$\text{SIN } \acute{a}_1 / \text{SIN } \acute{a}_2 = V_1 / V_2 \quad (3)$$

where

- $\acute{a}_1$  is the angle of incidence,
- $\acute{a}_2$  is the angle of the refracted wave, and
- $V_1$  and  $V_2$  are the velocities of layers 1 and 2, respectively.

For a homogeneous isotropic elastic medium, there are only two independent elastic parameters, and the velocities  $V_p$  and  $V_s$  are two such parameters. Therefore, based on the definitions and equations of infinitesimal elasticity theory, the velocities  $V_p$  and  $V_s$  together with density  $\rho$  can be used to calculate shear modulus, modulus of elasticity (also called Young's modulus), and Poisson's ratio.

#### 2.4 Determination of Average Shear Wave Velocity for Building Code Purposes.

The 2008 International Building Code (2008 IBC) and most, if not all, codes based on it use the average shear wave velocity averaged over the upper 100 ft as one method to determine Seismic Site Class. The average velocity  $V_{avg}$  is defined as follows:

$$V_{avg} = \left( \sum_{i=1}^N d_i \right) / \sum_{i=1}^N d_i / V_i \quad \text{Eq. 2.4-1}$$

- where  $V_{avg}$  is average shear wave velocity
- $d_i$  is thickness of the  $i^{\text{th}}$  layer
- $V_i$  is the shear wave velocity of the  $i^{\text{th}}$  layer
- $N$  is the number of layers

Equation 2.4-1 assumes that the velocity is constant in each layer. Such, however, is not always the case, and a function of the form  $Y = a * X + b$  often fits the observed data well. For sections in which the velocity varies as  $Y = a * X + b$ , the denominator of Eq 3.1-1 can be replaced with the following integral:

$$\int_{z_1}^{z_2} dZ / (aZ + b) = [Ln(aZ_2 + b) - Ln(aZ_1 - b)] / a \quad \text{Eq. 2.4-2}$$

where  $Z_1$  and  $Z_2$  are the depths of top and bottom of the layer in which the velocity varies as  $Y = a * X + b$ .

The Site Class, based on average shear wave velocity, is defined as follows:

Site Class	Soil Profile Name	Soil Shear Wave Velocity (ft/s)
A	Hard rock	$v_s > 5000$
B	Rock	$2500 < v_s \leq 5000$
C	Very dense soil and soft rock	$1200 < v_s \leq 2500$
D	Stiff soil profile	$600 \leq v_s \leq 1200$
E	Soft soil profile	$v_s < 600$

## 2.5 Site Specific

The borings were reportedly constructed in accordance with the recommendations of ASTM D4428/D4428 M-07 "Standard Test Methods for Crosshole Seismic Testing." A deviation survey was performed by Hager-Richter in both borings, and the data are given in Appendix 3. Examination of the plots for the two borings shows that they are essentially vertical through the fill to 20 ft depth and that most of the deviation occurs in the soft clay where the N-values are mostly "WOR." The maximum deviation is in the Boring B-104, 0.7 in Easting and 3.5 in Northing, resulting in a departure of about 3.57 inches at 63 ft.

The distance between borings, calculated as a function of depth using (1) the distance between borings at the surface and (2) the deviations is given in Table 1 and plotted in Figure 4.

Crosshole seismic data were obtained at an interval of 5 ft from 5 ft depth to the bottoms of the borings. We used an interval of 2.5 ft near the fill/natural soil and soil/bedrock interfaces. No more than three stacks of the seismic signals were required to increase the signal-to-noise ratio to an acceptable value.

## 2.6 Limitations of the Method

Like all geophysical methods, the crosshole seismic method is based on the assumption that the local geology is uncomplicated, and that rock and soil interfaces are planar. For those tests in which the signals are generated in a single boring only, the interfaces are assumed to be horizontal, and this assumption is inherent in correcting for refraction.

Thin units with velocities that are lower than the velocity of adjacent materials may not be detectable with the geometry of a particular installation. (The details important to this limitation are the velocities of adjacent materials, thickness of the units, and the distances as functions of depth between pairs of borings.)

If deviation measurements are not available, then the distance between boreholes is *assumed* to be constant from the surface to the bottom of the boreholes. Although ASTM D4428 does not require deviation measurements to be made for borings with depths less than 50 ft, we have measured departures from vertical of several feet in borings that were only 30 ft deep.

If the casing in each borehole is not grouted in accordance with ASTM D4428, or the grout is not continuous, then the signal may be significantly degraded for at least some depths. The practical result is that the velocity determined for a particular depth under such conditions is less accurate at best, and in some cases may not be determinable. The acoustic noise in the subsurface can be a significant problem, particularly at active construction sites and active industrial facilities, and may interfere with the signals generated in the crosshole seismic testing. Drilling, pile driving, and the activity of heavy construction equipment have been especially troublesome at some sites.

### 3. RESULTS AND DISCUSSION

#### 3.1 General

The *apparent* shear wave velocities are reported in Table 1 and are plotted as functions of depth in Figure 5.

As noted above, the boring logs for Borings B-101 and B-104 are reproduced in Appendix 2. In general, the stratigraphic sequence from surface downwards consists of 20 ft of fill over about 30 ft of clay over a few feet of sand and gravel. The depths of bedrock are reported as 59.5 ft and 53 ft for Borings B-101 and B-104, respectively. Blow counts are "WOR" for the clay.

#### 3.2 Data Quality

The quality of the seismic data obtained in this project is fair to good. The validity of this assessment can be confirmed by examining (1) Figure 6 which shows the arrivals at a depth of 35 ft and (2) Figure 7, a composite plot of horizontal component seismograms.

#### 3.3 Refraction Effects

As noted in section 2.3, the velocity obtained by dividing the distance between borings by the time required for the signal to travel between the borings, called *apparent* velocity, may not be the true velocity, especially where the source and receiver are located at a depth near an interface between two materials with different velocities and/or the distance between borings is large. The difference between apparent and true velocity is due to refraction. Inspection of the shear waves as a function of depth, Figure 5, shows a large change of velocity at the soil/bedrock interface. Only small changes of velocity are present at other depths.

We calculated the effects of refraction at the bedrock interface using the velocities of 550 fps and 4835 fps above and below the interface, respectively. We assumed a horizontal interface at a depth of 57.5 ft. Figure 8 shows the results. The calculated apparent velocities for depths of 52.5 ft, 55 ft, and 57.5 ft match the measured values well, and we interpret the good match as showing the measured values at those depths are in fact due to refraction.

### 3.4 Results

Our models of the velocities of shear waves consist of the simple functions  $Y = C$  and  $Y = A * X + B$ , where A, B, and C are constants determined by averaging or fitting by least squares the measured data, and the simple functions fit the data well.

The *apparent* velocity of shear waves ranges between about 500 fps and 600 fps for the fill — depths to about 20 ft — between about 550 fps and 5450 fps for the clay — depths between about 20 ft and 60 ft — and between about 7300 fps and 7400 fps for bedrock.

For the model velocities (that is, the true velocities) over the intervals 5-14.7 ft, 22.9-27.5 ft, 27.5-58 ft, and 58-100 ft, we have used the averages of the velocities measured for those intervals. For the model velocity in the interval 14.7-22.9 ft, we have fitted the function  $Y = A * X + B$  to the measured values. The results are reported in Table 2 and shown in Figure 8.

Using the model velocities — the true velocities — with the equation of section 2.4 above to determine the average shear wave velocity for the upper 100 ft, we obtain 968 fps. This value is near the middle of the velocity range for Site Class D, 600 fps-1200 fps, and, therefore, the Site Class is D.

#### 4. CONCLUSIONS

On the basis of the crosshole seismic testing conducted in the two-borehole array at the Portsmouth Naval Shipyard in Kittery, Maine, we conclude that the velocity of shear waves  $V_s$  varies with depth  $Z$  as follows:

$\Delta Z$ (feet)	VELOCITY (feet/second)
5 to 14.7	500
14.7 to 22.9	$V_s = 23.192 * Z + 158.3$
22.9 to 27.5	700
27.5 to 58	550
58 to 100	7350

The average shear wave velocity to a depth of 100 ft determined in accordance with the procedures specified in the building code is 968 fps and the Site Class is D.

## 5. LIMITATIONS

This report was prepared for the exclusive use of R. W. Gillespie & Associates, Inc. and its client (collectively Client) . Any use by any third party of this Report or any information, documents, records, data, interpretations, advice or opinions given to the Client by Hager-Richter Geoscience, Inc. in the performance of its work shall be at such third party's own risk and without any liability to Hager-Richter Geoscience, Inc.

Hager-Richter Geoscience, Inc. has performed its professional services, obtained its findings, and made its conclusions in accordance with generally accepted and customary principles and practices in the field of geophysics. No other warranty, either expressed or implied, is made. Hager-Richter Geoscience, Inc. is not responsible for the independent conclusions, opinions, or recommendations made by others based on the information, geophysical data, and interpretations presented in this report.

This geophysical testing included a limited set of data obtained at the project Site and was conducted with limited knowledge of the Site and its subsurface conditions. Hager-Richter Geoscience, Inc. does not assume responsibility for the accuracy of information that was provided to us by others about the Site and its subsurface conditions. The findings provided by Hager-Richter Geoscience, Inc. are based solely on the information described in this document. The conclusions drawn from this investigation are considered reliable; however, there may exist localized variations in subsurface conditions that have not been completely defined at this time. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, coring and laboratory testing.

**TABLE 1**  
**APPARENT VELOCITY OF SHEAR WAVES**

Depth (ft)	Distance between Borings (ft)	Vs (fps)
0	15.25	
5	15.24	498
10	15.24	499
15	15.29	514
17.5	15.34	557
20	15.41	614
22.5	15.47	688
25	15.52	691
30	15.54	558
35	15.46	532
40	15.32	559
45	15.12	562
47.5	15.03	555
50	14.93	510
52.5	14.85	1154
56	14.80	2189
57.5	14.78	5433
60	14.81	7305
62.5	14.87	7336
65	14.98	7391
67.5	15.19	7400

**TABLE 2**  
**MODEL VELOCITY OF SHEAR WAVES**

<b>ΔZ (feet)</b>	<b>VELOCITY (feet/second)</b>	<b>COMMENTS</b>
5 to 14.7	500	N = 3, Std = 7.2 fps, 1.4% of mean
14.7 to 22.9	$V_s = 23.192 * Z + 158.3$	N = 4, $r^2 = 0.986$
22.9 to 27.5	700	N = 2, Std = 1.3 fps, 0.2% of mean
27.5 to 58	550	N = 6, Std = 18.9 fps, 3.4% of mean
58 to 100	7350	N = 4, Std = 39.1 fps, 0.5% of mean

Abbreviations:

- V<sub>s</sub> = Velocity of shear waves, fps
- Z = Depth, feet
- ΔZ = Depth interval, feet
- N = Number of data points used
- Std = Standard deviation
- r<sup>2</sup> = Coefficient of determination

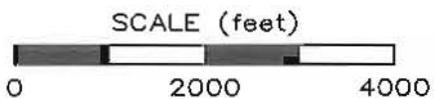
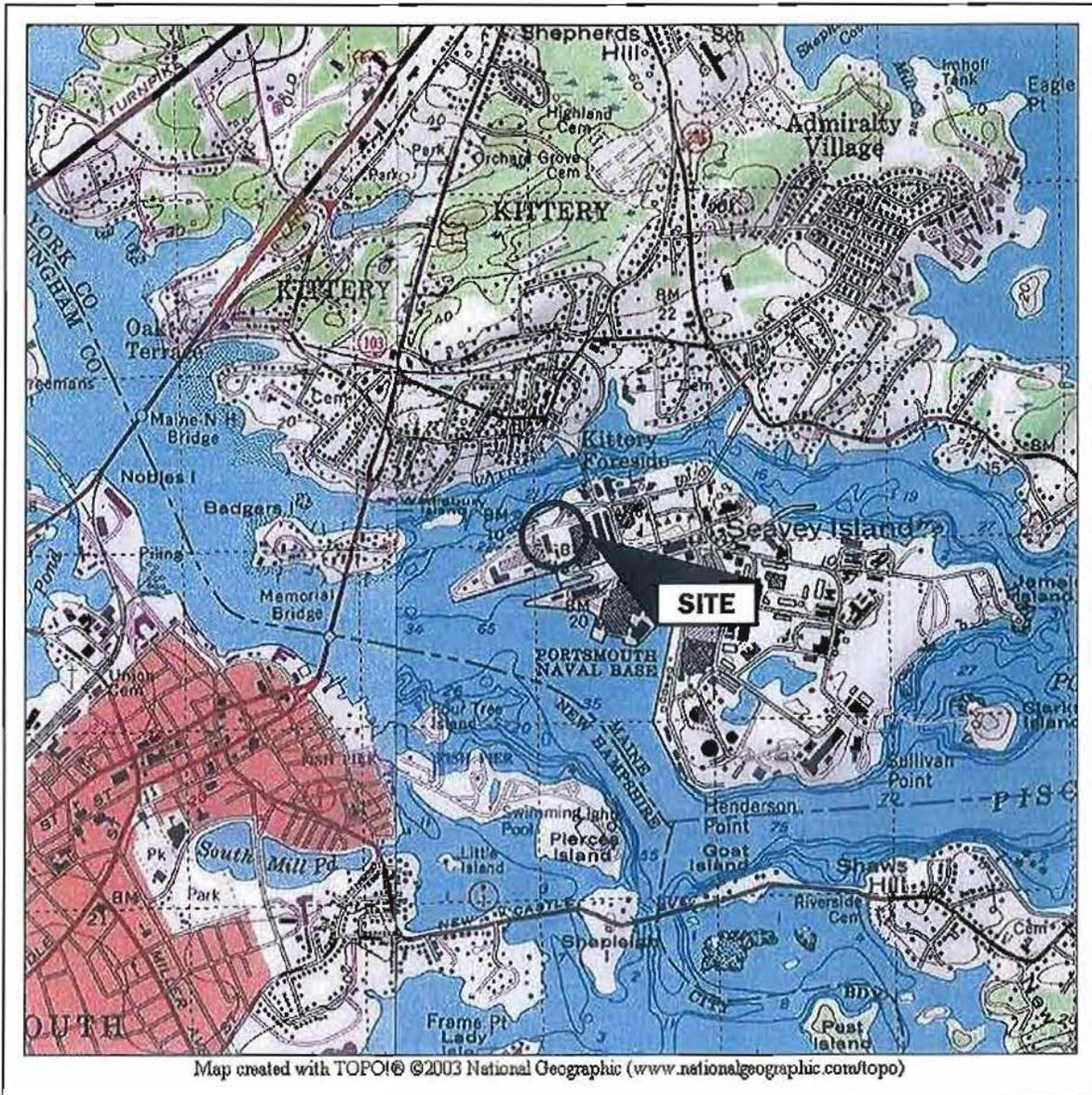
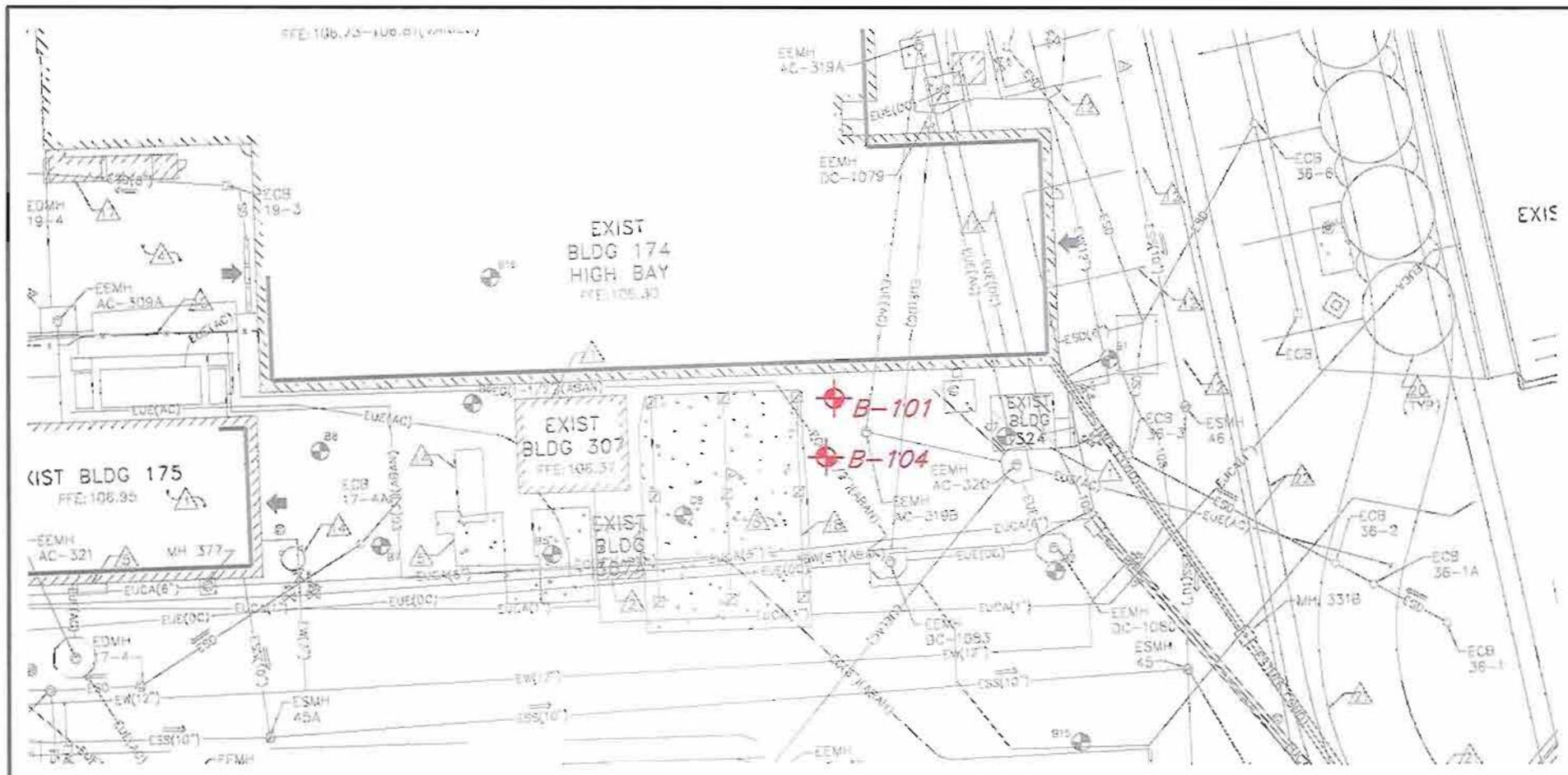


Figure 1  
 General Site Location  
 Building 174  
 Portsmouth Naval Shipyard  
 Kittery, Maine

File 09VD28	December, 2009
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



FFE:106.23-106.01, 106.02

EXIST  
BLDG 174  
HIGH BAY  
FFE:106.30

EXIST BLDG 175  
FFE:106.95

EXIST  
BLDG 307  
FFE:106.37

B-101  
B-104

EXIST  
BLDG  
324

EXIS

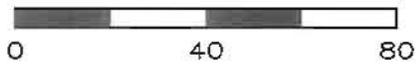


LEGEND



BORING USED  
FOR CROSSHOLE  
SEISMIC SURVEY

SCALE (feet)



NOTE:

Modified from site plan provided by  
R.W. Gillespie & Associates, Inc.

Figure 2  
Site Plan  
Building 174  
Portsmouth Naval Shipyard  
Kittery, Maine

File 09VD28

December, 2009

HAGER-RICHTER GEOSCIENCE, INC.  
Salem, New Hampshire

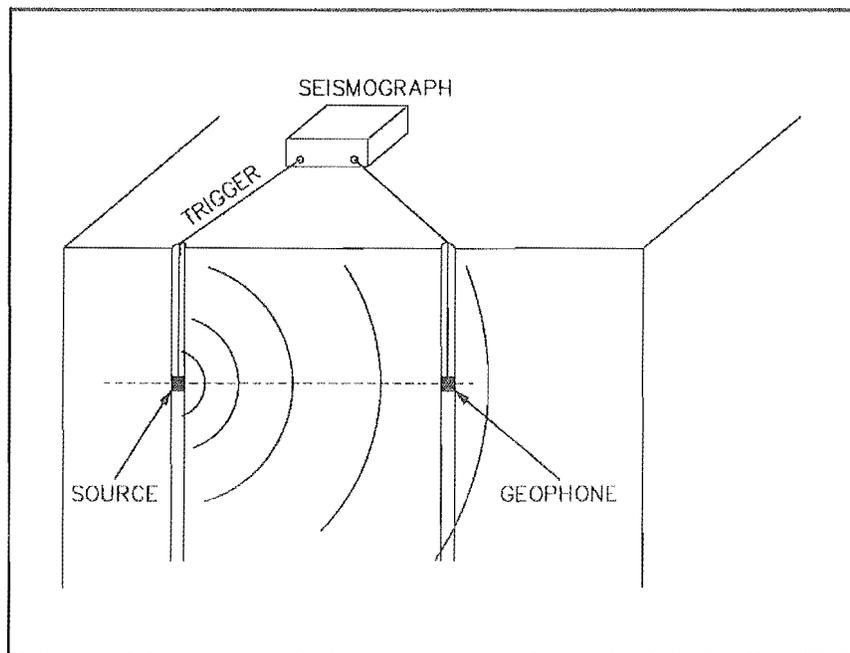


Figure 3. Geometry of crosshole seismic survey. The source and receivers are placed at the same depths in two different borings. A horizontally polarized shear wave is generated by the source, radiates in all directions, travels at the speed determined by the elastic properties and density of the soils, and is detected by the geophone in the receiver hole. When the wave is initiated, a signal is transmitted to the seismograph to start a timing clock, and the wave is recorded as a function of time in the seismograph.

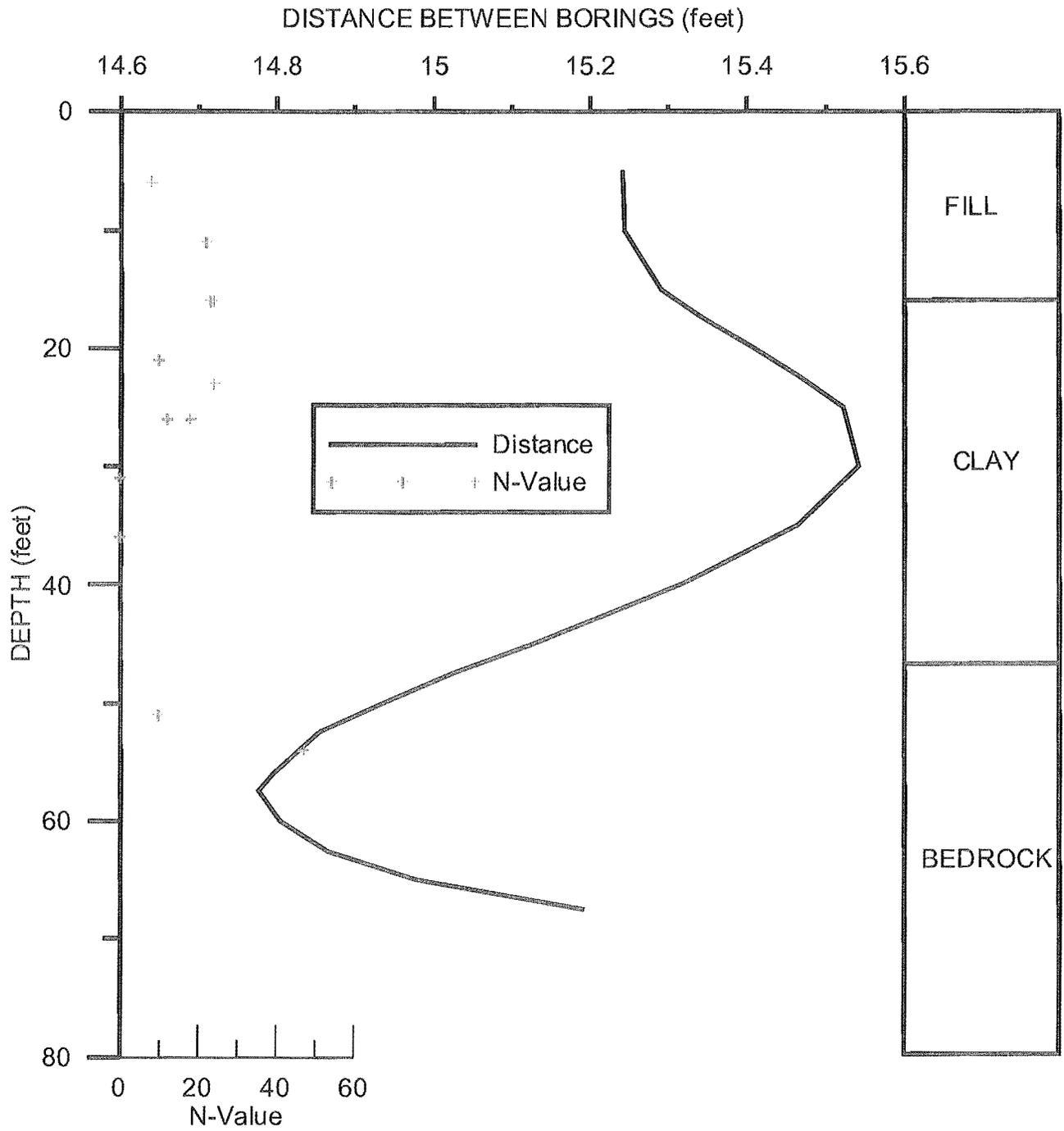


Figure 4. Distance between boreholes as a function of depth.

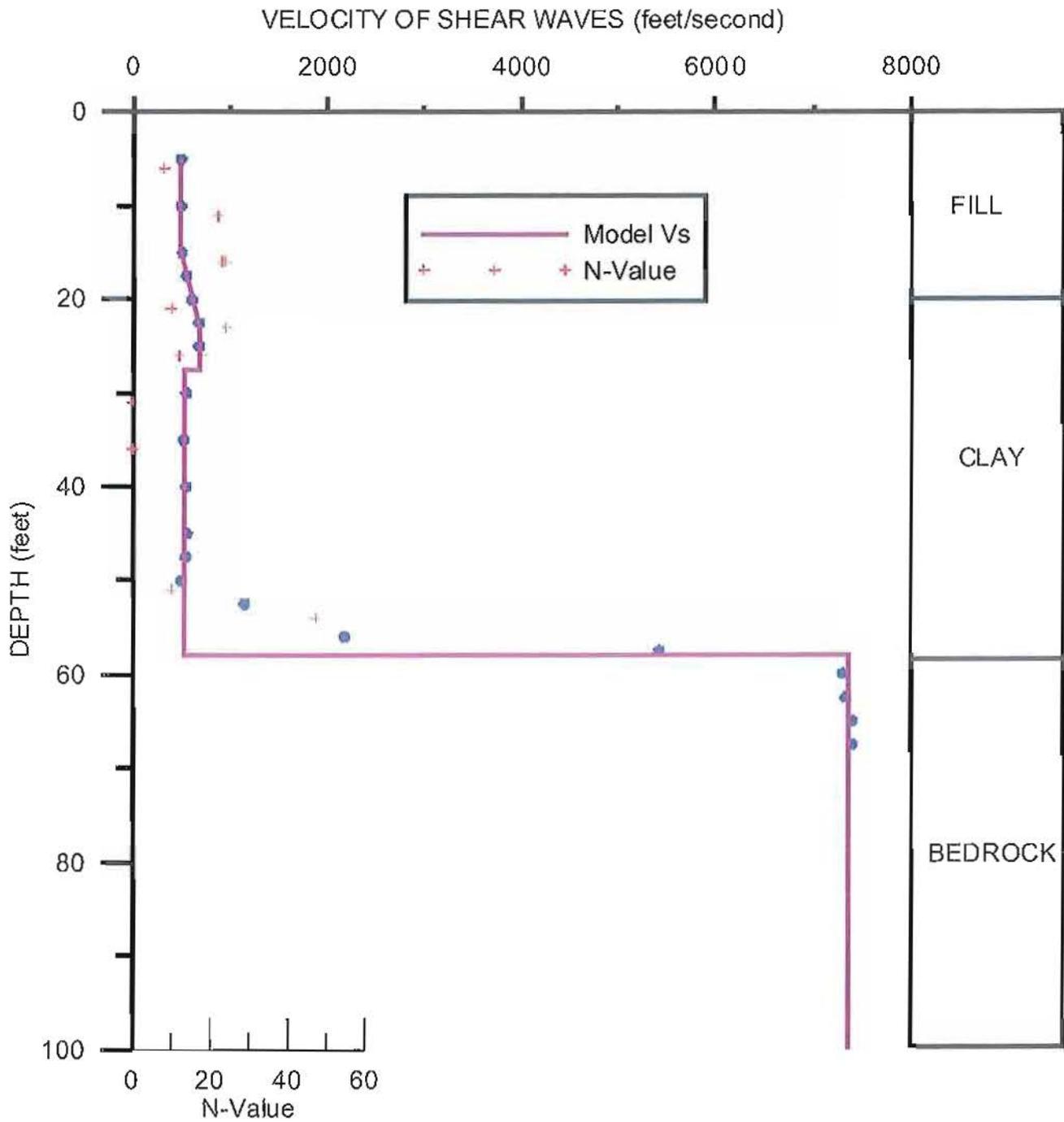


Figure 5. Velocity of Shear Waves. The line represents model velocity, and its parameters are reported in Table 2. The N-values for both borings are shown. The generalized boring log is for Boring B-101. The value of Vs shown for bedrock is the average of the four measurements at depths of 60-67.5 ft extrapolated to 100 ft.

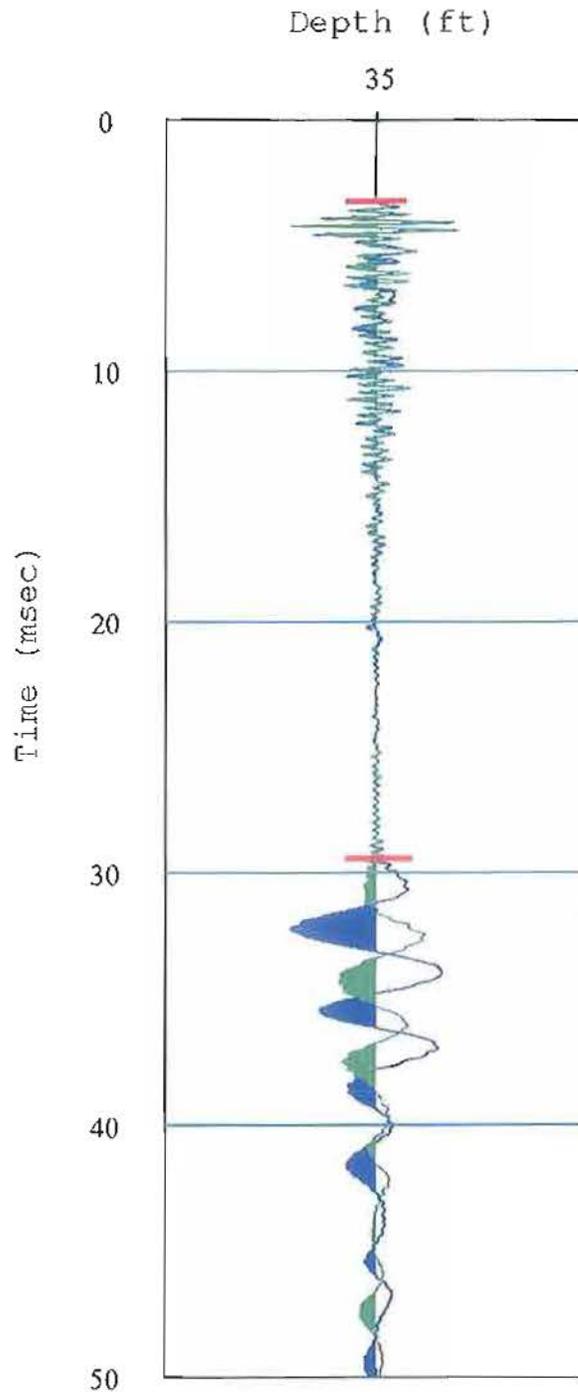


Figure 6. Opposing polarity of signals at 35 feet deep. The short red lines at about 3.2 ms and 29 ms mark the times of arrival of the compressional and shear waves, respectively. The opposite polarity of the shear waves is a major assistance in recognizing the arrival of the shear wave.

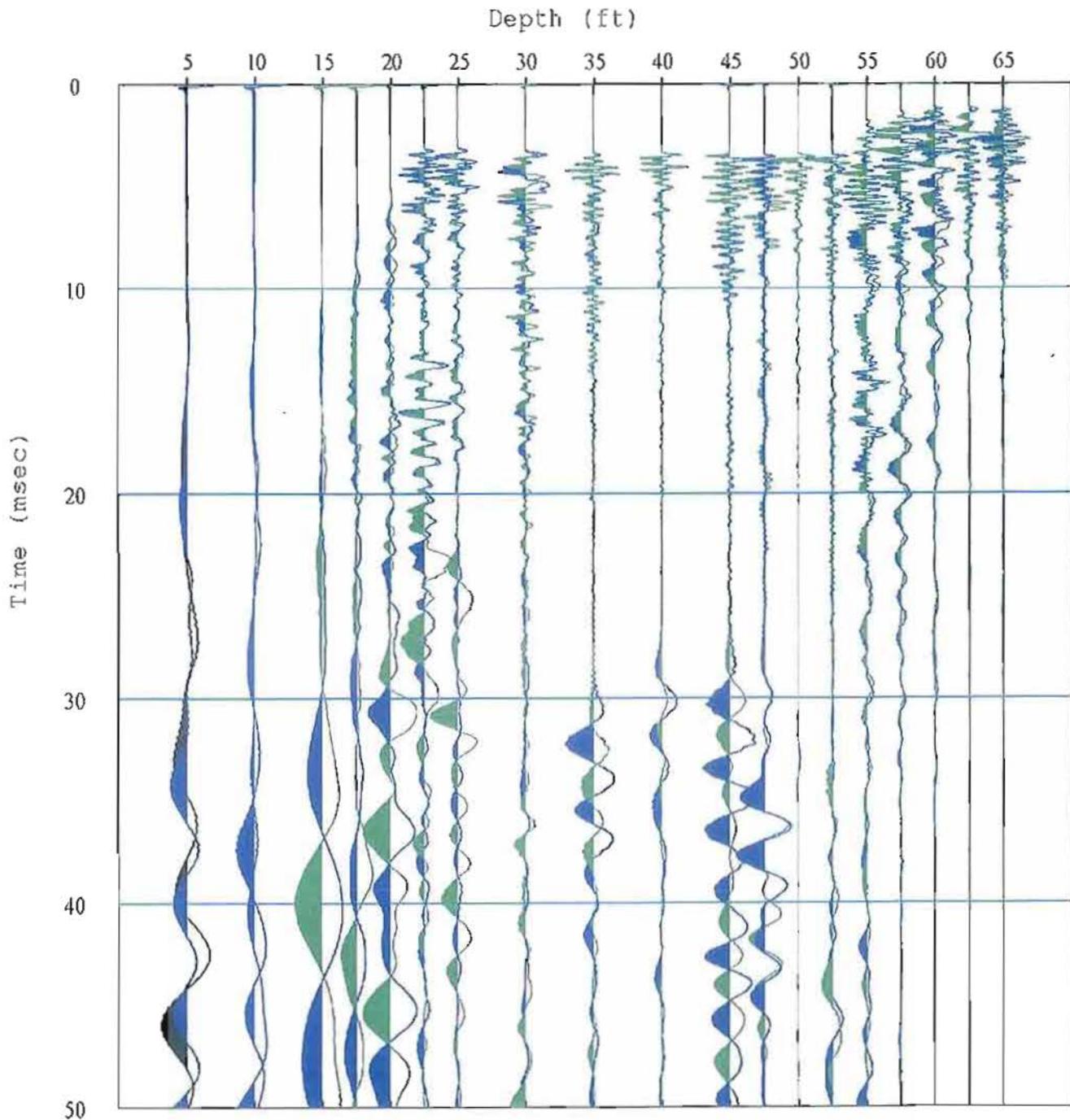


Figure 7. Composite seismograms. The source and geophone are at the same depth for each seismogram. Horizontal components of all seismograms are shown as a function of depth of the source/receiver geophone.

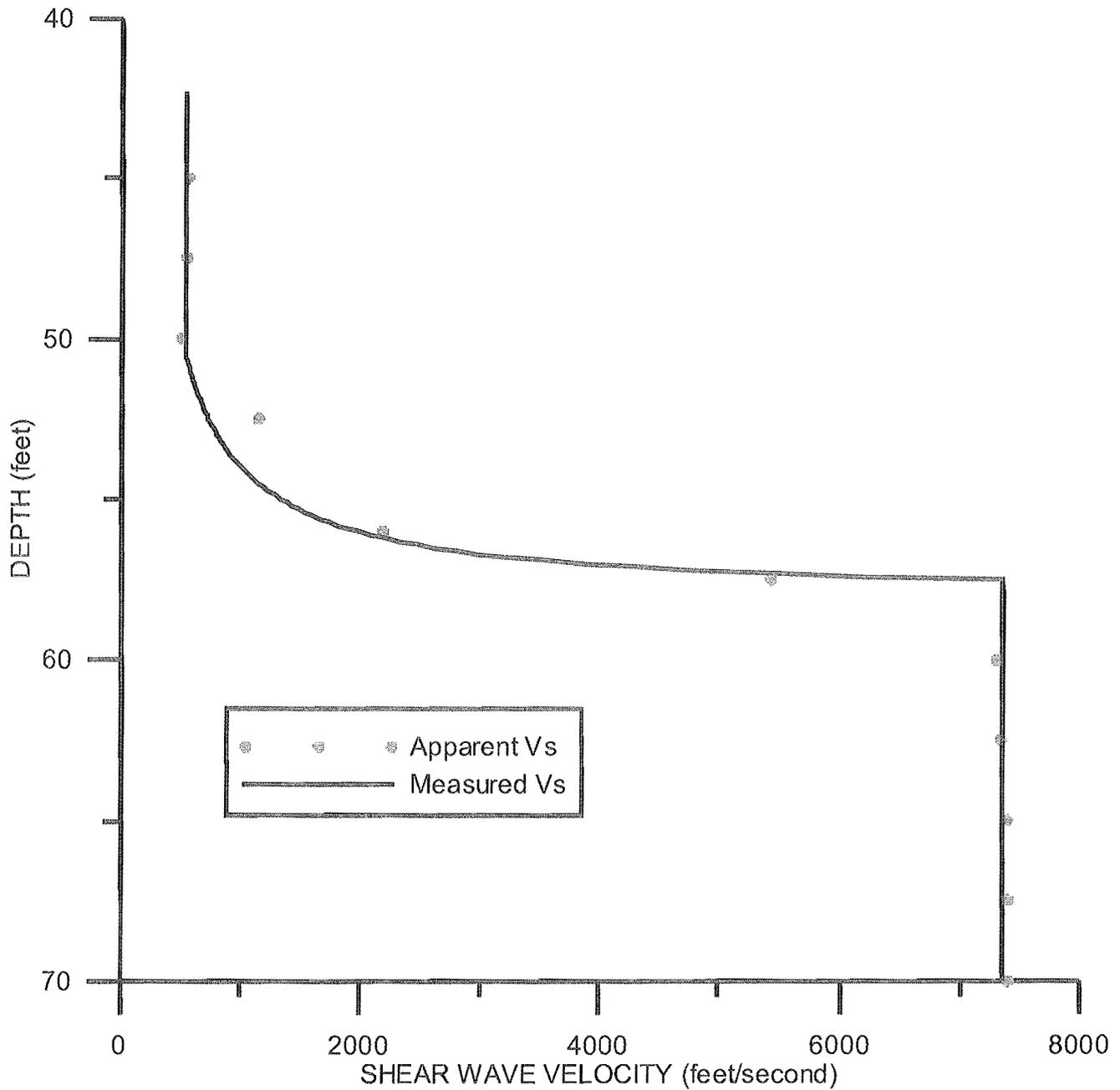


Figure 8. Refraction effects. The model used to calculate the line in the plot consisted of an interface at 57.5 ft depth, consistent with the depths of bedrock reported in the boring logs for Borings B-101 (59.5 ft) and B-104 (53 ft), and shear wave velocities of 550 fps and 7350 fps above and below the interface, respectively. See text.

Crosshole Seismic Testing  
Portsmouth Naval Shipyard  
Kittery, Maine  
File 09VD28 December, 2009

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## APPENDICES

Crosshole Seismic Testing  
Portsmouth Naval Shipyard  
Kittery, Maine  
File 09VD28 December, 2009

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## APPENDIX 1

### ASTM D4428/D4428M - 07 STANDARD TEST METHODS FOR CROSSHOLE SEISMIC TESTING



## Standard Test Methods for Crosshole Seismic Testing<sup>1</sup>

This standard is issued under the fixed designation D 4428/D 4428M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 These test methods are limited to the determination of horizontally traveling compression ( $P$ ) and shear ( $S$ ) seismic waves at test sites consisting primarily of soil materials (as opposed to rock). A preferred test method intended for use on critical projects where the highest quality data must be obtained is included. Also included is an optional method intended for use on projects which do not require measurements of a high degree of precision.

1.2 Various applications of the data will be addressed and acceptable interpretation procedures and equipment, such as seismic sources, receivers, and recording systems will be discussed. Other items addressed include borehole spacing, drilling, casing, grouting, deviation surveys, and actual test conduct. Data reduction and interpretation is limited to the identification of various seismic wave types, apparent velocity relation to true velocity, example computations, effective borehole spacing, use of Snell's law of refraction, assumptions, and computer programs.

1.3 It is important to note that more than one acceptable device can be used to generate a high-quality  $P$  wave or  $S$  wave, or both. Further, several types of commercially available receivers and recording systems can also be used to conduct an acceptable crosshole survey. Consequently, these test methods primarily concern the actual test procedure, data interpretation, and specifications for equipment which will yield uniform test results.

1.4 All recorded and calculated values shall conform to the guide for significant digits and rounding established in Practice D 6026.

1.4.1 The procedures used to specify how data are collected/recorded and calculated in these test methods are regarded as the industry standard. In addition, they are representative of the significant digits that should generally be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to

increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering design.

1.4.2 Measurements made to more significant digits or better sensitivity than specified in these test methods shall not be regarded a nonconformance with this standard.

1.5 These test methods are written using SI units. Inch-pound units are provided for convenience. The values stated in inch pound units may not be exact equivalents; therefore, they shall be used independently of the SI system. Combining values from the two systems may result in nonconformance with these test methods.

1.5.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The rationalized slug unit is not given, unless dynamic ( $F = ma$ ) calculations are involved.

1.5.2 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, these test methods include the gravitational system of inch-pound units and do not use or present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in  $\text{lbm/ft}^3$  shall not be regarded as nonconformance with this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.09 on Cyclic and Dynamic Properties of Soils.

Current edition approved July 1, 2007. Published August 2007. Originally approved in 1984. Last previous edition approved in 2000 as D 4428/D 4428M – 00.

\*A Summary of Changes section appears at the end of this standard.

D 6026 Practice for Using Significant Digits in Geotechnical Data

**3. Terminology**

3.1 *Definitions:* For definitions of other terms used in these Test Methods, see Terminology D 653.

**4. Summary of Test Method**

4.1 The Crosshole Seismic Test makes direct measurements of compression velocities, shear wave velocities, or both, in boreholes advanced through soil or rock. At selected depths down the borehole, a borehole seismic source is used to generate a seismic wave train. Downhole receivers are used to detect the arrival of the seismic wave train in offset borings. Cased borings that are spaced 10 to 20 ft apart are typically used. The distance between boreholes at the test depths is measured using a borehole deviation survey. The borehole seismic source is connected to and triggers a data recording system that records the response of the downhole receiver(s), thus measuring the travel time of the wave train between the source and receiver(s). The compression or shear wave velocity is calculated from the measured distance and travel time for the respective wave train.

NOTE 1—The quality of the results produced by these test methods is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing/sampling/inspection and so forth. Users of these test methods are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

**5. Significance and Use**

5.1 The seismic crosshole method provides a designer with information pertinent to the seismic wave velocities of the materials in question (1).<sup>2</sup> This data may be used as input into static/dynamic analyses, as a means for computing shear modulus, Young’s modulus, and Poisson’s ratio, or simply for the determination of anomalies that might exist between boreholes.

5.2 Fundamental assumptions inherent in the test methods are as follows:

5.2.1 Horizontal layering is assumed.

5.2.2 Snell’s laws of refraction will apply. If Snell’s laws of refraction are not applied, velocities obtained will be unreliable.

**6. Apparatus**

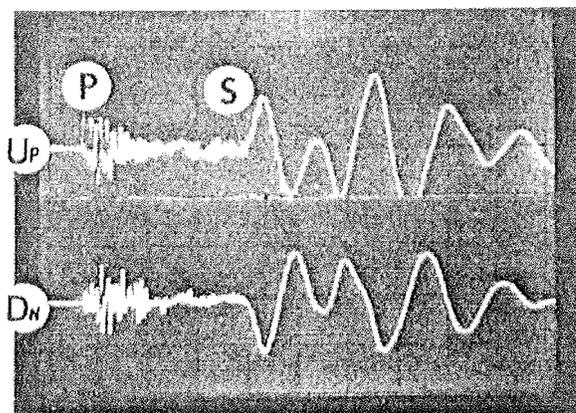
6.1 The basic data acquisition system consists of the following:

6.1.1 *Energy Sources*—These energy sources are chosen according to the needs of the survey, the primary consideration being whether P-wave or S-wave velocities are to be determined. The source should be rich in the type of energy required, that is, to produce good P-wave data, the energy source must transmit adequate energy to the medium in

compression or volume change. Impulsive sources, such as explosives, hammers, or air guns, are all acceptable P-wave generators. To produce an identifiable S wave, the source should transmit energy to the ground primarily by directionalized distortion. For good S waves, energy sources must be repeatable and, although not mandatory, reversible. The S-wave source must be capable of producing an S-wave train with an amplitude at least twice that of the P-wave train. Fig. 1 and Fig. 2 show examples of impulse and vibratory seismic sources.

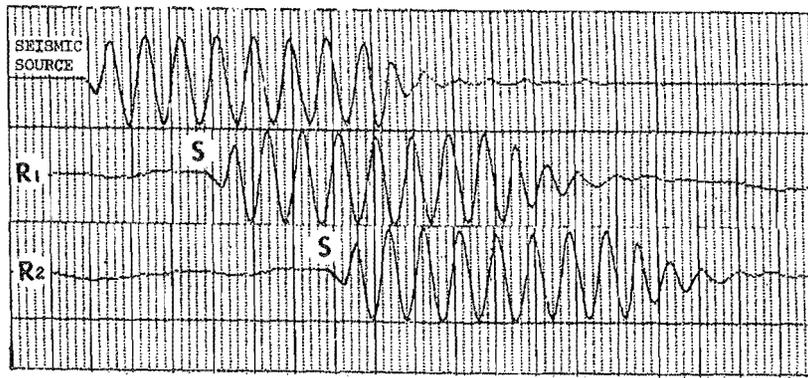
6.1.2 *Receivers*—The receivers intended for use in the crosshole test shall be transducers having appropriate frequency and sensitivity characteristics to determine the seismic wave train arrival. Typical examples include geophones and accelerometers. The frequency response of the transducer must not vary more than 5 % over a range of frequencies from 1/2 to 2 times the predominant frequency of the site-specific S-wave train. Each receiving unit will consist of at least three transducers combined orthogonally to form a triaxial array, that is, one vertical and two horizontal transducers mounted at right angles, one to the other. In this triaxis arrangement, only the vertical component will be acceptable for S-wave arrival determinations. In cases where P-wave arrivals are not desired, a uniaxial vertical transducer may be used. P-wave arrivals will be determined using the horizontal transducer oriented most nearly radially to the source. The transducer(s) shall be housed in a single container (cylindrical shape preferred) not exceeding 450 mm [18 in.] in length. Provision must be made for the container to be held in firm contact with the sidewall of the borehole. Examples of acceptable methods include: air bladder, wedge, stiff spring, or mechanical expander.

6.1.3 *Recording System*—The system shall consist of separate amplifiers, one for each transducer being recorded, having identical phase characteristics and adjustable gain control. Only digital signal filtering will be acceptable. Analog filtering, active or passive, will not be acceptable because of inherent phase delays. The receiver signals shall be displayed in a manner such that precision timing of the P and S-wave arrival referenced to the instant of seismic source activation can be



**FIG. 1 Reversible impulse seismic source (Produces Both P and S Wave Trains)**

<sup>2</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard.



**FIG. 2 Borehole Vibratory Seismic Source (Produces S Wave Train Only)**

determined within 0.1 ms when materials other than rock are being tested. Timing accuracy shall be demonstrated both immediately prior to and immediately after the conduct of the crosshole test. Demonstrate accuracy by inducing and recording on the receiver channels an oscillating signal of 1000 Hz derived from a quartz-controlled oscillator, or, a certified laboratory calibration obtained within the time frame recommended by the instrument manufacturer. Further, the timing signal shall be recorded at every sweep rate or recorder speed, or both, used during conduct of the crosshole test. As an optional method, the true zero time shall be determined by (1) a simultaneous display of the triggering mechanism along with at least one receiver, or (2) a laboratory calibration (accurate to 0.1 ms) of the triggering mechanism which will determine the lapsed time between the trigger closure and development of that voltage required to initiate the sweep on an oscilloscope or seismograph. Permanent records of the seismic events shall be made by either scope-mounted camera or oscillograph.

## 7. Procedure

### 7.1 Borehole Preparation:

7.1.1 *Preferred*—The preferred method for preparing a borehole set for crosshole testing incorporates three boreholes in line, spaced 3.0 m [10 ft] apart, center-to-center on the ground surface, as illustrated in Fig. 3. If, however, it is known that S wave velocities will exceed 450 m/s [1500 ft/s], such as is often encountered in alluvial materials, borehole spacings may be extended to 4.5 m [15 ft].

7.1.1.1 Drill the boreholes, with minimum sidewall disturbance, to a diameter not exceeding 175 mm [7.0 in.]. After the drilling is completed, case the borings with 50 to 100 mm [2 to 4 in.] inside diameter PVC pipe or aluminum casing, taking into consideration the size of the borehole source and downhole receivers. Before inserting the casing, close the bottom of the pipe with a cap which has a one way ball-check valve capable of accommodating 38 mm [1½ in.] outside diameter grout pipe. Center the casing with spacers and insert it into the bottom of the borehole. Grout the casing in place by (1) inserting a 38 mm [1½ in.] PVC pipe through the center of the casing, contacting the one-way valve fixed to the end cap (Fig. 4 (side A)), or (2) by a small diameter grout tube inserted to the bottom of the borehole between the casing and the borehole sidewall (Fig. 4 (side B)). Another acceptable method would be to fill the borehole with grout which would be displaced by

end-capped fluid-filled casing. The grout mixture should be formulated to approximate closely the density of the surrounding in situ material after solidification. That portion of the boring that penetrates rock should be grouted with a conventional portland cement which will harden to a density of about 2.20 Mg/m<sup>3</sup> [140 lb/ft<sup>3</sup>]. That portion of the boring in contact with soils, sands, or gravels should be grouted with a mixture simulating the average density of the medium (about 1.80 to 1.90 Mg/m<sup>3</sup> [110 to 120 lb/ft<sup>3</sup>]) by premixing 450 g [1 lb] of bentonite and 450 g [1 lb] of portland cement to 2.80 kg [6.25 lb] of water. Anchor the casing and pump the grout using a conventional, circulating pump capable of moving the grout through the grout pipe to the bottom of the casing upward from the bottom of the borehole (Fig. 4). Using this procedure, the annular space between the sidewall of the borehole and the casing will be filled from bottom to top in a uniform fashion displacing mud and debris with minimum sidewall disturbance. Keep the casing anchored and allow the grout to set before using the boreholes for crosshole testing. If shrinkage occurs near the mouth of the borehole, additional grout should be inserted until the annular space is filled flush with the ground surface (4).

7.1.2 *Optional*—If the scope or intended use of a particular project does not warrant the time and expense which would be incurred by the preferred method, or if the specific project such as an investigation beneath a relatively small machine foundation is undertaken, this optional method may be used.

7.1.2.1 In all cases, a minimum of two boreholes must be used. If the borings are to be 15 m [50 ft] deep or less, verticality will be controlled using a level on the drill stem extending into the borehole. Center-to-center surface borehole spacing will be determined by the nature of the project. Borings may be used either with or without casing; however, if casing is used, grout must be injected between the casing and sidewall of the borehole to ensure good contact in the manner described in 7.1.1.1. If the center-to-center surface borehole spacing exceeds 6.0 m [20 ft], the probability of measurement of refracted waves rather than a direct wave in each layer greatly increases. As a consequence, data obtained by the optional method must be used with caution.

7.2 *Borehole Deviation Survey*—A borehole deviation survey must be conducted to determine accurately the horizontal distance between borings.

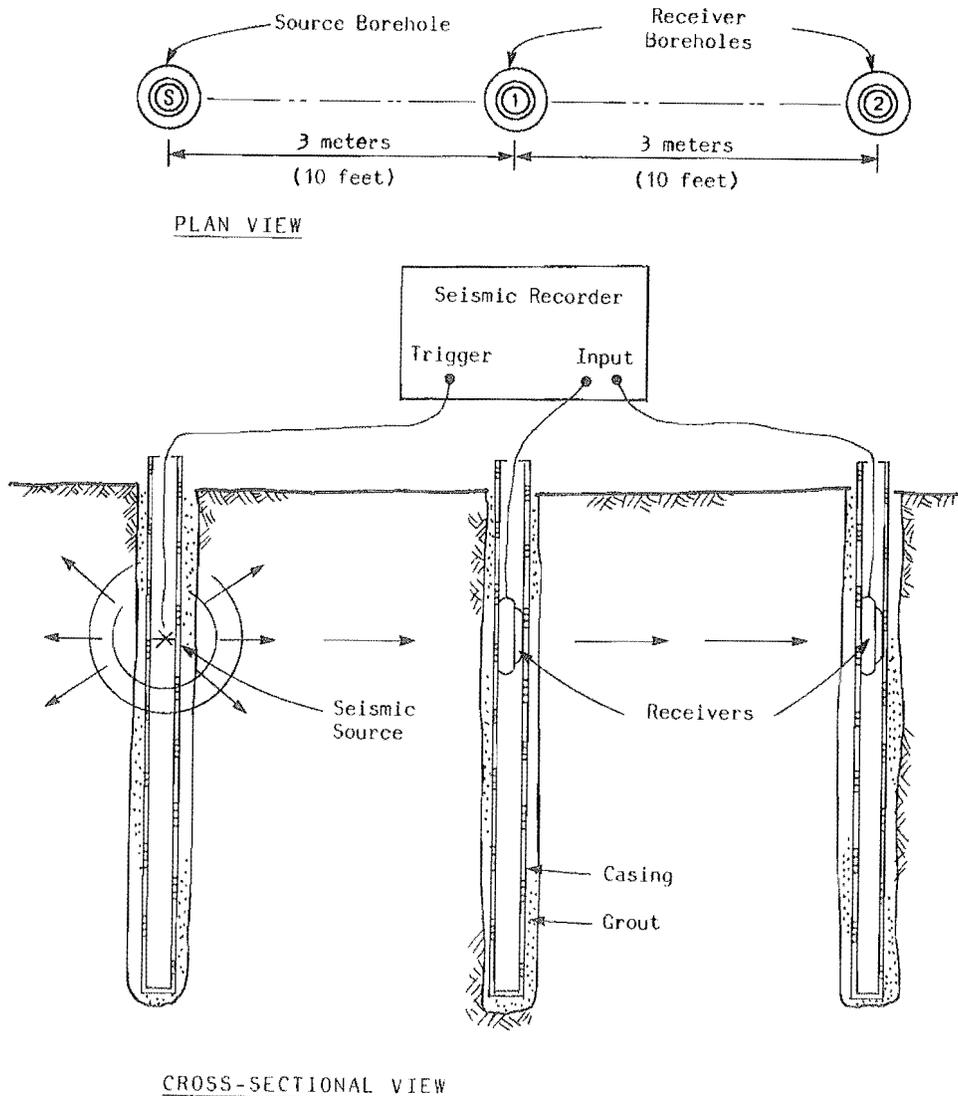


FIG. 3 Crosshole Seismic Test

7.2.1 *Preferred Method*—Conduct a borehole deviation survey in all three crosshole borings with an instrument capable of measuring the precise vertical alignment of each hole. The instrument must have the capability of determining horizontal orientation with a 2° sensitivity and an inclination range from 0 to 30° with a sensitivity of 0.1°. Information thus obtained will enable the investigator to compute true vertical depth and horizontal position at any point within the borehole so that actual distance between the holes can be computed to within ±2% to a depth of about 30.0 m [100 ft].

7.2.1.1 Proceed with the survey beginning at the mouth of the borehole obtaining deviation data at intervals not exceeding 3.0 m [10 ft] to the bottom of the boring. Repeat the measurements on the withdrawal trip at intervals not exceeding 6.0 m [20 ft] so that closure can be determined at the mouth of the borehole.

7.2.2 *Optional Method*—If the scope of a project dictates the use of the optional procedure described in 7.1.2, the following precautions must be undertaken to ensure verticality of the borings.

7.2.2.1 Level the borehole drilling apparatus using a level placed on the drill stem extending into the mouth of the borehole.

7.2.2.2 As drilling progresses, recheck the drill stem at 3.0 m [10 ft] depth intervals and realign as necessary.

7.2.2.3 Limit the maximum depth of investigation to less than 15 m [50 ft]. If the depth of investigation exceeds 15 m [50 ft] a deviation survey such as described in 7.2.1 must be conducted.

7.2.2.4 If casing is used, grout as described in 7.1.1, then evacuate all fluid from the interior and insert a lighted plumb-bob observing its attitude at 3-m [10-ft] intervals. If the plumb-bob strikes the sidewall, note that depth and the direction of deviation.

7.2.2.5 Estimate the distance between borings and provide appropriate caution statements on all data.

7.3 *Crosshole Test:*

7.3.1 *Preferred Method*—Begin the crosshole test by placing the energy source in an end hole at a depth no greater than 1.5 m [5 ft] (Fig. 3) into the stratum being investigated. Place

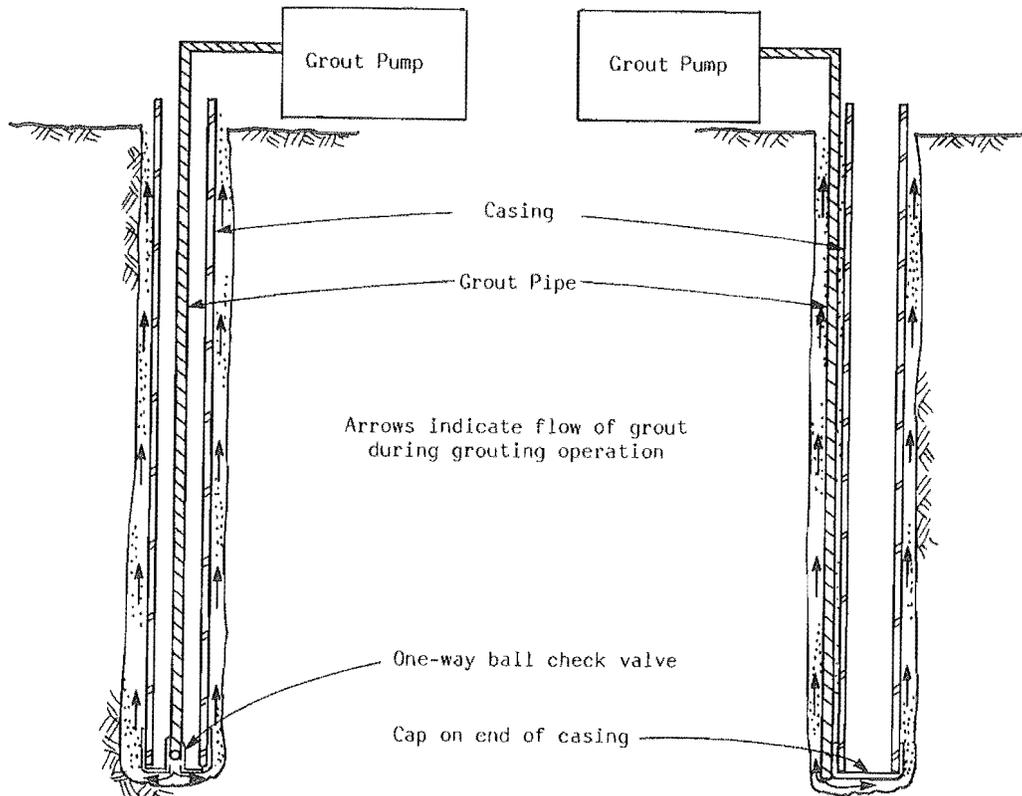


FIG. 4 Acceptable Grouting Techniques

the two receivers at the same elevation in each of the designated receiver holes. Clamp the source and receivers firmly into place. Check recording equipment and verify timing. Activate the energy source and display both receivers simultaneously on the recording device. Adjust the signal amplitude and duration such that the P-wave train or S-wave train, or both, are displayed in their entirety.

7.3.1.1 Best results will be obtained by performing two separate tests: one optimized for P-wave recovery (fastest sweep/recorder rate, higher gain settings) and the second for S-wave recovery (slower sweep/recorder rate, lower gain settings). If enhancement equipment is being used, repeatedly activate the energy source until optimum results are displayed. Do not overrange memory circuitry. A clipped signal is unacceptable. Perform the second test by lowering the energy source and receivers to a depth dictated by known stratification, but no greater than 1.5 m [5.0 ft] from the previous test locations in the borings and repeat the above procedure. Perform succeeding tests at intervals determined by stratification, or at intervals of 1.5 m [5 ft] until the maximum borehole depth has been reached. During withdrawal of the energy source and receivers from the boreholes, perform repeat tests at 6.0-m [20-ft] intervals until the ground surface is reached.

7.3.2 *Optional Method*—Use a minimum of two boreholes. If, however, only two boreholes are used, the importance of true zero time determination as described in 6.1.3 cannot be overemphasized. Place the energy source in one borehole at a depth dictated by test objectives and the receiver at the same elevation in the second borehole. Activate the seismic source and display the trigger mechanism and the receiver simulta-

neously on the recording device. Adjust the sweep rate so that the P-wave train or S-wave train, or both, are displayed in their entirety. If enhancement/stacking equipment is being used, the seismic source should be activated repeatedly until optimum results are displayed. After wave trains have been identified and duly recorded in their entirety, sweep rates may be expanded for optimum determination of arrival times. Additional permanent records should then be made. Overranging of memory circuitry resulting in a clipped signal is not acceptable. Repeat the test at a second location as predetermined by known stratification information and repeat the above procedure. Perform succeeding tests at intervals of about 1.5 m [5 ft], or intervals determined by stratification.

## 8. Data Reduction and Interpretation

8.1 *Deviation Survey*—The primary objective of the borehole deviation survey is to establish the correct horizontal distance between the three in-line borings. Seismic wave velocities compensating for borehole deviation will be computed by determining the straight-line distance,  $l$ , from source to receivers. To do this, the following data are needed:

- $E_S$  = elevation of the top of the source hole,
- $E_G$  = elevation of the top of the geophone hole,
- $D_S$  = depth of the seismic source,
- $D_G$  = depth of the geophone,
- $L$  = horizontal distance between the top of the source hole and geophone hole,
- $\phi$  = azimuth with respect to north from the top of the source hole to the geophone hole,

$x_S$  = the north deviation of the source borehole at the source depth,

$y_S$  = the east deviation of the source borehole at the source depth,

$x_G$  = the north deviation of the geophone borehole at the geophone depth, and

$y_G$  = the east deviation of the geophone borehole at the geophone depth.

8.1.1 The following equation determines the straight-line distance,  $l$ , from source to geophone using the data of 8.1:

$$l = \sqrt{[(E_S - D_S) - (E_G - D_G)]^2 + (L \cos \phi + x_G - x_S)^2 + (L \sin \phi + y_G - y_S)^2}$$

The apparent velocity is equal to  $l$  divided by the travel time. Use the same method to determine the straight-line distances between the geophone holes.

**8.2 Wave Train Identification:**

8.2.1 Identify the P-wave train arrival time as the first departure of the static horizontal receiver trace after time  $T = 0$ . It should be noted that the horizontally oriented geophones will often (correctly) respond earlier than the vertically oriented because of the longitudinal particle motion associated with the P wave (5). If both wave trains (P and S) are displayed simultaneously on the records, the S wave will be identified on the seismic signature by the following characteristics:

8.2.1.1 A sudden increase in amplitude of at least two times that of the P-wave train, and,

8.2.1.2 An abrupt change in frequency coinciding with the amplitude change which results in a period increase of at least two times that of the characteristic period of the P wave.

8.2.1.3 *Optional*—If a reversible polarity seismic source is used, the S wave arrival will be determined as that point meeting the criteria of 8.2.1.1 and 8.2.1.2 and where a 180° polarity change is noted to have occurred.

8.2.2 The above characteristics are displayed in Fig. 1. Determine the arrival time for the P wave or S wave directly from the record as the lapsed time between time zero (activation of the seismic source) and the arrival of the respective wave trains at each of the receivers. If a vertically polarized S wave vibratory source is used, the arrival time of the S wave will be determined from the time lapsed between the start up of

the seismic source monitor geophone and the first arrival of a seismic signal bearing the same characteristic frequency. No discernible P-wave signal is present; consequently, the vibratory source is unacceptable for P wave determinations (see Fig. 2).

**8.3 Data Tabulation:**

8.3.1 Three separate travel times observed in the field and recorded are as follows:

8.3.1.1 Source to Receiver 1,

8.3.1.2 Source to Receiver 2, and

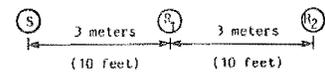
8.3.1.3 Time difference between Receivers 1 and 2.

8.3.2 Tabulate the data in a manner similar to that shown in Fig. 5. Determine preliminary velocity in the field (recognizing that borehole deviations have not been taken into account) by dividing the measured surface distance between source and receivers by the arrival time at each respective receiver. Determine incremental velocity by dividing the measured distance between receivers  $R_1$  and  $R_2$  by the difference in arrival times between source and  $R_2$  and source and  $R_1$ .

NOTE 2—Under ideal circumstances, (that is, nonlayered homogeneous materials, vertical boreholes, and no trigger delays in the recording equipment) all three computed velocities ( $S - R_1$ ,  $S - R_2$ , and  $R_1 - R_2$ ) should be the same value. In normal testing, however, this will rarely be true. Trigger delays up to 3 ms have been observed in some equipment, causing erroneously high computed velocities between  $S - R_1$  and  $S - R_2$ . If this occurs,  $S - R_1$  will compute the highest velocity, followed by  $S - R_2$ . The incremental  $R_1 - R_2$  velocity will not be affected by trigger errors. Other factors which can affect incremental velocity determinations are: (a) dissimilar materials between borings 1-2 and 2-3, (b) faulting or drastically inclined layering, and (c) refraction caused by the presence of a nearby higher velocity layer. Items (a) and (b) can only be determined by other direct tests. If such conditions exist, the usefulness of the crosshole test should be judged according to the purpose of the site investigation. Item (c) can be accounted for by proper use of Snell's law of refraction. Therefore, the standard crosshole velocity will be determined from the incremental time recorded between receiver holes  $R_1$  and  $R_2$  (5).

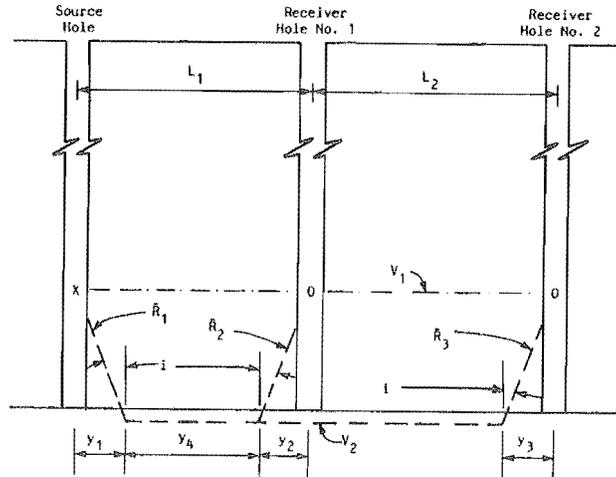
**8.4 Data Reduction:**

8.4.1 In materials where abrupt changes in density or elasticity occur, the ray travel path of the wave might not be a straight line (6). In such cases, Snell's law of refraction must be used. Examples are shown in Fig. 6 and the Appendixes.



Depth m (ft)	Travel Time (msec)						Apparent Velocity mps (fps)						
	S - R <sub>1</sub>		S - R <sub>2</sub>		R <sub>1</sub> - R <sub>2</sub>		S - R <sub>1</sub>		S - R <sub>2</sub>		R <sub>1</sub> - R <sub>2</sub>		
	P	S	P	S	P	S	P	S	P	S	P	S	

FIG. 5 Crosshole Data Tabulation



LEGEND:		Velocity	f/s	m/s
X	Location of Source	$V_1$	3500	1100
O	Location of Receivers	$V_2$	10000	3000
---	Straight Line Distance Travel Point			
---	Refracted Travel Path			
		Distance	Feet	Metres
$L_1 = L_2$	10.00			
$\bar{R}_1 = \bar{R}_2 = \bar{R}_3$	5.34			
$y_1 = y_2 = y_3$	1.87			
$y_4 = L_1 - (y_1 + y_2)$	6.26			

FIG. 6 Example Crosshole Computation

TABLE 1 Apparent Velocity as a Function of Hole Spacing

Depth, m [ft]	Time velocity profile, m/s [ft/s]	Interface depth, m [ft]	Apparent velocities <sup>A</sup> for hole spacings of:				
			6 m [20 ft]	12 m [40 ft]	18 m [60 ft]	21 m [70 ft]	30 m [100 ft]
1.5 [5.0]	300 [1000]	3.70 [12.0]	300 [1000]	367 [1245]	423 [1424]	532 [1760]	630 [2086]
3.0 [10.0]	300 [1000]		427 [1485]	499 [1705]	551 [1833]	682 [2252]	796 [2630]
4.5 [15.0]	600 [2000]	8.50 [28.0]	600 [2000]	600 [2000]	707 [2295]	858 [2792]	985 [3210]
6.0 [20.0]	600 [2000]		600 [2000]	697 [2363]	873 [2816]	1038 [3360]	1171 [3801]
7.5 [25.0]	600 [2000]		761 [2632]	931 [3175]	1141 [3644]	1313 [4218]	1444 [4658]
9.0 [30.0]	1200 [4000]	12.0 [42.0]	1200 [4000]	1286 [4000]	1522 [4726]	1675 [5264]	1783 [5651]
10.5 [35.0]	1200 [4000]		1286 [4000]	1675 [4981]	1862 [5697]	1973 [6139]	2046 [6439]
12.0 [40.0]	1200 [4000]		2400 [5942]	2400 [6819]	2400 [7172]	2400 [7362]	2400 [7482]
13.5 [45.0]	2400 [8000]	14.0 [46.0]	2400 [8000]	2400 [8000]	2400 [8000]	2400 [8000]	2400 [8000]
15.0 [50.0]	1800 [6000]	17.4 [57.0]	1855 [6000]	2092 [6801]	2186 [7158]	2236 [7527]	2290 [7782]
16.5 [55.0]	1800 [6000]		2022 [7355]	2312 [8095]	2428 [8376]	2491 [8524]	2530 [8615]
18.0 [60.0]	2700 [9000]		2700 [9000]	2700 [9000]	2700 [9000]	2700 [9000]	2700 [9000]

<sup>A</sup>All velocities are expressed in m/s [ft/s].

NOTE 3—Table 1 illustrates the differences between apparent and true velocities in a crosshole survey. This survey was conducted at 1.6-m [5-ft] increments to a depth of 18 m [60 ft] at the hypothetical site characterized by the true profile shown in the table. Assuming the data were obtained at the same elevations in receiver holes located about 6 to 30 m [20 to 100 ft] from the source, the user will observe that as borehole spacing increases, the low velocity zone located at a spacing increases, the low velocity zone located at a depth of 14 m [46 ft] becomes appreciably less evident at distances greater than 6 m [20 ft]; hence, the overall philosophy of limiting borehole spacing for a crosshole standard test to a maximum of 9 m [30 ft].

8.4.2 Calculations—Due to the nature and number of calculations which are involved in a typical application of the crosshole technique to a layered site where refractions are likely to occur, a computer program for crosshole seismic data interpretation may be used (7). The program must apply Snell's law to develop a true velocity interpretation consistent with all the data from a given survey. An acceptable example output of a computer program capable of solving the corrected distances, true velocities using Snell's law, and interface depths is shown

in Table 2. Computerized or manual data reduction and interpretation shall incorporate the following information:

- 8.4.2.1 Source and receiver depths,
- 8.4.2.2 Arrival times of P waves or S waves, or both,
- 8.4.2.3 Surface distance between holes, and
- 8.4.2.4 Borehole deviations (N-S and E-W).

8.4.3 The procedure used in either computer programs or hand calculations begins by assuming that the apparent velocity measured in either the shallowest or deepest crosshole test is a true velocity (Note 4). Layer interfaces are tentatively assumed to exist at middepth between successive test points in the hole, and arrival times from the second test point are computed for all possible paths from the apparent velocities and critical angles. The arrival time(s) at the geophone at the level consistent with the data is the plausible true path. The procedure is repeated until a consistent explanation for all of

the data from all of the tests in the borehole is determined. Fig. 6 and the Appendixes provide a numerical (hand) example of the process.

NOTE 4—The better practice is to use the shallowest depth since this velocity can be independently checked by a surface survey.

NOTE 5—*Example Calculation*—Consider the hypothetical case illustrated in Fig. 6. A seismic source and receivers are located at an assumed depth in a medium having a P wave velocity of 1100 m/s [3500 ft/s]. The receiver holes are spaced at distances of 0 and 6.0 m [0 and 20 ft] respectively, from the source hole. A zone of 3000 m/s [10 000 ft/s] velocity is assumed to be encountered at a depth 1.5 m [5 ft] below the source and receivers (Computations are given in Table 3). Example 1, in Appendix X1, and Appendix X2., is a case where the seismic source is located at a 3.0 m [10 ft] distance from the geophone. When Snell's law is applied, the shortest travel time results when the wave front travels through the 1100 m/s [3500 ft/s] velocity zone. Example 2 of Appendix X3 and Appendix X4, is a case where the seismic source is located 6.0 m

**TABLE 2 Results and Interpretation of Data from Crosshole Computer Program**

Crosshole Data—S-wave, no name dam, downstream slope (horizontal distance between holes is 10.0)											
Depth		Direct Path Distance	Time Increment	Apparent Velocity	Rec <sub>1</sub>		Rec <sub>2</sub>				
Rec <sub>1</sub>	Rec <sub>2</sub>				X-Dev	Y-Dev	X-Dev	Y-Dev			
Crosshole Data											
5.0	5.0	10.0	0.0110	908	-0.07	-0.03	-0.06	-0.07			
10.0	10.0	10.0	0.0095	1051	-0.14	-0.07	-0.11	-0.14			
15.0	15.0	10.0	0.0100	998	-0.14	-0.07	-0.11	-0.14			
20.0	20.0	10.0	0.0098	1024	-0.14	-0.07	-0.11	-0.14			
25.0	25.0	10.0	0.0088	1141	-0.16	-0.09	-0.13	-0.16			
30.0	30.0	10.0	0.0085	1175	-0.18	-0.11	-0.14	-0.18			
35.0	35.0	10.0	0.0090	1109	-0.11	-0.07	-0.08	-0.14			
40.0	40.0	10.0	0.0085	1175	-0.04	-0.03	-0.01	-0.10			
45.0	45.0	10.0	0.0085	1175	0.05	-0.00	0.09	-0.07			
50.0	50.0	10.0	0.0075	1331	0.15	0.02	0.18	-0.05			
Computed Travel Times, s											
Rec <sub>1</sub> Depth	Rec <sub>2</sub> Depth	True Velocity Average	Interface Depth	Direct	Down 1 Layer	Down 2 Layer	Down 3 Layer	Up 1 Layer	Minimum Time	Apparent Velocities	
										Computed	Measured
Crosshole Interpretation—S-wave, no name dam, downstream slope											
5.0	5.0	908		0.0120	0.0110		0.0230		0.0110	908	908
		1051	6.3			0.0185	0.0442		0.0095	1051	1051
			14.2								
15.0	15.0	998		0.0100	0.0146	0.0382		0.0100	0.0100	998	998
20.0	20.0	998		0.0100	0.0097	0.0316		0.0131	0.0097	1024	1024
			21.0								
25.0	25.0	1142		0.0087	0.0266				0.0087	1142	1141
30.0	30.0	1142		0.0087	0.0221				0.0087	1142	1175
35.0	35.0	1142		0.0087	0.0176				0.0087	1142	1109
40.0	40.0	1142		0.0087	0.0131				0.0087	1142	1175
45.0	45.0	1142		0.0087	0.0086				0.0086	1158	1175
50.0	50.0	1331	46.2	0.0075					0.0075	1331	1331
Crosshole Diagnostic—S-wave, no name dam, downstream slope											
<i>Caution</i> —The interface calculated to be at 6.3 could be anywhere between 6.3 and 10.0				<u>Execution Check</u>		<u>Layer 1</u>	<u>Depth 1</u>	<u>Down 1</u>			
<i>Caution</i> —The interface calculated to be at 14.2 could be anywhere between 10.0 and 14.2.				<u>Execution Check</u>		<u>Layer 2</u>	<u>Depth 2</u>	<u>Down 1</u>			
<i>Caution</i> —At geophone depth 20.0, the 1024 could be a true velocity.				<u>Execution Check</u>		<u>Layer 3</u>	<u>Depth 3</u>	<u>Down 1</u>			
<i>Caution</i> —The interface calculated to be at 25.6 could be anywhere between 25.6 and 30.0.				<u>Execution Check</u>		<u>Layer 4</u>	<u>Depth 5</u>	<u>Down 1</u>			
<i>Caution</i> —The interface calculated to be at 34.2 could be anywhere between 30.0 and 34.2.				<u>Execution Check</u>		<u>Layer 5</u>	<u>Depth 6</u>	<u>Up 1</u>			
<i>Caution</i> —At geophone depth 40.0, the 1175 could be a true velocity.				<u>Execution Check</u>		<u>Layer 6</u>	<u>Depth 7</u>	<u>Down 1</u>			
<i>Caution</i> —The interface calculated to be at 46.2 could be anywhere between 46.2 and 50.0.				<u>Execution Check</u>		<u>Layer 7</u>	<u>Depth 9</u>	<u>Down 1</u>			

[20 ft] from the geophone. In this example, the application of Snell's law shows that the shortest travel time would be along a path influenced by the 3000 m/s [10 000 ft/s] velocity zone. Example 2, a case involving the same velocity profile and a 6.0 m [20 ft] spacing, shows a case where analysis reveals that the measured travel time is not an arrival via a straight-line path and that the apparent velocity is not a true velocity.

**8.5 Comparisons With Other Data**—After the reduction and interpretation of the crosshole data, the results must be analyzed in conjunction with other data, including surface refraction and available boring data, and a velocity zone profile descriptive of subsurface conditions made.

### 9. Report: Test Data Sheet(s)/Form(s)

9.1 The methodology used to specify how data are recorded on the test data sheet/form, as given below, is covered in 1.4.

9.2 Record as a minimum the following general information (data):

9.2.1 Project description, operator, weather conditions.

9.2.2 Make and model of borehole seismic source, down-hole receivers and recording equipment.

9.2.3 Borehole information, method of installation, casing diameter(s).

9.2.4 Method used to interpret results.

9.2.5 Distance between each borehole or borehole coordinates at ground surface.

9.3 Record as a minimum the following test data at each measurement depth:

9.3.1 Measured deviations of each bore hole.

9.3.2 Distance between each pair of borehole sets.

9.3.3 Travel time between each of the three borehole pairs.

9.3.4 Apparent velocity between each of the three borehole pairs.

### 10. Precision and Bias

**10.1 Precision**—Test data on precision are not presented due to the nature of the soil or rock, or both materials tested by these test methods. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. In addition, it is either not feasible or too costly to produce multiple specimens that have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation.

10.1.1 Subcommittee D18.09 is seeking any data from users of this test method that might be used to make a limited statement on precision.

**10.2 Bias**—There is no accepted reference value for these test methods, therefore, bias cannot be determined.

### 11. Keywords

11.1 accelerometers; compression wave; geophones; machine foundations; seismic waves; shear waves; wave velocity

## APPENDIXES

### (Nonmandatory Information)

#### X1. Example 1 of the Application of Snell's Law in SI Units

X1.1 Assume seismic source and receiver 3.0 m apart in velocity layer and above a 3000 m/s velocity layer:

X1.1.1 The critical angle of refraction is:

$$I = \arcsin\left(\frac{V_1}{V_2}\right) = \frac{1100 \text{ m/s}}{3000 \text{ m/s}} = 21.5^\circ \quad (\text{X1.1})$$

X1.1.2 Hypotenuse distances:

$$\bar{R}_1 = (1.5 \text{ m}/\cos 21.5^\circ) = 1.61 \text{ m} \quad (\text{X1.2})$$

$$\bar{R}_2 = (1.5 \text{ m}/\cos 21.5^\circ) = 1.61 \text{ m}$$

X1.1.3 Abscissa distances:

$$Y_1 = 1.5 \tan (21.5^\circ) = 0.59 \text{ m} \quad (\text{X1.3})$$

$$Y_2 = 1.5 \tan (21.5^\circ) = 0.59 \text{ m}$$

X1.2 Assume possible travel path through both 1100 m/s and 3000 m/s materials:

X1.2.1 Travel time in 1100 m/s material:

$$t_1 = 2(1.61)/1100 = 0.003 \text{ s} \quad (\text{X1.4})$$

X1.2.2 Travel time in 3000 m/s material:

$$t_2 = (3 - 2(0.59))/3000 = 0.00061 \text{ s} \quad (\text{X1.5})$$

X1.2.3 Total travel time:

$$(t_1 + t_2) = 0.00361 \text{ s} \quad (\text{X1.6})$$

X1.3 Assume possible travel path through 1100 m/s material only using straight line distance method:

X1.3.1 Then travel time:

$$1.5 \text{ m (at 1100 m/s)} = 3.0/1100 = 0.0027 \text{ s} \quad (\text{X1.7})$$

X1.3.2 Actual measured time = 0.0027 s.

X1.3.3 Since travel time by direct path is equal to measured time and less than possible refracted path travel time, it is concluded that the velocity is true and indicative of a path through the lower velocity layer only.

### X2. Example 1 of the Application of Snell's Law in Inch-Pound Units

X2.1 Assume seismic source and receiver 10 ft apart in 3500 ft/s velocity and 5 ft above a 10 000 ft/s velocity layer:

X2.1.1 The critical angle of refraction is:

$$I = \arcsin \frac{V_1}{V_2} = \frac{3500 \text{ ft/s}}{10\,000 \text{ ft/s}} = 20.5^\circ \quad (\text{X2.1})$$

X2.1.2 Hypotenuse distances are:

$$\bar{R}_1 = (5 \text{ ft}/\cos 20.5^\circ) = 5.34 \text{ ft} \quad (\text{X2.2})$$

$$\bar{R}_2 = (5 \text{ ft}/\cos 20.5^\circ) = 5.34 \text{ ft}$$

X2.1.3 Abscissa distances are:

$$Y_1 = 5 \tan 20.5^\circ = 1.87 \text{ ft} \quad (\text{X2.3})$$

$$Y_2 = 5 \tan 20.5^\circ = 1.87 \text{ ft}$$

X2.2 Assume possible travel path through both 3500 ft/s and 10 000 ft/s materials:

X2.2.1 Travel time in 3500 ft/s material:

$$t_{3500} = (2(5.34)/3500) = 0.003 \text{ s} \quad (\text{X2.4})$$

X2.2.2 Travel time in 10 000 ft/s material:

$$t_{10\,000} = (10 - (2 \times 1.87)/10\,000) = 0.00063 \text{ s} \quad (\text{X2.5})$$

X2.2.3 Total travel time,  $(t_{3500} + t_{10\,000}) \approx 0.00363 \text{ s}$

X2.3 Assume possible travel path through 3500 ft/s material only using straight-line distance method:

X2.3.1 Travel time,  $s_{3500} = 10/3500 = 0.0029 \text{ s}$ .

X2.3.2 Actual measured travel time = 0.0029 s

X2.3.3 Since travel time by direct path is equal to measured time and less than possible refracted path travel time, it is concluded that the velocity is true and indicative of a path through the lower velocity layer only.

### X3. Example 2 of the Application of Snell's Law in SI Units

X3.1 Assume seismic source and receiver geophone 6 m apart in 1100 m/s velocity layer and 1.6 m above a 3000 m/s velocity layer:

X3.1.1 The critical angle of refraction is:

$$I = \arcsin \frac{V_1}{V_2} = 1100 \text{ m/s}/3000 \text{ m/s} = 21.5^\circ \quad (\text{X3.1})$$

X3.1.2 Hypotenuse distances:

$$\bar{R}_1 = 1.5/\cos (21.5^\circ) = 1.61 \text{ m} \quad (\text{X3.2})$$

$$\bar{R}_2 = 1.5/\cos (21.5^\circ) = 1.61 \text{ m}$$

X3.1.3 Abscissa distances:

$$Y_1 = 1.5 \tan (21.5^\circ) = 0.59 \text{ m} \quad (\text{X3.3})$$

$$Y_3 = 1.5 \tan (21.5^\circ) = 0.59 \text{ m}$$

X3.2 Assume possible travel path through both 1100 m/s and 3000 m/s materials:

X3.2.1 Travel time in 1100 m/s material:

$$t_1 = 2(1.61)/1100 = 0.003 \text{ s} \quad (\text{X3.4})$$

X3.2.2 Travel time in 3000 m/s material:

$$t_2 = (6 - (2 \times 0.59))/3000 = 0.00161 \text{ s} \quad (\text{X3.5})$$

X3.2.3 Total travel time:

$$(t_1 + t_2) = 0.003 + 0.00161 = 0.00461 \text{ s} \quad (\text{X3.6})$$

X3.3 Assume possible travel path through 1100 m/s material only using straight line distance method:

X3.3.1 Then travel time:

$$t_1 = 6/1100 = 0.0055 \text{ s} \quad (\text{X3.7})$$

X3.3.2 Actual measured travel time = 0.0055 s.

X3.3.3 Since travel time by the possible refracted path is equal to the measured time and less than the direct path travel time, it is concluded that the ray path was refracted. If the velocity had been computed from the straight line distance (6 m) divided by the measured time (0.0055), the value 1300 m/s would be apparent rather than true.

### X4. Example 2 of the Application of Snell's Law in Inch-Pound Units

X4.1 Assume seismic source and receiver geophone 20 ft apart in 3500 ft/s velocity layer and 5 ft above a 10 000 ft/s velocity layer:

X4.1.1 The critical angle of refraction is:

$$I = \arcsin \frac{V_1}{V_2} = \frac{3500 \text{ ft/s}}{10\,000 \text{ ft/s}} = 20.5^\circ \quad (\text{X4.1})$$

X4.1.2 Hypotenuse distances are:

$$\bar{R}_1 = (5 \text{ ft}/\cos 20.5^\circ) = 5.34 \text{ ft} \quad (\text{X4.2})$$

$$\bar{R}_2 = (5 \text{ ft}/\cos 20.5^\circ) = 5.34 \text{ ft}$$

X4.1.3 Abscissa distances are:

$$Y_1 = 5 \tan 20.5^\circ = 1.87 \text{ ft} \quad (\text{X4.3})$$

$$Y_3 = 5 \tan 20.5^\circ = 1.87 \text{ ft}$$

X4.2 Assume possible travel path through both 3500 ft/s and 10 000 ft/s materials:

X4.2.1 Travel time in 3500 ft/s material:

$$t_{3500} = (2(5.34)/3500) = 0.003 \text{ s} \quad (\text{X4.4})$$

X4.2.2 Travel time in 10 000 ft/s material:

$$t_{10\ 000} = (20 - (2 \times 1.87)/10\ 000) = 0.00163 \text{ s} \quad (\text{X4.5})$$

X4.2.3 Total travel time ( $t_{3500} + t_{10\ 000}$ ) = 0.003 + 0.00163 = 0.00463 s.

X4.3 Assume possible travel path through 3500 ft/s mate-

rial only using straight-line distance method:

X4.3.1 Travel time,  $t_{3500} = 20/3500 = 0.0057 \text{ s}$ .

X4.3.2 Actual measured travel time = 0.0046 s

X4.3.3 Since travel time by the possible refracted path is equal to the measured time and less than the direct path travel time, it is concluded that the ray path was refracted. If the velocity had been computed from the straight-line distance (20 ft) divided by the measured time (0.0046), the value 4350 ft/s would be apparent rather than true.

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## SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D 4428/D 4428M – 00) that may impact the use of this standard. (Approved July 1, 2007.)

- (1) Added Section 1.4 on significant digits.
- (2) Updated Section 1.5 on the use of SI units.
- (3) Added Section 2, Referenced Documents.
- (4) Added Section 3, Terminology.
- (5) Added Section 4, Summary of Test Methods.
- (6) Added Note 1.
- (7) Modification to precision statement in 10.1.
- (8) Addition of bias statement in 10.2.
- (9) Added Section 9, Report.

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Crosshole Seismic Testing  
Portsmouth Naval Shipyard  
Kittery, Maine  
File 09VD28 December, 2009

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HAGER-RICHTER  
GEOSCIENCE, INC.

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**APPENDIX 2**  
**BORING LOGS**



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: As marked  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 6'

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 11/10/09  
 Date Completed: 11/10/09  
 Surface Elevation: ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0			ASPHALTIC PAVEMENT. SAND (FILL); Loose, moist to wet, fine to medium sand, few silt, trace gravel and coarse sand, brown.					
5		S-1		8	4 5 3 4	8		
10		S-2	CLAYEY SILT WITH SAND (FILL); Medium dense, wet, silt and clay, few fine sand, with shell fragments, organic odor, black and gray.	4	6 12 10 8	22		
15		S-3	GRAVELLY SAND (FILL); Medium dense, wet, fine to medium sand, little gravel, with rock fill, organic odor, dark gray.	6	7 17 7 10	24		
20		S-4	SILTY CLAY (CL); Very stiff, wet, silty clay, with occasional fine sand seams, brown and gray. No recovery, pushed small cobble through sample interval.	0	4 5 5 9	10		
25		S-5		4	7 11 7 5	18		
30								

Notes:



**R.W. Gillespie & Associates, Inc.**  
 Geotechnical Engineering • Geohydrology • Materials Testing Services

Boring Log: B-101

Total Depth: 76

Sheet 2 of 3

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 6'

RWG&A Project No. 767-42  
 Surface Elevation: ()  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30		S-6	Becomes very soft.	20	WOR WOR WOR WOR	0		
35								
40								
45								
50								
55		S-7	SILTY SAND WITH GRAVEL (SM); Dense, wet, fine sand, little silt, few fine gravel, gray.	21	8 17 3 20	20		
60								

Notes:



**R.W. Gillespie & Associates, Inc.**  
 Geotechnical Engineering • Geohydrology • Materials Testing Services

Boring Log: B-101

Total Depth: 76

Sheet 3 of 3

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 6'

RWG&A Project No. 767-42  
 Surface Elevation: ()  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
60			Top of bedrock, began rollercone drilling.					
65  70  75  80  85  90			Bottom of Exploration at 76'; Refusal at 59.5'.					

Notes:

Preliminary



Project Name: Waterfront Support Facility  
 RWG&A Project No. 767-42  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 RWG&A Representative: C. Morrell  
 Boring Location: As marked  
 Boring Abandonment Method: Backfilled with cuttings  
 Observed Water Depth: 8'

Drilling Contractor: Great Works Test Boring  
 Drill Rig: B 59 Truck  
 Driller Rep.: Pete Michaud  
 Date Started: 11/10/09  
 Date Completed: 11/11/09  
 Surface Elevation: ( )  
 Drilling Method: 4-inch Tri-Cone  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 5'	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
0		ASPHALTIC PAVEMENT.					
0 - 14		SAND (FILL); Loose, moist to wet, fine to medium sand, few silt, trace gravel and coarse sand, brown.					
14 - 19		GRAVEL AND SILT (FILL); wet, gravel, with rock fill, few silt and clay, gray.					
15	S-1		6	16 10 13 4	23		
20 - 22		Drilling resistance increased, possible boulder. (20' to 22')					
22 - 25	S-2	SILTY CLAY (CL); Very stiff to very soft, wet, silty clay, gray.	19	5 10 14 15	24		
25 - 30	S-3		12	4 6 6 7	12		

Notes:



**R.W. Gillespie & Associates, Inc.**  
 Geotechnical Engineering • Geohydrology • Materials Testing Services

Boring Log: B-104

Total Depth: 70.5

Sheet 2 of 3

Project Name: Waterfront Support Facility  
 Location: Kittery, Maine  
 Client: Oak Point Associates  
 Observed Water Depth: 8'

RWG&A Project No. 767-42  
 Surface Elevation: ()  
 Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
30	FV	Field Vane: Undrained Shear Strength: $S_u=0.87$ ksf, Residual=0.11 ksf.					
35	S-4		24	WOR WOR WOR WOR	0		
40	FV	Field Vane: Undrained Shear Strength: $S_u=0.71$ ksf, Residual=0.22 ksf.					
	FV	Field Vane: Undrained Shear Strength: $S_u=0.69$ ksf, Residual=0.22 ksf.					
45	FV	Field Vane: Undrained Shear Strength: $S_u=0.76$ ksf, Residual=0.22 ksf.					
	FV	Field Vane: Undrained Shear Strength: $S_u=0.76$ ksf, Residual=0.22 ksf.					
50	S-5	Occasional fine sand seams.	19	WOH WOH 10 10	10		
		SILTY SAND WITH GRAVEL (SM); Dense, wet, fine sand, little silt, few fine gravel, gray.					
		Top of bedrock, began rollercone drilling.					
55							
60							

Notes:



**R.W. Gillespie & Associates, Inc.**  
 Geotechnical Engineering • Geohydrology • Materials Testing Services

Boring Log: B-104

Total Depth: 70.5

Sheet 3 of 3

Project Name: Waterfront Support Facility

Location: Kittery, Maine

Client: Oak Point Associates

Observed Water Depth: 8'

RWG&A Project No. 767-42

Surface Elevation: ( )

Casing Type: 4 inch driven

DEPTH, FT.	SYMBOL SAMPLES	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLE RECOVERY, IN.	BLOWS PER 6"	SPT-N BLOWS PER FT.	MOISTURE CONTENT %	LAB TESTS
60								
65								
70								
			Bottom of Exploration at 75'; Refusal at 53'					

Notes:

Preliminary

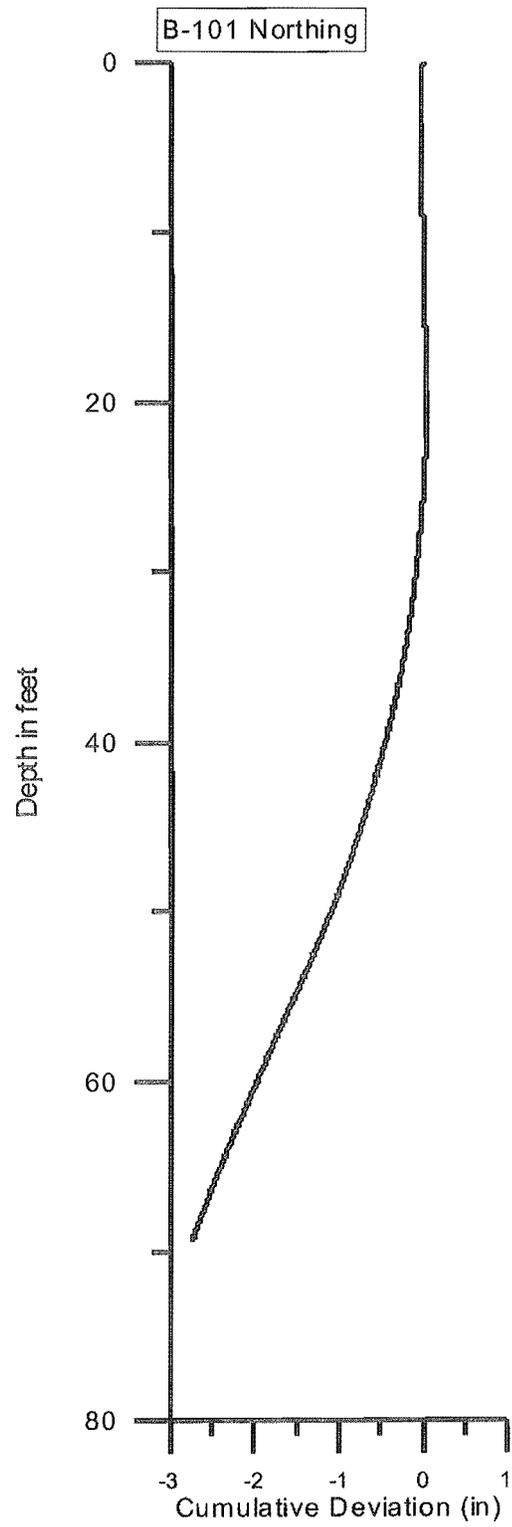
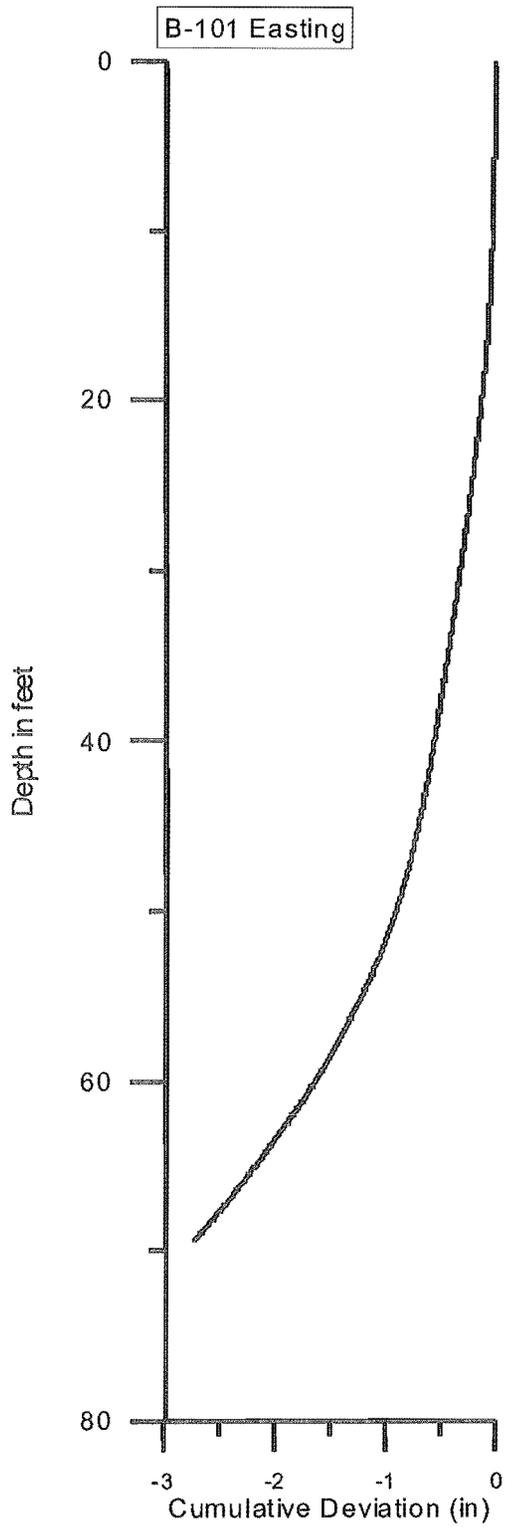
Crosshole Seismic Testing  
Portsmouth Naval Shipyard  
Kittery, Maine  
File 09VD28 December, 2009

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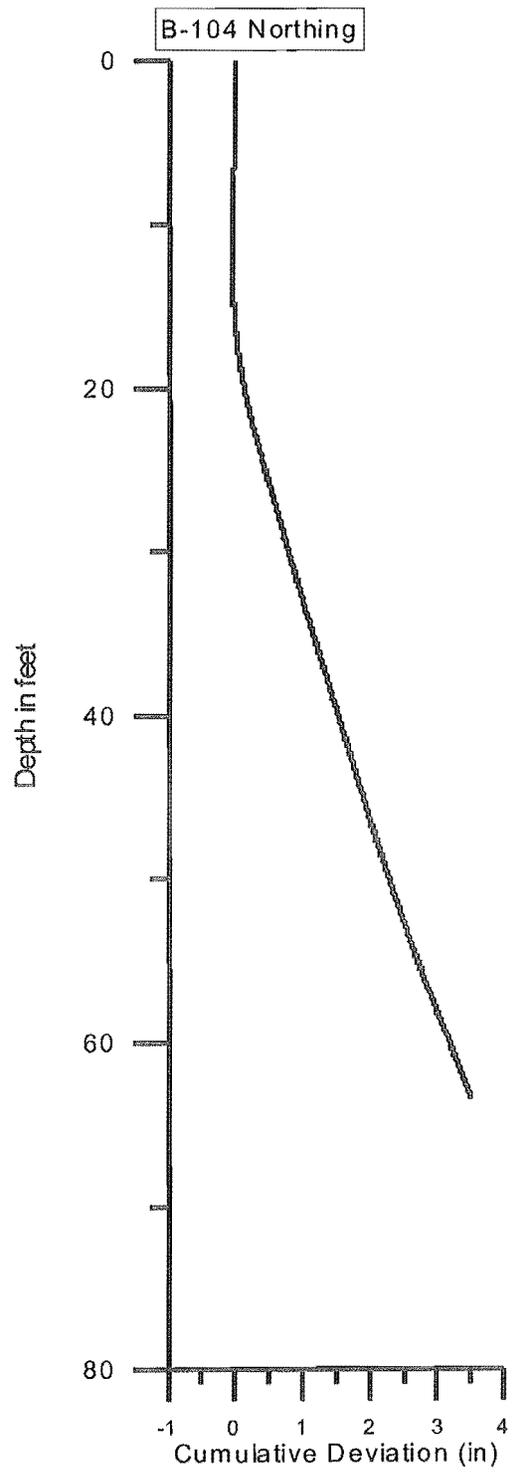
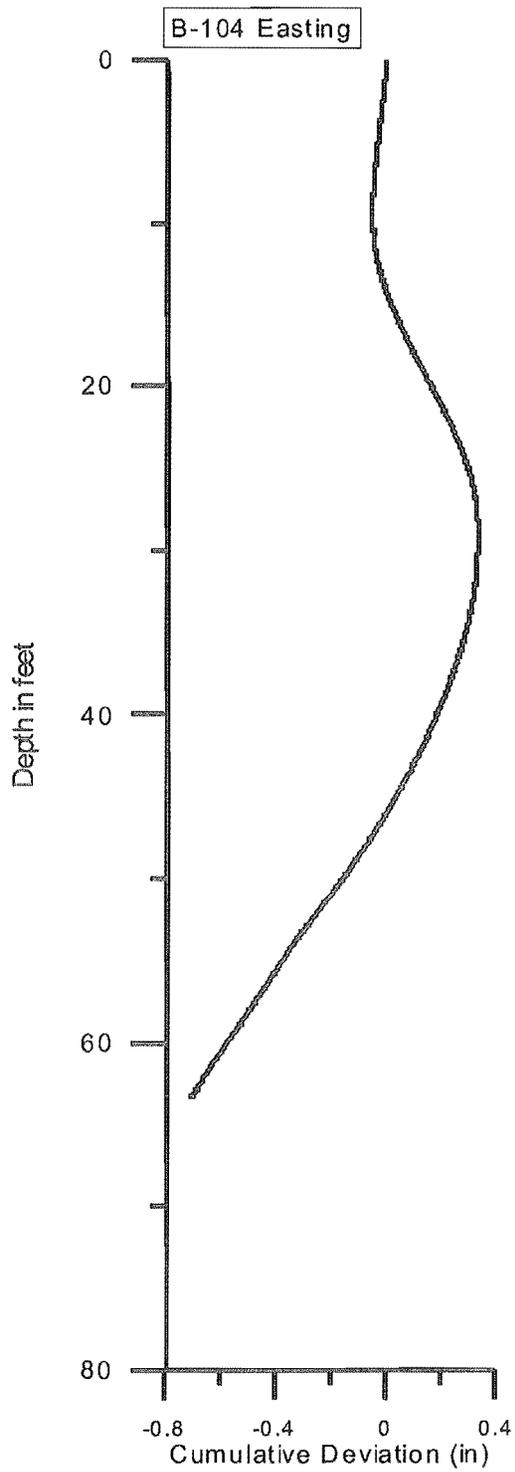
HAGER-RICHTER  
GEOSCIENCE, INC.

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**APPENDIX 3**  
**DEVIATION DATA**



Deviation Survey, Boring B-101.

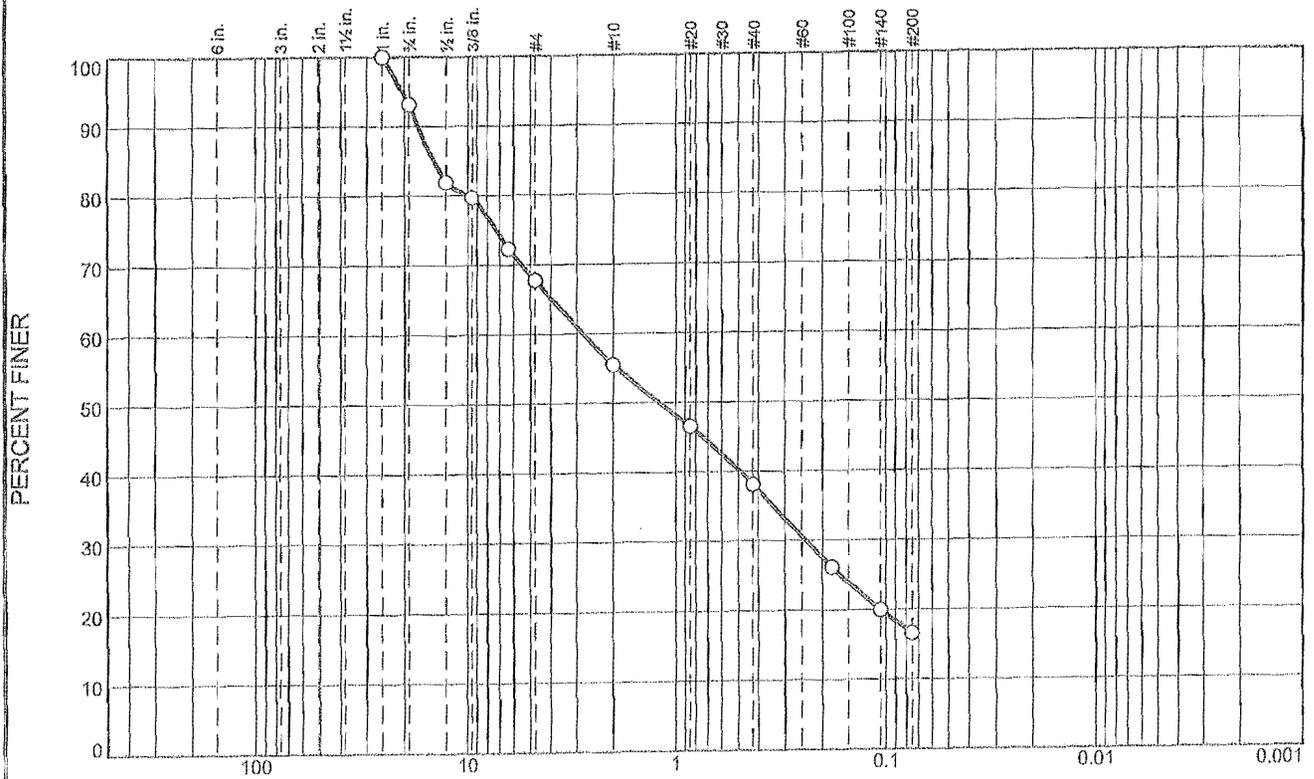


Deviation Survey, Boring B-104.

**APPENDIX D**  
**LABORATORY TESTING**

Geotechnical Evaluation  
Waterfront Support Facility - Portsmouth Naval Shipyard  
Kittery, Maine

# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	6.9	25.4	12.2	17.4	21.5	16.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	93.1		
1/2"	82.0		
3/8"	79.7		
1/4"	72.3		
#4	67.7		
#10	55.5		
#20	46.5		
#40	38.1		
#80	26.1		
#140	20.0		
#200	16.6		

**Soil Description**

silty sand with gravel

**Atterberg Limits**

PL= np      LL= nv      PI= np

**Coefficients**

D<sub>85</sub>= 14.5843      D<sub>60</sub>= 2.7952      D<sub>50</sub>= 1.1955  
 D<sub>30</sub>= 0.2396      D<sub>15</sub>=      D<sub>10</sub>=  
 C<sub>u</sub>=      C<sub>c</sub>=

**Classification**

USCS= SM      AASHTO= A-1-b

**Remarks**

Moisture Content: 6.4%

\* (no specification provided)

Sample No.: S-1  
 Location: Kittery, Maine

Source of Sample: B-1

Date: 6/12/09  
 Elev./Depth: 1' to 3'

**R.W. Gillespie  
 & Associates, Inc.  
 Saco, Maine**

Client: Oak Point Associates  
 Project: MCON Waterfront Support Facility

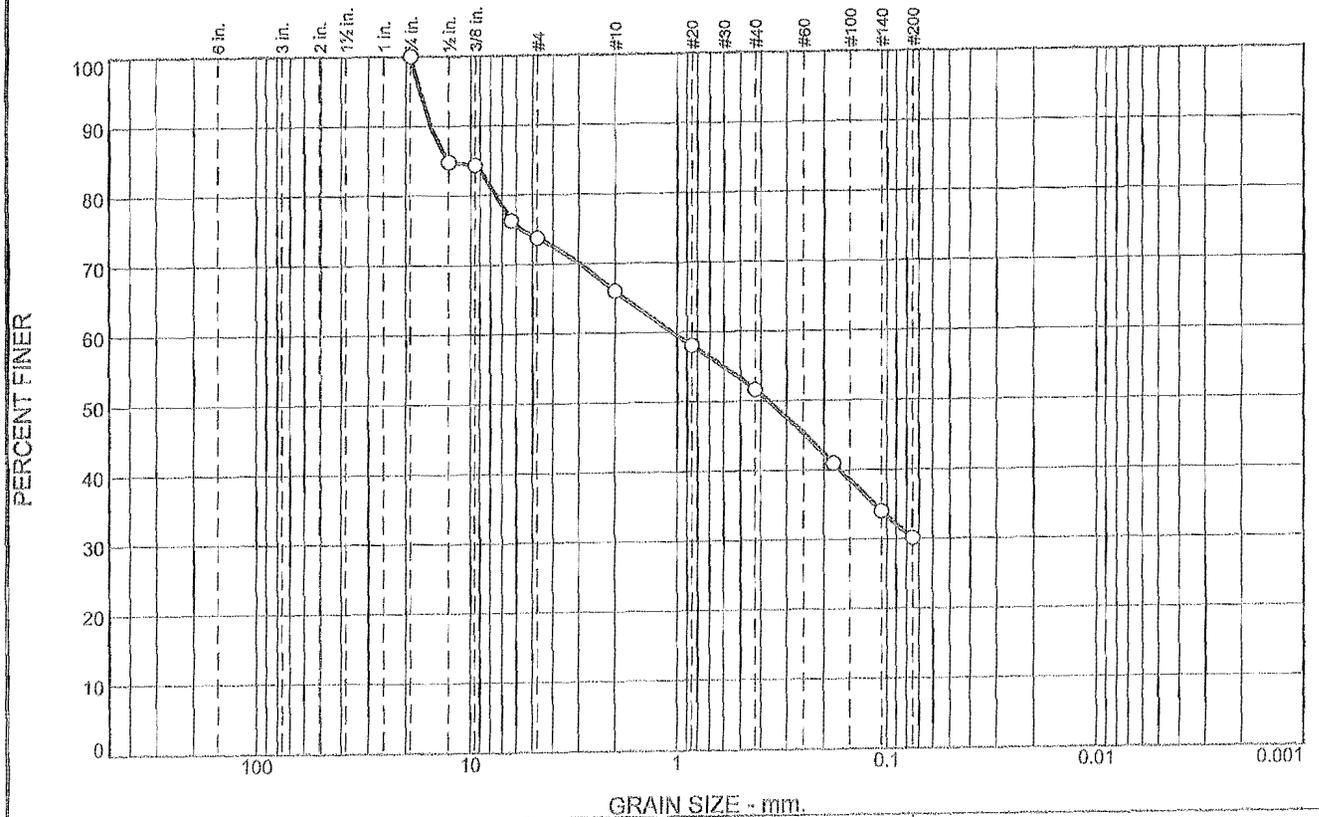
Project No: 767-42

Figure 10807A

Tested By: JJH

Checked By: MTG *MTG*

# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	26.2	7.8	14.3	21.6	30.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
1/2"	84.8		
3/8"	84.4		
1/4"	76.4		
#4	73.8		
#10	66.0		
#20	58.1		
#40	51.7		
#80	41.0		
#140	34.1		
#200	30.1		

**Soil Description**

silty sand with gravel

**Atterberg Limits**

PL= np      LL= nv      PI= np

**Coefficients**

D<sub>85</sub>= 12.8668      D<sub>60</sub>= 1.0567      D<sub>50</sub>= 0.3650  
 D<sub>30</sub>=              D<sub>15</sub>=              D<sub>10</sub>=  
 C<sub>u</sub>=              C<sub>c</sub>=

**Classification**

USCS= SM              AASHTO= A-2-4(0)

**Remarks**

Moisture Content: 10.2%

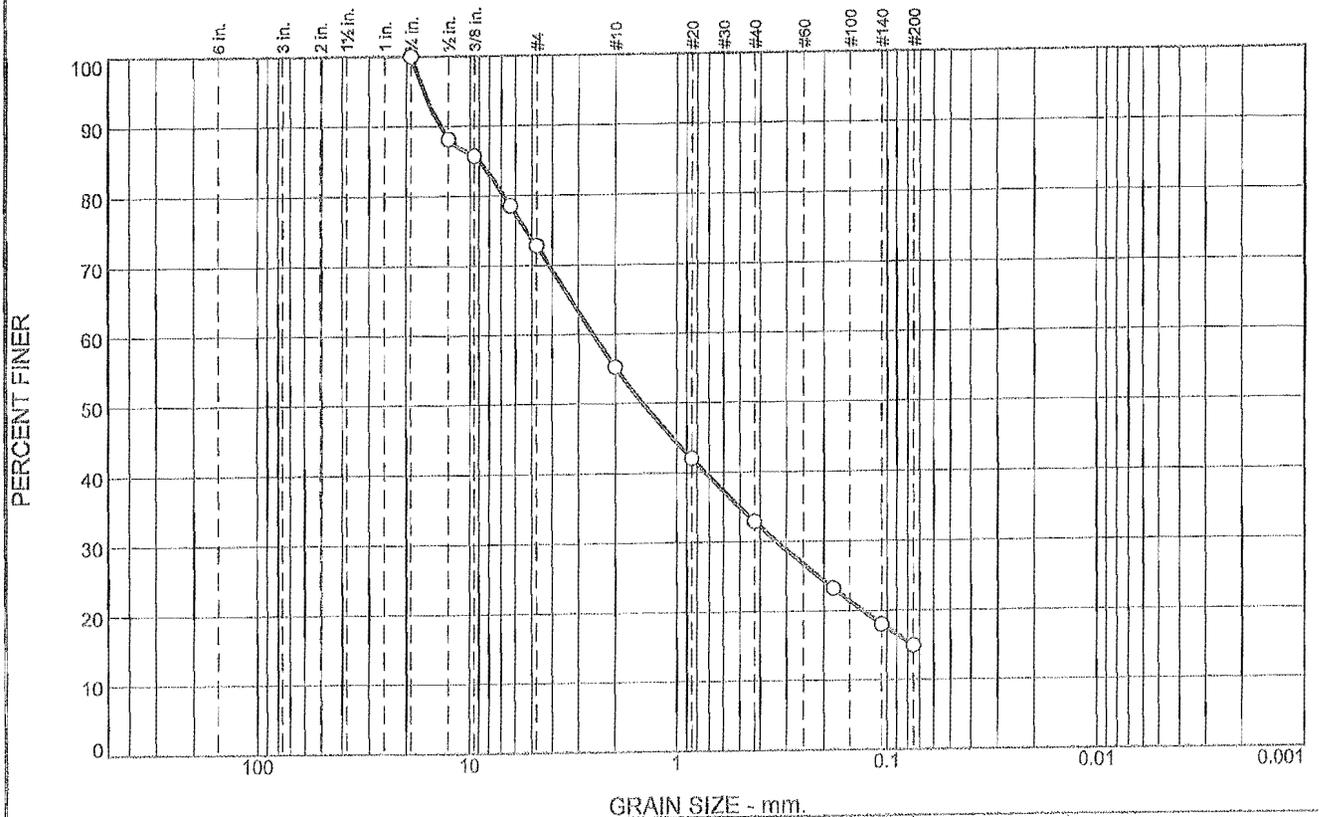
\* (no specification provided)

Sample No.: S-1                      Source of Sample: B-8                      Date: 6/12/09  
 Location: Kittery, Maine                      Elev./Depth: 1' to 3'

<b>R.W. Gillespie &amp; Associates, Inc. Saco, Maine</b>	Client: Oak Point Associates Project: MCON Waterfront Support Facility Project No: 767-42                      Figure 10807B
--	--

Tested By: J.J.H.                      Checked By: MTG *MTG*

# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	27.1	17.6	22.4	18.0	14.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
1/2"	88.1		
3/8"	85.8		
1/4"	78.6		
#4	72.9		
#10	55.3		
#20	42.1		
#40	32.9		
#80	23.3		
#140	18.0		
#200	14.9		

**Soil Description**  
silty sand with gravel

**Atterberg Limits**  
 PL= np      LL= nv      PI= np

**Coefficients**  
 D<sub>85</sub>= 8.9182      D<sub>60</sub>= 2.5511      D<sub>50</sub>= 1.4679  
 D<sub>30</sub>= 0.3328      D<sub>15</sub>= 0.0756      D<sub>10</sub>=  
 C<sub>u</sub>=                      C<sub>c</sub>=

**Classification**  
 USCS= SM                      AASHTO= A-1-b

**Remarks**  
 Moisture Content: 34.3%

\* (no specification provided)

Sample No.: S-1  
 Location: Kittery, Maine

Source of Sample: B-13

Date: 6/12/09  
 Elev./Depth: 5' to 7'

**R.W. Gillespie  
 & Associates, Inc.  
 Saco, Maine**

Client: Oak Point Associates  
 Project: MCON Waterfront Support Facility

Project No: 767-42

Figure 10807C

Tested By: JJH

Checked By: MTG *MTG*

## MOISTURE DETERMINATIONS

Project Name: MCON Waterfront Support Facility  
 Project No. 767-42

Lab No. 10807  
 Date: June 12, 2009

BORING NO.	B-1	B-1	B-1	B-1			
SAMPLE NO.	S-2/5'-7'	S-3/7'-9'	S-4/15'-17'	S-5/20'-22'			
TARE No.	M-3	15	M-1	1			
Wt of Dish + Wet Soil	174.8	206.5	252.8	204.7			
Wt of Dish + Dry Soil	166.4	193.6	227.6	194.8			
Wt. of Tare	92.2	92.7	92.2	96.8			
Wt. of Water	8.4	12.9	25.2	9.9			
Wt. Of Dry Soil	74.2	100.9	135.4	98.0			
Percent Moisture	11.3	12.8	18.6	10.1			

BORING NO.	B-7	B-7	B-7	B-7	B-7	B-7
SAMPLE NO.	S-1/1'-3'	S-2/5'-7'	S-3/7'-9'	S-4/10'-12'	S-5/12'-14'	S-6/15'-17'
TARE No.	17	M-4	14	10	M-4	47
Wt of Dish + Wet Soil	197.4	243.3	221.4	212.6	131.7	195.8
Wt of Dish + Dry Soil	189.6	221.8	205.4	192.5	128.7	181.8
Wt. of Tare	94.0	92.2	94.0	96.5	92.3	94.1
Wt. of Water	7.8	21.5	16.0	20.1	3.0	14.0
Wt. Of Dry Soil	95.6	129.6	111.4	96.0	36.4	87.7
Percent Moisture	8.2	16.6	14.4	20.9	8.2	16.0

BORING NO.	B-12	B-12	B-12	B-12		
SAMPLE NO.	S-1/5'-7'	S-2/10'-12'	S-3/15'-17'	S-4/17'-19'		
TARE No.	13	11	55	M-6		
Wt of Dish + Wet Soil	192.4	130.2	189.5	173.2		
Wt of Dish + Dry Soil	167.2	120.1	151.8	154.6		
Wt. of Tare	94.1	92.6	92.5	94.0		
Wt. of Water	25.2	10.1	37.7	18.6		
Wt. Of Dry Soil	73.1	27.5	59.3	60.6		
Percent Moisture	34.5	36.7	63.6	30.7		

Checked by: *Matthew P. Goff*

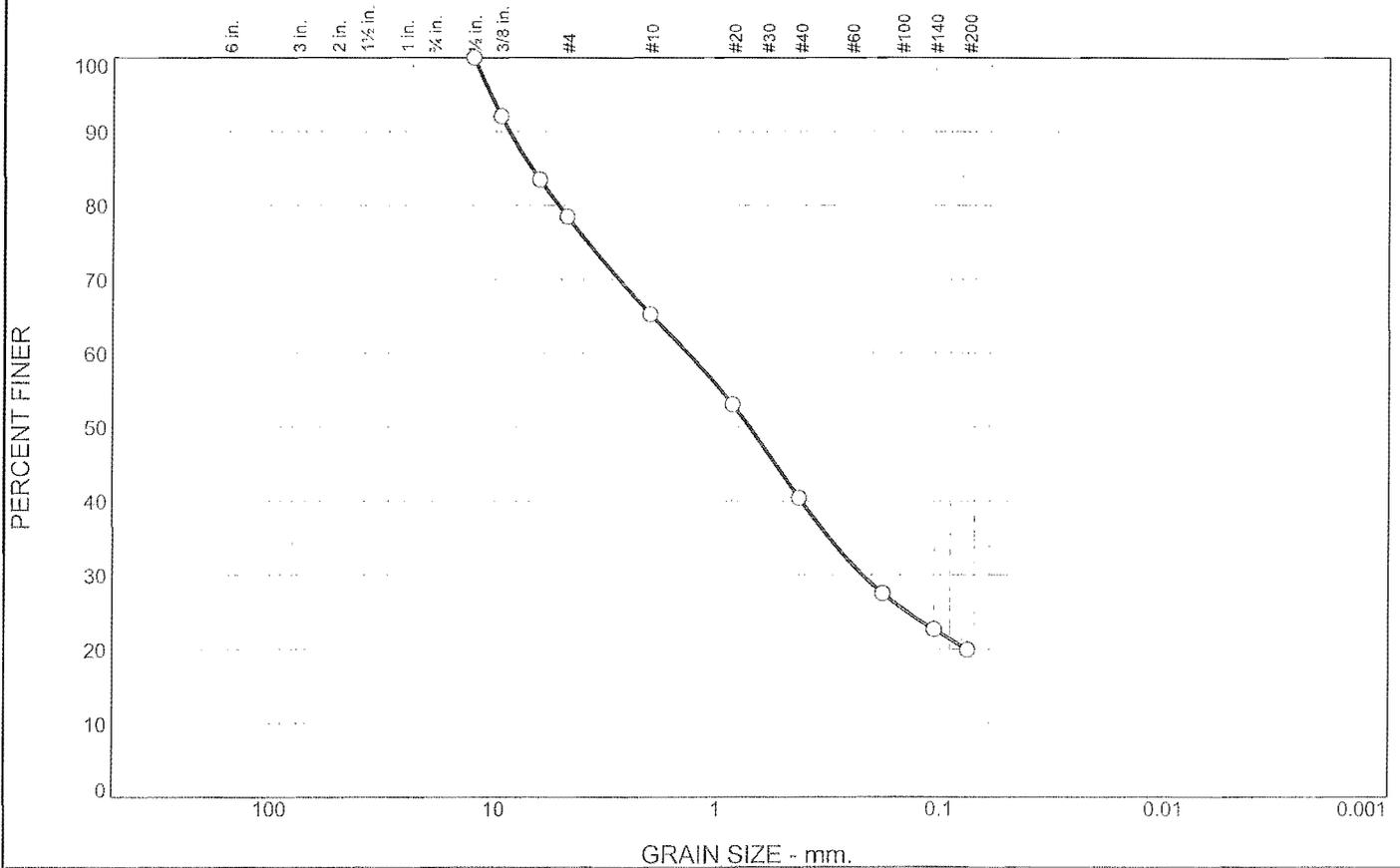
### R.W. GILLESPIE & ASSOCIATES, INC.

86 Industrial Park Road, Suite 4  
 Saco, Maine 04072

200 International Drive, Suite 170  
 Portsmouth, NH 03801

P.O. Box 289  
 Augusta, Maine 04332

# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	21.5	13.2	24.9	20.5	19.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2"	100.0		
3/8"	92.1		
1/4"	83.5		
#4	78.5		
#10	65.3		
#20	53.1		
#40	40.4		
#80	27.6		
#140	22.7		
#200	19.9		

**Soil Description**

silty sand with gravel

**Atterberg Limits**

PL= np      LL= nv      PI=

**Coefficients**

D<sub>85</sub>= 6.8715      D<sub>60</sub>= 1.3523      D<sub>50</sub>= 0.7125  
D<sub>30</sub>= 0.2201      D<sub>15</sub>=              D<sub>10</sub>=  
C<sub>u</sub>=                  C<sub>c</sub>=

**Classification**

USCS= SM                  AASHTO= A-1-b

**Remarks**

Moisture Content: 9.9%

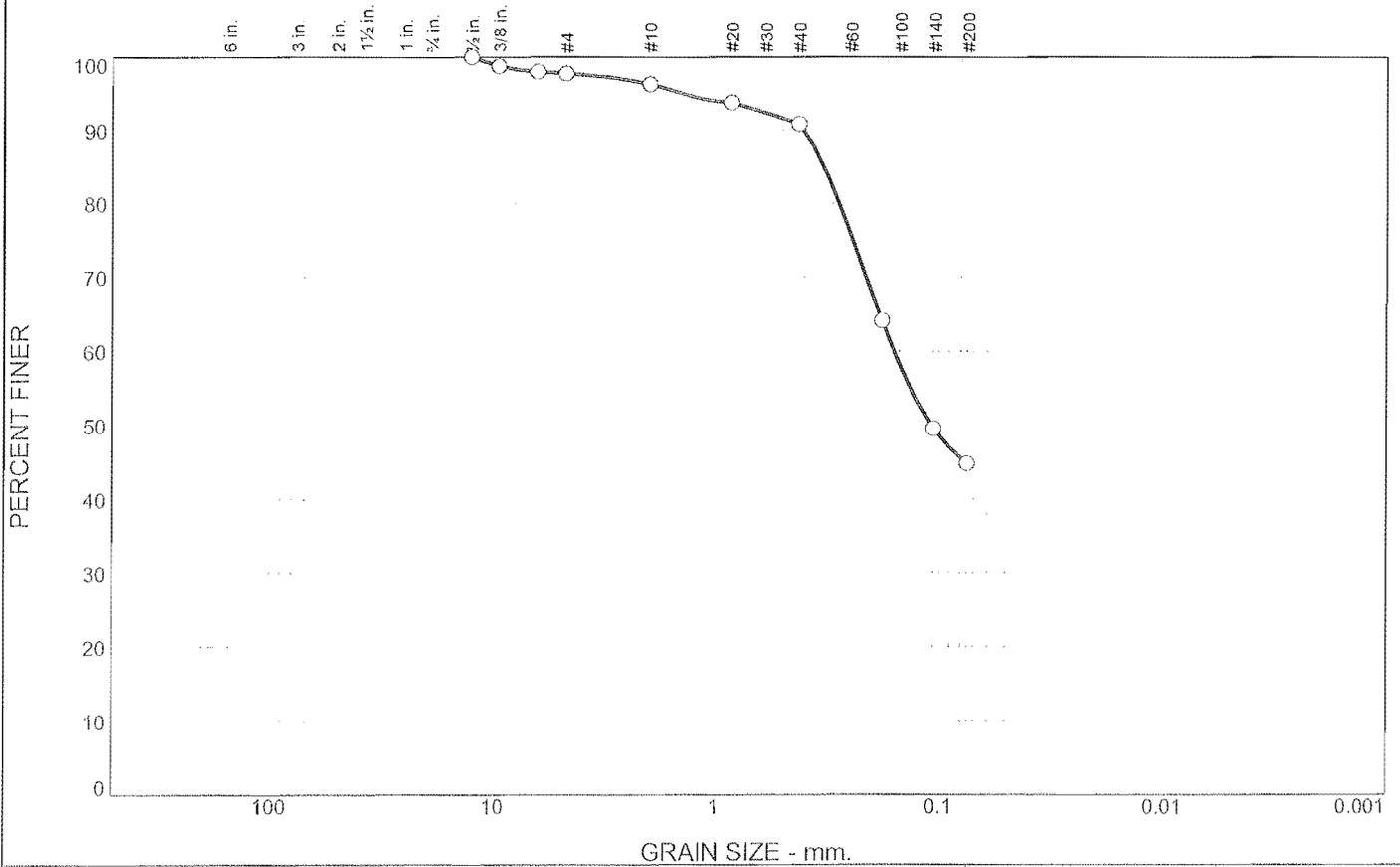
\* (no specification provided)

Sample No.: S-1                      Source of Sample: B-2                      Date: 12/29/09  
Location: Kittery, ME                      Elev./Depth: 5'-7'

<b>R.W. Gillespie &amp; Associates, Inc. Saco, Maine</b>	<b>Client:</b> Oak Point Associates <b>Project:</b> MCON P-268  <b>Project No:</b> 767-42 <b>Lab No.</b> 11081a
--	--

Tested By: JJH                      Checked By: MTG *MTG*

# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.3	1.4	5.4	46.1	44.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2"	100.0		
3/8"	98.8		
1/4"	98.0		
#4	97.7		
#10	96.3		
#20	93.8		
#40	90.9		
#80	64.2		
#140	49.6		
#200	44.8		

**Soil Description**

silty sand

**Atterberg Limits**

PL= NP      LL= NV      PI=

**Coefficients**

D<sub>85</sub>= 0.3299      D<sub>60</sub>= 0.1587      D<sub>50</sub>= 0.1085  
D<sub>30</sub>=              D<sub>15</sub>=              D<sub>10</sub>=  
C<sub>u</sub>=              C<sub>c</sub>=

**Classification**

USCS= SM              AASHTO= A-4(0)

**Remarks**

Moisture Content: 21.9 %

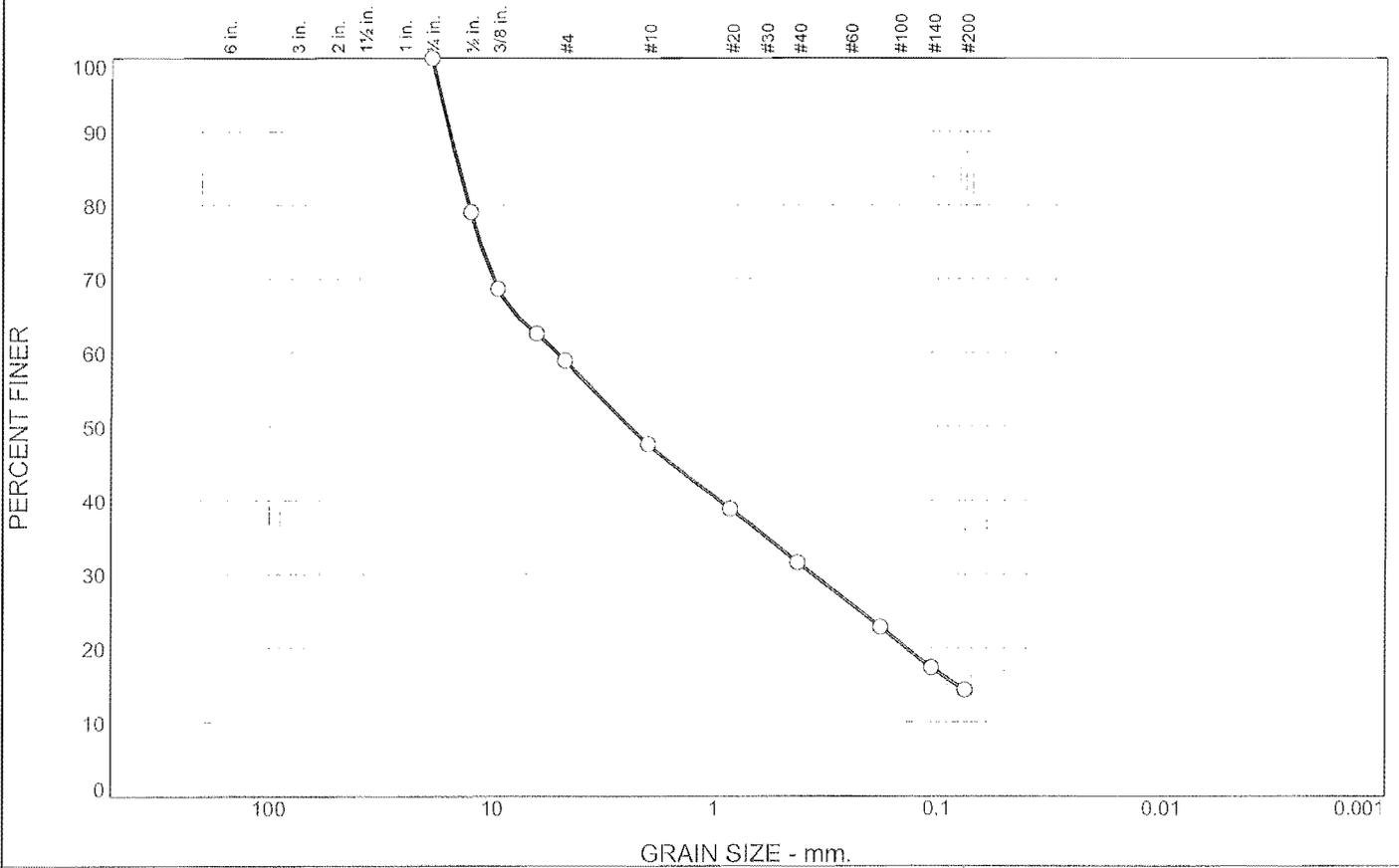
\* (no specification provided)

Sample No.: S-1                      Source of Sample: B-5                      Date: 12/29/09  
Location: Kittery, ME                      Elev./Depth: 5'-7'

<b>R.W. Gillespie &amp; Associates, Inc. Saco, Maine</b>	Client: Oak Point Associates Project: MCON P-268  Project No: 767-42	Lab No. 11081b
--	---	----------------

Tested By: JJH                      Checked By: MTG *MTG*

# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	41.1	11.3	16.0	17.2	14.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
1/2"	79.1		
3/8"	68.7		
1/4"	62.6		
#4	58.9		
#10	47.6		
#20	38.9		
#40	31.6		
#80	22.9		
#140	17.4		
#200	14.4		

**Soil Description**

silty sand with gravel

**Atterberg Limits**

PL= np      LL= nv      PI=

**Coefficients**

D<sub>85</sub>= 14.3858      D<sub>60</sub>= 5.1509      D<sub>50</sub>= 2.4319  
D<sub>30</sub>= 0.3636      D<sub>15</sub>= 0.0807      D<sub>10</sub>=  
C<sub>u</sub>=                  C<sub>c</sub>=

**Classification**

USCS= SM                  AASHTO= A-1-b

**Remarks**

Moisture content: 11.1%

\* (no specification provided)

Sample No.: S-1                      Source of Sample: B-9                      Date: 12/29/09  
Location: Kittery, ME                      Elev./Depth: 5'-7'

<b>R.W. Gillespie &amp; Associates, Inc. Saco, Maine</b>	Client: Oak Point Associates Project: MCON P-268  Project No: 767-42	Lab No. 11081c
--	---	----------------

Tested By: JJH                      Checked By: MTG *MTG*

# GEOTECHNICAL ENGINEERING SERVICES

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## Structural Shops Addition – Portsmouth Naval Shipyard Kittery, ME

---

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*Prepared For:*

**Ewing Cole architects**

Federal Reserve Bank Building  
100 N. 6<sup>th</sup> Street  
Philadelphia, PA 19106-4590

*Prepared By:*

**Pennoni Associates Inc.**

2041 Avenue C, Suite 100  
Bethlehem, PA 18017

May 25, 2011

---

**Craig B. St. Peter, PE**



May 25, 2011

ECCF 1003

Mr. Peter J. Welsh, PE, SE  
Principal, Director of Structural Engineering  
Ewing Cole Architects  
Federal Reserve Bank Building  
100 N. 6<sup>th</sup> Street  
Philadelphia, PA 19106-4590

**RE: Geotechnical Engineering Services  
Structural Shops Addition  
Portsmouth Naval Shipyard  
Kittery, ME**

Mr. Welsh:

We are pleased to submit our geotechnical engineering report for the proposed project. Work was initiated in general accordance with the scope of work presented in our proposal and your authorization to proceed.

We trust that the information presented in this report is what you require at this time and we thank you for the opportunity to assist you with this project. If you have any questions, or if you need any further assistance with this project, please contact this office at your earliest convenience.

Respectfully yours,

PENNONI ASSOCIATES INC.

A handwritten signature in blue ink, appearing to read "Edward J. Sander". The signature is fluid and cursive, written over the printed name.

Edward J. Sander  
Vice President  
Chief Geotechnical Engineer

Craig B. St Peter, PE  
Principal Engineer



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2.2. LABORATORY WORK.....	2
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## Appendices

### APPENDIX A – Field Data

Geotechnical Boring Logs	GTB-101 through GTB-111;
Geoprobe Logs	GP- 114 through GP-116; GP-119 through GP-121
Environmental Boring Logs	TB-113, TB-117, TB-118, TB-122, TB-124 and TB-125
GeoConcepts Engineering Inc Boring Logs	B-1 through B-17A
Test Boring Location Plan	Drawing TB-1
Estimated Top of Rock Contour Map	Drawing TOR - 1

### APPENDIX B – Laboratory Data

Summary of Laboratory Test Data	Table L-1
Gradation Curves	S-1 through S-3
Laboratory Testing Procedures	

## 1. INTRODUCTION

### 1.1 PROPOSED CONSTRUCTION

The purpose of this project is to consolidate and improve the functions of the Structural Shop Facilities and Operations at the Portsmouth Naval Shipyard located in Kittery, Maine. This project will be divided into two distinct phases that may occur simultaneously or separately. Task P-266, Structural Shops Addition - Phase 1, will relocate and consolidate the Sheet Metal Shop operations from Building 75 into the southern portion of Building 76. Task P-266 includes the partial demolition of Building 76 and Building #46 Shredder Building; the remaining LAN equipment slab will require underpinning and a new enclosure. Task P-266 also includes the addition of an Annex which replaces the demolished portion of Building 76 and infills a portion of Ridgeley Street between Buildings 76 and 92. Task P-326, Consolidation of Structural Shops - Phase 2, will serve to relocate and consolidate the Welding and Forge / Heat Treat Shop operations in the northern portion of Building 76. Task P-326 includes the partial demolition of Building 76 and the addition of an Annex which replaces the demolished portion of Building 76 and infills a portion of Ridgeley Street between Buildings 76 and 92. Renovations to Building 92 are planned as part of a separate special project, RM 09-3802 Repair and Energy Improvements for Structural Shop. RM 09-3802 will include the addition of a steel framed mezzanine and the relocation of large/heavy pieces of equipment within Building 92. The new additions will be separated from remaining existing Buildings 76 and 92 by expansion joints.

The existing structures and resulting proposed structure are 1-story steel frame buildings with masonry non-load bearing walls. Anticipated column loads are not expected to exceed 150 to 300 kips; wall loads may be up to 4 klf. New floor slabs are anticipated to be concrete, constructed on-grade at the same elevations as existing slabs. Floor loads are not expected to be more than 250 psf in most areas, but could be higher under equipment.

### 1.2 OBJECTIVES

Our objectives were to determine subsurface conditions within the area of the proposed structure, evaluate these conditions with respect to the proposed construction, and present our conclusions and recommendations regarding:

- design frost depth;
- recommendations for foundation design, including discussion of alternate solutions if applicable;
- “general procedure” soil Site Class based on applicable IBC requirements;
- slab-on-grade design;
- ground water conditions and their impact on design and construction;
- removal or treatment of objectionable material;
- rock excavation, if necessary;
- discussion of potential for consolidation and/or differential settlements of substrata encountered;
- use and treatment of in-situ materials for controlled fill;
- quality assurance and field-testing and inspection during construction

## **2. FIELD AND LABORATORY WORK**

### **2.1. FIELD WORK**

#### **2.1.1 Previous Subsurface Exploration**

A preliminary subsurface exploration was conducted in 2004 by GeoConcepts Engineering, Inc. (GCEI) that included seventeen borings in and around the existing structures including the area(s) of proposed new construction. The boring locations are presented on the Boring Location Plan, Drawing TB-1, presented in Appendix A. The boring data from the GeoConcepts report is presented in Appendix A.

#### **2.1.2 Current Scope**

An additional 17 borings and 6 geoprobes were drilled as part of this study at the approximate locations presented on Drawing TB-1. The recent boring locations were mutually selected by Pennoni Associates Inc. (PAI) and EwingCole personnel; the locations were established in the field by PAI personnel. The borings were advanced using hollow-stem augers. Soil samples from the test borings were obtained in general accordance with ASTM D 1586 using a manually operated hammer (rope and cat-head); the standard penetration test (SPT) values reported on the logs are uncorrected. Rock samples were obtained in accordance with ASTM D 2113.

Our E. Sander, Director of Geotechnical Services directed the field work; Dennis Giustra, PE Senior Engineer observed the field exploration operations.

### **2.2. LABORATORY WORK**

The soil samples collected during our field work were delivered to our laboratory. Representative samples were selected and tested to determine moisture contents, and gradation and volumetric characteristics of the subsoils. Laboratory testing results and a list of testing procedures are presented in Appendix B.

## **3. SITE CHARACTERISTICS**

### **3.1 LOCATION AND SURFACE FEATURES**

The project site is located at the Portsmouth Naval Shipyard in Kittery, ME. The new additions will encompass areas between Buildings 92 and 76 as well as an area currently within the footprint of Building 76 identified as Building 46 and within the interior of Building 92. The subject site is bordered on the north by Constitution Square, on the east by Creighton Street and then Building 75, on the south by Portsmouth Square, and an open area to the west of Building 92.

The project site currently consists of existing buildings and roadways; railway tracks traverse the surrounding roadways. The topography in the area is relatively flat. Evidence of buried utilities was observed throughout the project area.

### 3.2 GEOLOGY

The project site is located within Northern Appalachian Province of Maine. Available geological data indicate that the subject site is underlain by rock belonging to the Kittery Formation reportedly consisting of metamorphosed sedimentary and volcanic rocks that have been subjected to severe folding and faulting with intrusions of granitic rocks. Based on examination and identification testing (hardness, acid reaction, etc.) of the rock samples obtained a it is our professional opinion the site is underlain by phyllite.

### 3.3 SUBSOILS

The borings disclosed surface layers consisting of plain cement concrete and bituminous concrete pavement. At the GCEI boring locations the concrete was found to vary from 7.5 to 10 in. thick; the bituminous concrete pavement was determined to vary from 3 to 6.5 in. thick. The recent PAI borings and geoprobes revealed the bituminous concrete pavement varied from 2.5 to 5.5 in. thick; the concrete was found to vary from 6 to 12 in. thick. The underlying soils generally consist of a fill deposit placed to extend the original shoreline. The fill is noted to consist mostly of sand and gravel size rock fragments in varying amounts with inclusions of concrete, asphalt, wood, ash, etc.; layers of each are interbedded throughout. To remain consistent with the GCEI report and soil classifications, we have separated the soils encountered in the PAI borings into strata with designations used by GCEI, where feasible.

STRATUM	DESCRIPTION
A	FILL - Gravel and Sand in varying proportions, trace or some silt, with concrete, brick, asphalt, ash, wood, etc.
B1	Firm to hard silt and/or clay (Alluvium)
B2	Dense to very dense Sand, trace or some silt/silty clay (Alluvium)
C1	Very dense Sand, some rock fragments, trace or some silt (Decomposed Rock)
C2	Quartzite

Delineation between the fine grained soils of the fill stratum and the fine grained alluvium soils of Stratum B1 is in some instances difficult to ascertain. Where questionable, engineering judgment has been used based on the SPT values and descriptions. As indicated above, ash and other debris was encountered in the fill; petroleum odors were also noted in several borings. Environmental sampling, testing and evaluation is being conducted by Pennoni; the results and findings of that study will be presented in a separate report.

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Refusal to further penetration of the drilling/sampling tools was encountered in the GCEI and PAI borings/probes at depths varying from 2 to approximately 25 ft below grade, where encountered. These depths correspond approximately to Elev. 109.5 to Elev. 84.3, respectively. Refusal is typically inferred as top of rock. Ten feet of rock was cored at Boring B-8A (GCEI) and Borings GTB 101 and GTB 102; 5 ft of rock was cored in Boring GTB-108. Core recoveries were noted to be high; thus, it is our professional opinion that the data disclosed is indicative of top of rock and not boulders. An estimated approximate top of rock contour map (Drawing TOR - 1) was developed based on our interpretation of the available data and is presented in Appendix A.

### 3.4 GROUND WATER

Observations for ground water were made in each boring during sampling and shortly after completion of drilling, but prior to rock coring. These readings indicate the water level varies from 8 to 12 ft below the ground surface. Water level readings obtained by GCEI indicate the water level varies from 2 to 13 ft below existing grades. These observations are for the times and locations noted and may not be indicative of seasonal and daily fluctuations in ground water levels. Since the project is adjacent to a body of water affected by tides, tidal fluctuations must be considered for any excavation.

## 4. ANALYSES AND RECOMMENDATIONS

### 4.1 GENERAL

Based on our evaluation of available field exploration data and laboratory testing results, we conclude that construction of the proposed additions/modifications is feasible. The subsurface conditions are variable throughout the project area. The existing fill (Stratum A) is mostly granular (sand and gravel with varying amounts of clay/silt), but also contains construction debris including brick, concrete, ash, and asphalt. Additionally, petroleum based products were noted in many of the borings. These soils and the soils of Stratum B1 are considered unsuitable for the support of foundations. It is our professional opinion that the proposed new structures should be founded on deep foundations bearing on/in the underlying rock formation. It is our opinion because of existing structures, utilities, etc. that the most cost effective foundations would be micro-piles socketed into the rock.

Shallow water and/or seepage should be expected in shallow excavations. The borings indicate the water could be petroleum contaminated which will require handling/treatment in accordance with appropriate regulations. Rock was encountered as shallow as 2 ft below existing grade; rock excavation should be expected for new and/or relocated utilities as well as new foundations under certain circumstances.

On-site inert soils can be re-used in compacted fills provided they meet the requirements established in section 4.2 below. The laboratory testing indicates the existing fill appears to be predominantly granular gravel and sand with construction debris. The testing results indicate the largest particle size is on the order of 1 inch. The gradation tests completed by Pennoni indicate the Stratum A soils are fairly uniform in consistency with only slight variability. If particles larger than that encountered in the borings are encountered in excavations, screening of those soils might be required.

Total settlements less than 1.0 in. and differential settlements less than 0.50 in. are expected if the recommendations presented herein are followed.

The borings disclosed subsurface conditions generally described according to the 2009 International Building Code (IBC) as having a soil-profile corresponding to Site Class C – very dense soil and/or soft rock profile.

#### 4.2 EARTHWORK

It is our understanding that minimal general grading will occur as part of this project, with the exception of filling the below-grade area of Building 46. Most earthwork is expected to be related to backfilling of foundation elements and utility trenches. Some minor site filling may occur as part of obtaining floor subgrade elevations.

Before construction of new foundations, ground floor slabs, and paving and before the construction of any new fills, the existing bituminous concrete, concrete, and railway remnants must be removed from within the areas of proposed construction. Pavement millings (well graded with a maximum particle size of 2 in.) can be considered for use in compacted load bearing fills not exposed to precipitation provided there are no environmental hazards associated with the materials or regulatory restrictions. Since ground water was noted to be relatively shallow, a vapor barrier beneath floor slabs should be considered. If slab edge curling is not a concern, the vapor barrier can be provided immediately beneath the slab. If curling of slab edges and subsequent spalling from equipment movement might impact the performance of the slab long-term, we recommend placing the vapor barrier below a drainage layer placed immediately beneath the slab. The use of the pavement millings as a base course (in place of stone aggregate) below the slab will assist with creating a vapor barrier. The use of recycled materials will also help the project with LEED certification. The millings can also be considered in backfills in utility trenches and around foundation units. The millings should not be used where drainage is a requirement. Existing utilities located within the proposed construction areas should be abandoned and relocated outside the proposed final footprint. Any existing utility line 4 in. in diameter or larger abandoned in-place should be grouted or the line should be removed and the trench appropriately backfilled.

Exposed subgrades should be thoroughly proof-rolled (where feasible due to space constraints), in the presence of a qualified representative of a geotechnical engineering firm, using a tri-axle truck loaded with soil or aggregate, or equivalent equipment approved by the engineer in an attempt to disclose unstable surface areas. During proofrolling, any unsuitable area found should be stabilized by excavating and replacing those soils with suitable soil (adequately compacted), by adjusting the moisture content of the subgrade soils and compacting them, or by other methods (placing a geotextile and stone layer, etc.). Once localized, shallow unsuitable conditions are stabilized, exposed subgrades within building footprints should be thoroughly densified with a minimum of 6 passes (3 in each direction) of a minimum 12 ton vibratory compactor under the supervision of a geotechnical engineer. The number of passes and use of vibratory equipment should be modified by the engineer if unstable conditions are occurring due to high ground water conditions.

Protect subgrades from softening, undermining, washout, or damage by rain or water accumulation. When a subgrade for foundations or floor slab has been disturbed by water, remove disturbed material to firm undisturbed material after water is brought under control. Replace disturbed subgrade in trenches with concrete or material approved by the geotechnical engineer.

Our experience and laboratory testing results indicate that the on-site soils of Strata A, B2 and C1 can be reused in compacted fills based on particle size and geotechnical criterion. Excavated soils will need to be characterized for contamination as outlined in the environmental report prior to being reused in new fills. Fine grained soils of Stratum A and B1 are unsuitable for use in load bearing fills; these soils can be used in proposed landscaped areas, if present, or they must be removed from the premises. Frozen soils shall not be used. The Pennoni laboratory test results indicate that the near surface soils of Stratum A are generally granular with the percent passing the No. 200 sieve varying from 3 to 37% with the largest particle size being approximately 1 inch. The moisture contents of the laboratory tested soils were determined to vary approximately between 1 and 32%; the higher moisture contents correspond to those soils with a higher percentage of fines passing the No. 200 sieve. Segregating soils with different gradations or blending excavated soils to provide a more consistent fill matrix might be required. Deleterious materials (wood, slag) that might compromise the integrity of the fill must be removed. Adjusting the moisture contents of the on-site soils before use in any compacted fills and/or subgrade preparation should be expected. During warm weather periods, this can be accomplished by aerating the soils using a disc harrow, the teeth on front-end loaders, rakes, etc.; this technique may not be feasible however because of space constraints. During wet weather periods not conducive to air drying, reducing the moisture content of the soils will most likely require soil additives such as lime or cement. The contractor should prepare a submission related to the application rate and degree of moisture content and moisture-density relationship corresponding to different application rates. The proper compaction equipment and placing the soil in thin layers should be considered when preparing earthwork schedules. **Initiating earthwork during climatic periods not conducive to soil drying should be avoided, if possible.**

Imported fill material, if required, should be selected from suitable borrow sources and be approved by a qualified geotechnical engineering firm well in advance of fill construction. Granular fill should consist of well-graded material with not more than 20 percent passing the No. 200 sieve and have a plasticity index not greater than 8 percent. Excavated rock that has been crushed to a usable size (i.e. AASHTO No. 3 Aggregate) may also be used in compacted load bearing fills. Fill having USCS classifications of GW, GP, GM, GC, SW, SP, SM, and SC is considered acceptable.

Fine-grained (silt/clay) used in landscaped areas and granular fills should be placed in layers not exceeding 6 in. and 10 to 12 in. thick, respectively and at a moisture content within 2% +/- of the laboratory determined optimum moisture content. This criterion might be adjusted by a geotechnical engineer in the field depending on the conditions present at the time of construction, on the compaction equipment used, and on the fill material selected. Fills for support of foundations/floor slabs and pavements should be compacted to at least 95 percent of the laboratory determined maximum dry density, ASTM D 1557. Backfills that are compacted using small hand operated equipment may have difficulty achieving this requirement. In the

event the degree of compaction cannot be attained, a comparison of maximum dry unit weights determined in accordance with ASTM D 698 and ASTM D 1557 at variable degrees of compaction will be required to assess whether the compaction requirements can be modified accordingly. Fills should extend a minimum of 5 ft beyond the exterior edge of a loaded area and have side slopes not steeper than 2 horizontal to 1 vertical.

New fill shall not be placed on wet, soft, muddy, or frozen subgrades. Do not fill or backfill until all debris, water, unsatisfactory soil, including frozen soils, obstructions, and deleterious materials have been removed from excavations. For fill and backfill, use excavated soils and borrow meeting the criteria specified herein, as applicable. Do not use unsuitable excavated soil. Do not backfill until foundation walls have been completed above-grade and adequately braced, waterproofing or damp-proofing applied, foundation drainage, and pipes coming in contact with backfill have been installed and work inspected and approved as required by contract documents.

Specifications should indicate that the percentage of maximum dry density attained in the field is not the only criteria to be used for assessing fill compaction. Observation of the behavior of the fill under the loads of construction equipment should also be used. If the test results indicate that the percentage of compaction is being achieved, but the soil mass is moving under the equipment, placement of additional fill should not be continued until the movement is stabilized. Otherwise, settlement of the fill will occur.

Comparison of the estimated top of rock elevations to proposed foundation and floor grades indicates that rock could impact new utility construction and foundation construction.

#### 4.3 FOUNDATIONS

The borings disclosed highly variable depths to competent natural soils and/or rock. The soils associated with the fill deposit are not suitable for support of foundations. It is our understanding that the existing structures are supported either on footings bearing on rock or by pile foundations extending through the fill. Based on the anticipated structural loads several foundation schemes can be considered.

##### General

It is our understanding that at locations of some existing interior walls new shear walls and foundations may be required to resist temporary pressures resulting from lateral forces. Shallow foundations can be considered for support of these new shear walls. Footings can be designed for a net allowable bearing capacity of 3,500 psf. The subgrade soils should be tested to confirm the design bearing capacity prior to placing reinforcing steel and concrete.

### New Foundations

The test borings and probes disclosed the presence of uncontrolled fill and variable subsurface conditions. The borings indicate the top of rock dips down to the west/southwest with refusal to further penetration of the drilling tools encountered at depths varying from approximately 3.5 ft to 18 ft below the ground surface. The top of rock appears to be on the order of 4 to 8 ft below grade in the central portion of the footprint, on the order of 6 to 18 ft on the northern portion of the footprint, and 8 to 14 ft below grade in the southern portion of the footprint.

Because of the highly variable subsurface conditions, supporting shallow foundations on soil is not recommended. The proposed structures/additions can be supported on spread footings bearing on rock where the bearing surface is within 6 to 8 ft below the ground surface. Isolated and continuous footings should be at least 2.5 ft square and 18 in. wide, respectively. These foundations can be designed using an allowable net rock bearing capacity up to 30 tsf; however, based on the recommendations for minimum footing sizes the contact pressures may not exceed 10 tsf. Where the footing will be supported partially on soil and rock the soil should be removed and replaced with lean concrete having an unconfined compressive strength on the order of 3,000 psi. If the rock surface beneath spread footings slopes downward at an angle steeper than 4 horizontal to 1 vertical means should be provided (dowelling, benching, etc.) to resist sliding. Temporary dewatering measures will most likely be required during foundation construction.

Based on the estimated column loads and anticipated facility constraints we recommend the new structures (building frame, interior mezzanine, and any heavy pieces of settlement sensitive equipment) be supported by Type-A mini-piles consisting of 7 in. diameter permanent steel casing with a load carrying capacity of 60 tons bearing in the underlying rock. The casing should be extended to the top of competent rock; a minimum 11.5 ft rock socket should extend into competent rock. We estimate competent bedrock will be encountered at depths ranging from 8 to 25 ft below existing ground surface elevations. The above pile details are based on the mini-pile casing being filled with a neat cement grout having a 28-day compressive strength of at least 6,000 psi and design/ultimate bond strength between grout and rock of 14.5 ksf. Higher bond strengths can be considered, but the minimum number of piles per location and an industry recommended minimum pile length of 10 ft may not warrant the higher values. An uplift and lateral capacity of 40 and 3 tons/pile, respectively, can be used for design. Battered piles with an angle of batter up to 20° from the vertical can also be considered to resist lateral loads.

A minimum center to center pile spacing of 2 ft should be maintained for grouped piles. There should be no casing joint within the upper 10 ft of the pile. The pile casing should meet tensile requirements of ASTM A252, Grade 3, except the yield strength should be a minimum of 50 to 80 ksi. Threaded pipe joints should be located at least 2 casing diameters (OD) from any splice in a reinforcing bar. Grout should be introduced into the drill hole through a tremie pipe extended to the bottom of the hole. Grout should be pumped using no excess pressure until grout with similar qualities as that being pumped exits the mouth of the casing.

The final design details including allowable capacities should be determined by a specialty contractor with adequate experience in mini-pile design and construction. Factors of safety should be at least 2 for axial compression and 3 for uplift and lateral capacities. As part of the contract the design details should be submitted for review and approval.

#### 4.3.1 Load Tests

In accordance with Building Codes the pile foundations recommended herein will require at least 1 load test in accordance with ASTM D 1143 and/or ASTM D 3689 for axial compressive and tension, respectively. The governing load application should determine which test should be conducted. The test pile should be loaded to at least 2.5 times the design capacity. The requirement for lateral load testing in accordance with ASTM D 3966 will depend on the actual design load. Each compression and tension test pile should be equipped with two telltale rods to measure deformation during load tests in accordance with ASTM D 1143. The load test location should be selected by the geotechnical engineer. Details regarding the number, the particular method of testing, etc. should be further developed as the foundation design progresses.

The load test pile should not be a production pile if the pile/rock interface is failed during testing. No construction activity transmitting vibratory or impact loads should be permitted on the project site during load testing. The load test set-up should be protected from inclement weather (wind, rain, intense heat, sunlight, etc.), provided with lights for night-time readings, and guarded on a full-time basis. Technical details (sketch, description, etc.) of the load test set-up together with certification of the loading device, etc. should be submitted to the geotechnical engineer at least 1 week in advance of load test construction. The load test must be monitored on a full-time basis and test results analyzed by a registered geotechnical engineer.

Detrimental post-construction settlements are not expected if the recommendations presented herein are followed. The subgrade of exterior foundation units (footings, pile caps, etc.) and any other foundation unit exposed to freezing temperatures, during construction and/or the life of the structure should be established at least 48 in. below adjacent exposed grades or otherwise protected against frost action. Where the subgrade consists of sound, competent rock the foundation subgrade should be established at least 2 ft below adjacent grade. Foundation subgrades should be checked by a qualified representative of a geotechnical engineering firm to confirm conditions suitable for support of the design bearing pressure. Where an area is questionable, it should be further explored and/or remedied by removal and replacement of unsuitable material.

#### 4.4 FLOOR SLAB(S)

The proposed ground floor slab(s) can be constructed on-grade on a properly prepared subgrade. Because of the variability of the fill type and consistency, we recommend that a modulus of vertical subgrade reaction,  $k_v$ , not exceeding 125 pci be used to design the floor slabs. A 6 in. thick granular base course should be placed beneath the slab(s) to provide a uniform bearing surface and to aid in the proper curing of the slab concrete. Pavement millings (well graded with a maximum particle size of 2 in.) can be considered for use as the base course (in place of stone aggregate) provided there are no environmental hazards associated with the materials or regulatory restrictions. Since ground water was noted to be relatively shallow in some areas, a vapor barrier beneath floor slabs should be considered. If slab edge curling is not a concern, the vapor barrier can be provided immediately beneath the slab. The use of the pavement millings as a base course below the slab will assist with creating a vapor barrier in this case. If curling of slab edges and subsequent spalling from equipment movement might impact the performance of the slab long-term, we recommend placing the vapor barrier below a drainage layer placed

immediately beneath the slab. The millings should not be used where drainage is a requirement. At least 6 in. should be maintained between the bottom of the slab(s) and the tops of the foundations to minimize the potential for slab cracking at the foundation edges or the slab(s) should be designed accordingly (adequate reinforcing) to minimize cracking. The floor slab(s) should be isolated from other structural elements of the building to allow for independent movements.

#### 4.5 GROUND AND SURFACE WATER MANAGEMENT

The ground water observations made in the borings indicate that encountering ground water in foundation and/or utility excavations as shallow as 2 ft below existing grades should be expected. Most borings/probes indicate the water is 8 ft below existing grades or deeper, but because of tidal fluctuations variations in the reported water levels need to be considered. A review of tidal data for Kittery Point, ME indicates the water height can vary from 8 to 9 ft during any tide change. Since the affect of the tide height on the ground water level away from the shoreline is dependent on distance, soil type, density, porosity, etc. the actual change in the ground water level at the project site is expected to be considerably less than the change in tidal water height. For design purposes a variation in the ground water level of 1 to 2 ft can be considered. Based on the data disclosed by the previous study and this exploration, it is our professional opinion underslab drainage is not required.

The use of sumps and high capacity pumps should be expected to maintain stable conditions within excavations. Depending on the depth of the excavation and the length of time an excavation may need to remain open, a well-point system might be required. Since the borings/probes disclosed the presence of petroleum in the soils, ground water discharge must be handled in accordance with the applicable regulations. Recommendations for specific ground water treatment/handling will be presented in an environmental report submitted under separate cover.

During construction, surface runoff should not be allowed to contact the subsoils in foundation excavations. When moisture is added to these soils they can become unstable and lose strength. Excavations for foundations should be backfilled as rapidly as possible after excavation; while exposed to precipitation the foundation excavation should be protected against infiltration.

A foundation excavation should not be used as a detention basin or sump. During construction surface runoff should be prevented from entering or ponding in the excavation by creating soil berms or diversion swales along the perimeter if the excavation will be left open for an extended period of time. Where ponding does occur, the water should be removed immediately by pumping. Grades should then be established to prevent further ponding, subject to review by the geotechnical engineer.

#### 4.6. EXCAVATIONS/SHORING

All excavations shall be sloped or shored in accordance with applicable OSHA and/or NAVFAC Standards. The soil parameters presented on Page 11 can be used to estimate lateral earth pressures to design below-grade structures and temporary shoring. If the top of the structure is restrained from movement, thereby preventing the mobilization of active soil pressures, the structure should be designed using the at-rest pressure coefficient,  $k_o$ . The earth pressure coefficients are based on the assumption of vertical faces, horizontal backfill, no surcharges, no surface friction, and a safety factor of 1.0. A foundation drain is recommended to be placed behind walls to relieve hydrostatic pressures.

Parameter	Existing Granular Fill	Existing Fine Grained Fill, Ash & Stratum B1 Soils	Newly Compacted Structural Fill
Unit Weight	135 pcf	125 pcf	135 pcf
Angle of Internal Friction	36°	16°	38°
Friction Factor	0.4	0.3	0.45
Cohesion	0 psf	500 psf	0 psf
$k_a$	0.26	0.6	0.24
$k_o$	0.41	0.72	0.43
$k_p$	3.85	1.67	4.2

If the contractor is responsible for the design of temporary or permanent retaining structures, then the contract documents should clearly require that a competent registered engineer performs the design and that satisfactory earth support is solely the contractor's responsibility. Furthermore, the contract documents should require the contractor to notify the engineer immediately if differing or unforeseen subsurface conditions are encountered during construction.

#### 5. FURTHER GEOTECHNICAL SERVICES

To determine if soils, other materials, and ground water conditions encountered during construction are similar to those encountered in the test borings, and that they have comparable engineering properties or influences on the design of the structures, we recommend that a qualified representative of a reputable geotechnical engineering firm provide field observation services during excavation; construction of compacted fill; preparation of foundation and floor slab subgrades; and construction of foundations (footings/piles) and floor slabs.

## 6. LIMITATIONS

This work has been done in accordance with our authorized scope of work and in accordance with generally accepted professional practice in the fields of geotechnical and foundation engineering. This warranty is in lieu of all other warranties either expressed or implied. Our conclusions and recommendations are based on the data revealed by this exploration. We are not responsible for any conclusions or opinions drawn from the data included herein, other than those specifically stated, nor are the recommendations presented in this report intended for direct use as construction specifications. This report is intended for use with regard to the specific project described herein; any changes in loads, structures, or locations should be brought to our attention so that we may determine how they may affect our conclusions. An attempt has been made to provide for normal contingencies but the possibility remains that unexpected conditions may be encountered during construction. If this should occur, or if additional or contradictory data are revealed in the future, we should be notified so that modifications to this report can be made, if necessary. If we do not review relevant construction documents and witness the relevant construction operations, then we cannot be responsible for any problems that may result from misinterpretation or misunderstanding of this report or failure to comply with our recommendations.

## APPENDICES

## APPENDIX A

### Field Data







# GEOPROBE LOG

Geoprobe No.: GP-116

PROJECT	PROJECT NO.
STRUCTURAL SHOPS ADDITION	ECCF 1003
LOCATION	DATE
	11-2-10
EXCAVATOR/OPERATOR	ELEV.
	110.3
EXCAVATION METHOD	RECORDED BY
HOLLOW STEM AUGERS	D. GIUSTRA
DEPTH TO - Water: 8'      When checked:      Caving: -	

ELEVATION/ DEPTH	SOIL SYMBOLS AND SAMPLERS		DESCRIPTION	REMARKS
	GRAPHIC	SAMPLE NUMBER		
110 - 0			12" CONCRETE	
105 - 5		S-1	LOOSE, DRY COARSE TO MEDIUM LIGHT BROWN SAND SOME ROCK	
100 - 10		S-2	LOOSE, MOIST DARK SANDY FILL, GRAVEL AND ROCK	
95 - 15		S-3	WET LOOSE DARK COARSE TO MEDIUM SAND, SOME ROCK	
90 - 20		S-4	WET RUNNY	
85 - 25				
80 - 30				

Notes:



# GEOPROBE LOG

Geoprobe No.: GP-119

PROJECT	PROJECT NO.
STRUCTURAL SHOPS ADDITION	ECCF 1003
LOCATION	DATE
	11-2-10
EXCAVATOR/OPERATOR	ELEV.
	110.2
EXCAVATION METHOD	RECORDED BY
HOLLOW STEM AUGERS	D. GIUSTRA
DEPTH TO - Water: 8'      When checked:      Caving: -	

ELEVATION/ DEPTH	SOIL SYMBOLS AND SAMPLERS			REMARKS
	GRAPHIC	SAMPLE NUMBER	DESCRIPTION	
110 — 0  105 — 5 100 — 10 95 — 15 90 — 20 85 — 25 80 — 30	 S-1 S-2 S-3	6" CONCRETE 0.5' DRY, LOOSE CONCRETE, ROCK MEDIUM TO FINE SAND ROCK IN TIP 5' GRAVEL, ROCK LOOSE DRY 8' WET, LOOSE ROCK, MEDIUM SAND		

Notes:

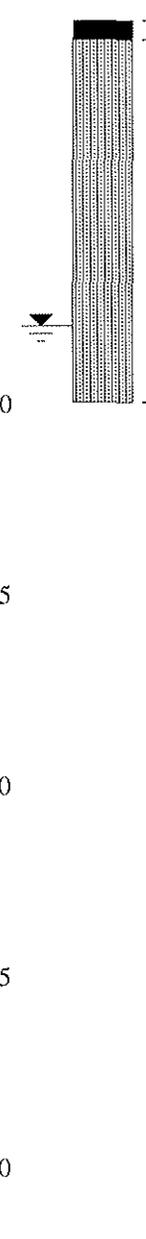




# GEOPROBE LOG

Geoprobe No.: GP-121

PROJECT <p style="text-align: center;">STRUCTURAL SHOPS ADDITION</p>	PROJECT NO. <p style="text-align: center;">ECCF 1003</p>
LOCATION	DATE <p style="text-align: center;">11-3-10</p>
EXCAVATOR/OPERATOR	ELEV. <p style="text-align: center;">110.2</p>
EXCAVATION METHOD <p style="text-align: center;">HOLLOW STEM AUGERS</p>	RECORDED BY <p style="text-align: center;">D. GIUSTRA</p>
DEPTH TO - Water: 8'                      When checked:                      Caving: -	

ELEVATION/ DEPTH	SOIL SYMBOLS AND SAMPLERS			REMARKS
	GRAPHIC	SAMPLE NUMBER	DESCRIPTION	
110 — 0  105 — 5 100 — 10 95 — 15 90 — 20 85 — 25 80 — 30		S-1   S-2   S-3	6" CONCRETE  DRY LOOSE LIGHT BROWN MEDIUM SAND AND ROCK, SOME SILTY SAND AT END <span style="float: right;">0.5</span>  DRY LOOSE BROWN MEDIUM SAND AND ROCK  WET LOOSE ROCK DARK GRAY FILL, SAND, SOME SILT	

Notes:

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.0  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-19-10      **DATE COMPLETED:** 10-19-10  
**DEPTH TO WATER> INITIAL:** NE      **AFTER 24 HOURS:**      **CAVING>** C

  
**LOG OF BORING  
No. GTB-101**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	5.5" ASPHALT						
0.5	FILL: COARSE TO FINE GRAVEL, SOME COARSE TO MEDIUM TO FINE SAND, TRACE SILT (BRICK FRAGMENTS), MEDIUM DENSE		A	S-1	10	11-8-9	DRY
2	BROWN/LIGHT BROWN MEDIUM TO FINE SAND, SOME SILT, SOME COARSE TO FINE GRAVEL SIZE ROCK FRAGMENTS (SILTY SAND WITH GRAVEL - SM), MEDIUM DENSE TO VERY DENSE		B2	S-2	12	15-11-9-4	DRY
5				S-3	10	3-6-50/6"	MOIST GRAVEL IN TIP
6.5	GRAY HARD, HIGHLY WEATHERED, MODERATELY FRACTURED PHYLLITE					REC=94% RQD=60%	
10			C1				
15							
16.5	Boring terminated at 16.5 ft.						
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.0  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-19-10      **DATE COMPLETED:** 10-19-10  
**DEPTH TO WATER > INITIAL:**  $\nabla$  NE      **AFTER 24 HOURS:**  $\nabla$       **CAVING >** C



**LOG OF BORING  
No. GTB-102**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	5" ASPHALT						
0.4	FILL: BROWN MEDIUM TO FINE SAND, SOME COARSE TO FINE GRAVEL SIZE ROCK FRAGMENTS, LITTLE SILT, MEDIUM DENSE		A	S-1	8	21-12-5	DRY
				S-2	12	8-8-5-9	MOIST
4.6	GRAY HARD, FRESHLY WEATHERED, SLIGHTLY FRACTURED PHYLLITE						
			R-1			REC= 100%RQD= 67%	
10			C2				
			R-2			REC= 100%RQD= 70%	
15	Boring terminated at 14.6 ft.						
20							
25							
30							
35							

PROJECT: STRUCTURAL SHOPS ADDITION PROJECT NO.: ECCF 1003  
 PROJECT LOCATION: PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
 DRILLING FIRM: MILLER ENGINEERING AND TESTING INC. ELEVATION: 110.0  
 FOREMAN: R. MARCOUX LOGGED BY: D. GIUSTRA  
 DRILLING METHOD: HOLLOW STEM AUGERS  
 DATE STARTED: 10-19-10 DATE COMPLETED: 10-19-10  
 DEPTH TO WATER > INITIAL: 8' AFTER 24 HOURS: - CAVING > C. -

  
**LOG OF BORING**  
**No. GTB-103**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	5" ASPHALT						
0.4	FILL: BROWN MEDIUM TO FINE SAND AND COARSE TO FINE GRAVEL SIZE ROCK FRAGMENTS, MEDIUM DENSE		A	S-1	8	25-13-14	DRY
3	FILL: BROWN MEDIUM TO FINE SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, LITTLE SILT, MEDIUM DENSE TO DENSE			S-2	4	18-10-11-14	DRY
5				S-3	10	8-7-9-9	MOIST
				S-4	6	16-25-18-11	MOIST
				S-5	10	7-7-3-1	PETROLEUM ODOR WET
10	GRAY CLAY & SILT, LITTLE FINE SAND, (CLAY AND SILT - CL-ML), STIFF		B1				
15	Boring terminated at 14 ft.						Auger refusal at 14 ft.
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.4  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-27-10      **DATE COMPLETED:** 10-27-10  
**DEPTH TO WATER> INITIAL:** 12'      **AFTER 24 HOURS:** -      **CAVING>** C -

  
**LOG OF BORING  
No. GTB-104**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks	
0	FILL: LIGHT BROWN/BLACK MEDIUM TO FINE TO COARSE SAND, SOME FINE GRAVEL SIZE ROCK FRAGMENTS, TRACE SILT, MEDIUM DENSE TO LOOSE  BROWN SILT, SOME MEDIUM TO FINE SAND, (SILT - ML), VERY STIFF  BROWN/GRAY SILT, LITTLE FINE SAND (SILT - ML), VERY STIFF  BROWN MEDIUM TO FINE SAND, SOME SILTY CLAY (CLAYEY SAND - SC), MEDIUM DENSE		A	S-1	20	11-13-10-13	DRY	
				S-2	10	4-5-5-8	MOIST	
5				B1	S-3	20	4-8-10-15	MOIST
7					S-4		10-15-23-25	MOIST
8				B2	S-5	18	9-12-13-18	MOIST
10								
13	Boring terminated at 13 ft.						Auger refusal at 13 ft.	
15								
20								
25								
30								
35								

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.5  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-27-10      **DATE COMPLETED:** 10-27-10  
**DEPTH TO WATER > INITIAL:**  NE      **AFTER 24 HOURS:**  -      **CAVING >** C. -

  
**LOG OF BORING**  
**No. GTB-105**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	7" CONCRETE SLAB	0.6			8		
	FILL: BROWN/BLACK MEDIUM TO FINE TO COARSE SAND, SOME COARSE TO FINE GRAVEL SIZE ROCK FRAGMENTS, LITTLE SILT, VERY DENSE	0.6	A	S-1		5-30-21	DRY
				S-2	4	8-6-50/2"	WET ROCK IN SPOON TIP
5	Boring terminated at 3.5 ft.						Auger refusal at 3.5 ft
10							
15							
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.6  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-27-10      **DATE COMPLETED:** 10-27-10  
**DEPTH TO WATER > INITIAL:** 8'      **AFTER 24 HOURS:** -      **CAVING > C:** -



**LOG OF BORING  
No. GTB-106**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	6" CONCRETE						
0.5	FILL: BROWN/ORANGE COARSE TO MEDIUM TO FINE SAND, SOME FINE GRAVEL, TRACE SILT, VERY DENSE		A	S-1	10	10-25-31	DRY
				S-2	14	16-35-27-17	DRY
4	BROWN/GRAY SILT, SOME FINE TO MEDIUM SAND(SILT - ML), VERY STIFF			S-3	20	5-8-13-17	MOIST
6	GRAY SILTY CLAY, LITTLE FINE SAND (CLAY - CL), HARD		B1	S-4	24	17-20-25-28	MOIST
8	BROWN/GRAY FINE TO MEDIUM SAND, SOME SILT (SILTY SAND - SM), MEDIUM DENSE		B2	S-5	20	5-7-5-9	MOIST
10	Boring terminated at 10 ft.						Auger refusal at 10 ft.
15							
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 112.0  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-18-10      **DATE COMPLETED:** 10-18-10  
**DEPTH TO WATER > INITIAL:**  NE      **AFTER 24 HOURS:**       **CAVING >**  C

  
**LOG OF BORING**  
**No. GTB-107**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	3" ASPHALT	0.3	A	S-1	6	8-8-11 60/5"	DRY
	FILL: DARK BROWN FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, LITTLE MEDIUM TO FINE TO COARSE SAND, MEDIUM DENSE			S-2	3		DRY
5	Boring terminated at 2.5 ft.						Auger refusal at 2.5 ft.
10							
15							
20							
25							
30							
35							

PROJECT: STRUCTURAL SHOPS ADDITION PROJECT NO.: ECCF 1003  
 PROJECT LOCATION: PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
 DRILLING FIRM: MILLER ENGINEERING AND TESTING INC. ELEVATION: 111.5  
 FOREMAN: R. MARCOUX LOGGED BY: D. GIUSTRA  
 DRILLING METHOD: HOLLOW STEM AUGERS  
 DATE STARTED: 10-18-10 DATE COMPLETED: 10-18-10  
 DEPTH TO WATER> INITIAL:  NE AFTER 24 HOURS:  - CAVING> C



**LOG OF BORING  
No. GTB-108**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	2.5" ASPHALT						
0.2	FILL: FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, LITTLE MEDIUM TO COARSE TO FINE SAND (WOOD FRAGMENTS), MEDIUM DENSE		A	S-1	12	10-13-16	DRY
2.4	GRAY HARD, LIGHTLY WEATHERED, SLIGHTLY FRACTURED PHYLLITE		C2	R-1		REC=92% RQD=78%	
5	Boring terminated at 7.4 ft.						
10							
15							
20							
25							
30							
35							

PROJECT: STRUCTURAL SHOPS ADDITION PROJECT NO.: ECCF 1003  
 PROJECT LOCATION: PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
 DRILLING FIRM: MILLER ENGINEERING AND TESTING INC. ELEVATION: 109.7  
 FOREMAN: R. MARCOUX LOGGED BY: D. GIUSTRA  
 DRILLING METHOD: HOLLOW STEM AUGERS  
 DATE STARTED: 10-20-10 DATE COMPLETED: 10-20-10  
 DEPTH TO WATER > INITIAL: 8' AFTER 24 HOURS: - CAVING > C



**LOG OF BORING  
No. GTB-109**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	4" ASPHALT						
0.3	FILL: DARK BROWN MEDIUM TO COARSE TO FINE SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, SOME SILT, DENSE TO MEDIUM DENSE		A	S-1	6	11-20-11-12	DRY GRAVEL IN TIP
				S-2	10	10-10-7-7	DRY
4	FILL: BLACK/BROWN MEDIUM TO FINE TO COARSE SAND, SOME SILT, MEDIUM DENSE			S-3	8	4-7-5-4	DRY
6	FILL: BLACK/BROWN MEDIUM TO FINE TO COARSE SAND, LITTLE SILT, MEDIUM DENSE			S-4	18	6-9-9-4	MOIST
8	FILL: BLACK/BROWN MEDIUM TO COARSE TO FINE SAND AND FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, SOME SILT, LOOSE			S-5	4	3-2-3-7	WET
10							
15				S-6	1	4-1-5-6	WET WOOD IN TIP
19							
20	BROWN/GRAY SILTY CLAY, SOME FINE SAND (CLAY - CL), FIRM		B1	S-7	20	4-4-2-4	WET
	Boring terminated at 21 ft.						
25							
30							
35							

PROJECT: STRUCTURAL SHOPS ADDITION PROJECT NO.: ECCF 1003  
 PROJECT LOCATION: PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
 DRILLING FIRM: MILLER ENGINEERING AND TESTING INC. ELEVATION: 110.0  
 FOREMAN: R. MARCOUX LOGGED BY: D. GIUSTRA  
 DRILLING METHOD: HOLLOW STEM AUGERS  
 DATE STARTED: 10-21-10 DATE COMPLETED: 10-21-10  
 DEPTH TO WATER> INITIAL: 8' AFTER 24 HOURS: - CAVING> C -

  
**LOG OF BORING**  
**No. GTB-110**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks	
0	4" ASPHALT							
0.3	FILL: BLACK/BROWN FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, SOME MEDIUM TO COARSE TO FINE SAND, LITTLE SILT, DENSE TO MEDIUM DENSE		A	S-1	12	18-18-113	DRY	
				S-2	10	9-6-4-5	DRY	
4	FILL: BROWN MEDIUM TO FINE SAND, SOME SILT, LITTLE FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, LOOSE			S-3	8	2-3-4-6	DRY	
5	FILL: BLACK MEDIUM TO COARSE TO FINE SAND, LITTLE FINE GRAVEL (SLAG), LOOSE			S-4	10	6-3-7-6	MOIST	
6	FILL: BLACK MEDIUM TO COARSE TO FINE SAND, LITTLE FINE GRAVEL (SLAG), VERY LOOSE			S-5	4	4-1-0-2	WET GRAVEL IN TIP	
10								
12	BROWN MEDIUM TO FINE TO COARSE SAND, TRACE SILT (WELL-GRADED SAND - SW), MEDIUM DENSE		B2	S-6	4	7-12-7-4	WET RUNNING SAND	
15								
18	BROWN/GRAY COARSE TO FINE TO MEDIUM SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, SOME SILT (SILTY SAND WITH GRAVEL - SM), VERY DENSE			S-7	22	16-22-21-14	WET	
20								
	Boring terminated at 21 ft.							
25								
30								
35								

PROJECT: STRUCTURAL SHOPS ADDITION PROJECT NO.: ECCF 1003  
 PROJECT LOCATION: PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
 DRILLING FIRM: MILLER ENGINEERING AND TESTING INC. ELEVATION: 108.5  
 FOREMAN: R. MARCOUX LOGGED BY: D. GIUSTRA  
 DRILLING METHOD: HOLLOW STEM AUGERS  
 DATE STARTED: 10-21-10 DATE COMPLETED: 10-21-10  
 DEPTH TO WATER> INITIAL: 8' AFTER 24 HOURS: CAVING> C



**LOG OF BORING  
No. GTB-111**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	3.5" ASPHALT						
0.3	FILL: GRAY/BLACK FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, SOME COARSE TO MEDIUM TO FINE SAND, TRACE SILT, MEDIUM DENSE		A	S-1	6	11-13-15	DRY
				S-2	10	19-16-10-13	MOIST
4	FILL: BROWN/BLACK MEDIUM TO FINE TO COARSE SAND, SOME FINE GRAVEL SIZE ROCK FRAGMENTS, LITTLE SILT, MEDIUM DENSE TO DENSE		A	S-3	16	11-13-20-12	DRY
5				S-4	16	32-27-12-5	MOIST
8	LIGHT BROWN/GRAY SILTY CLAY AND FINE TO MEDIUM SAND (CLAY - CL), SOFT		B1	S-5	20	3-1-1-1	
10							
13	GRAY FINE TO MEDIUM SAND, SOME SILT (SM) MEDIUM DENSE		B2	S-6	12	6-5-7-21	WET
15							
17	GRAY SILTY CLAY, LITTLE FINE SAND (CL)		B1				
19	DARK GRAY MEDIUM TO FINE SAND, SOME CLAY (SC), MEDIUM DENSE		B2	S-7	24	6-9-12-14	WET
20	Boring terminated at 21 ft.						
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 108.0  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-20-10      **DATE COMPLETED:** 10-20-10  
**DEPTH TO WATER > INITIAL:** 8'      **AFTER 24 HOURS:**      **CAVING >** C



**LOG OF BORING  
No. TB-113**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	4" ASPHALT		A	S-1	8	X-7-25-12	DRY
0.3	FILL: DARK BROWN MEDIUM TO FINE TO COARSE SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, TRACE SILT, DENSE TO MEDIUM DENSE			S-2	8	10-15-6-14	DRY
2	FILL: BLACK MEDIUM TO COARSE TO FINE SAND, SOME FINE GRAVEL, TRACE SILT, TRACE COAL, MEDIUM DENSE			S-3	10	13-8-7-8	DRY
5				S-4	10	7-4-7-7	MOIST
8				S-5	6	50/0"	WET RUNNING SAND
10	BROWN MEDIUM TO FINE TO COARSE SAND, LITTLE SILT (SILTY SAND - SM), VERY DENSE	C1				Auger refusal at 9 ft.	
	Boring terminated at 9 ft.						
15							
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 106.8  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-20-10      **DATE COMPLETED:** 10-20-10  
**DEPTH TO WATER > INITIAL:** 10'      **AFTER 24 HOURS:** -      **CAVING > C:** -



**LOG OF BORING  
No. TB-117**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (ft.)	Blow Counts	Remarks
0	3.5" ASPHALT						
0.3	FILL: BLACK/BROWN FINE TO COARSE GRAVEL, SOME COARSE TO MEDIUM TO FINE SAND, TRACE SILT, DENSE		A	S-1	10	8-15-16	DRY
				S-2	12	12-16-19-13	DRY
5	FILL: BLACK COARSE TO MEDIUM TO FINE SAND, SOME FINE GRAVEL SIZE ROCK FRAGMENTS, TRACE SILT, DENSE			S-3	18	10-15-16-16	DRY
6	FILL: BLACK COARSE TO MEDIUM SAND, SOME FINE GRAVEL SIZE ROCK FRAGMENTS (SLAG), LOOSE			S-4	14	5-3-4-2	DRY
8	FILL: DARK BROWN/BLACK COARSE TO FINE GRAVEL SIZE ROCK FRAGMENTS, SOME MEDIUM TO COARSE TO FINE SAND, LITTLE SILT (WOOD FRAGMENTS), LOOSE TO MEDIUM DENSE			S-5	8	4-3-3-2	MOIST
10				S-6	12	5-21-6-5	WET
12	FILL: DARK BROWN COARSE TO MEDIUM TO FINE SAND, SOME FINE GRAVEL SIZE ROCK FRAGMENTS, LITTLE SILT, (WOOD FRAGMENTS), LOOSE			S-7	6	3-4-6-3	WET
15	BLACK CLAYEY SILT, SOME FINE TO MEDIUM SAND (ELASTIC SITL - MH), FIRM			S-8	12	3-2-2-2	WET
14.5	Boring terminated at 16 ft.		B1				
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 109.5  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-20-10      **DATE COMPLETED:** 10-20-10  
**DEPTH TO WATER> INITIAL:** ∇ 10'      **AFTER 24 HOURS:** ∇ -      **CAVING>** C. -



**LOG OF BORING  
No. TB-118**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	5" ASPHALT						
0.4	FILL: GRAY COARSE TO MEDIUM TO FINE SAND AND FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, DENSE TO MEDIUM DENSE		A	S-1	12	28-13-18	DRY
				S-2	6	17-8-4-6	DRY
4	S-3			12	6-13-22-17	DRY	
	S-4			12	17-12-12-8	DRY	
	S-5			14	20-25-51-73	WET	
	S-6			2	65/2"	WET	
10	Boring terminated at 10.2 ft.						Auger refusal at 10.2 ft.
15							
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.0  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-19-10      **DATE COMPLETED:** 10-19-10  
**DEPTH TO WATER > INITIAL:**  NE      **AFTER 24 HOURS:**  -      **CAVING >** C -



**LOG OF BORING  
No. TB-122**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	5" ASPHALT						
0.4	FILL: DARK BROWN MEDIUM TO COARSE TO FINE SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, TRACE SILT (WOOD FRAGMENTS), MEDIUM DENSE		A	S-1	12	18-13-7	DRY
2				S-2	12	7-6-5-6	MOIST
5	LIGHT BROWN CLAYEY SILT, SOME FINE TO MEDIUM SAND, (ELASTIC SILT - MH), STIFF		B1	S-3	12	3-2-4-7	MOIST
5	BROWN CLAYEY SILT, SOME MEDIUM TO FINE SAND (ELASTIC SILT - MH), FIRM			S-4	24	8-9-9-15	MOIST
6	LIGHT BROWN/GRAY SILT, SOME FINE TO MEDIUM SAND (SILT - ML), VERY STIFF			S-5	8	8-75/5"	MOIST
10	Boring terminated at 9 ft.						Auger refusal at 9 ft.
15							
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 111.0  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-20-10      **DATE COMPLETED:** 10-20-10  
**DEPTH TO WATER > INITIAL:** 10'      **AFTER 24 HOURS:** -      **CAVING > C:** -

  
**LOG OF BORING**  
**No. TB-124**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks
0	3.5" ASPHALT						
0.3	FILL: GRAY MEDIUM TO FINE TO COARSE SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, DENSE TO MEDIUM DENSE		A	S-1	12	13-19-20	DRY
				S-2	18	20-24-25-31	DRY
5				S-3	18	16-21-17-17	DRY
				S-4	16	20-21-23-15	DRY
				S-5	16	13-11-13-17	MOIST
10	BROWN COARSE TO MEDIUM TO FINE SAND, SOME FINE GRAVEL, SOME SILT (SILTY SAND WITH GRAVEL - SM), DENSE		B2	S-6	14	20-19-21-50/3"	WET
	Boring terminated at 12 ft.						Auger refusal at 12 ft.
15							
20							
25							
30							
35							

**PROJECT:** STRUCTURAL SHOPS ADDITION      **PROJECT NO.:** ECCF 1003  
**PROJECT LOCATION:** PORTSMOUTH NAVAL SHIPYARD; KITTERY, ME  
**DRILLING FIRM:** MILLER ENGINEERING AND TESTING INC.      **ELEVATION:** 110.8  
**FOREMAN:** R. MARCOUX      **LOGGED BY:** D. GIUSTRA  
**DRILLING METHOD:** HOLLOW STEM AUGERS  
**DATE STARTED:** 10-19-10      **DATE COMPLETED:** 10-19-10  
**DEPTH TO WATER > INITIAL:** NE      **AFTER 24 HOURS:** -      **CAVING >** C



**LOG OF BORING  
No. TB-125**

Depth (feet)	Description	Graphic	Stratum	Sample No.	Recovery (in.)	Blow Counts	Remarks	
0	2.5" ASPHALT		A	S-1	18	13-16-19	DRY	
0.2	FILL: BLACK MEDIUM TO FINE TO COARSE SAND, SOME SILT, LITTLE FINE GRAVEL SIZE ROCK FRAGMENTS, DENSE TO VERY DENSE			S-2	8	27-30-29-16	DRY	
1.5	FILL: DARK BROWN MEDIUM TO COARSE TO FINE SAND, SOME FINE TO COARSE GRAVEL SIZE ROCK FRAGMENTS, LITTLE SILT, DENSE			S-3	10	25-19-10-10	DRY	
4	FILL: BROWN MEDIUM TO FINE TO COARSE SAND, SOME SILT (SM), DENSE			B2	S-4	18	6-3-3-5	MOIST
6	LIGHT BROWN SILT, SOME FINE TO MEDIUM SAND (SILT - ML), FIRM			C1	S-5	12	6-90/6"	MOIST
10	Boring terminated at 10.5 ft.						Auger refusal at 10.5 ft.	
15								
20								
25								
30								
35								



# GeoConcepts Engineering, Inc.

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703 443-0309  
703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-1</b>
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/21/04
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.2	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/21/04

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
108.7			Asphalt = 6.5 inches											
			lean clay FILL, with sand and asphalt, moist, black-brown			11								
						13								
						10								
105.7						5								
						3								
			clayey sand FILL, with gravel, moist, brown			6								
	5	A				31								
						36								
						24								
100.7			DISINTEGRATED QUARTZITE BEDROCK, moist, gray			58								
		C1				118								
99.5			Auger and Spoon Refusal at 9.7 ft			100/1								
	10													
	15													
	20													

GROUND WATER LEVELS: ∇ ENCOUNTERED: <u>8.5</u> ft ELEV. <u>100.7</u> CAVED: <u>7.5</u> ft ELEV. <u>101.7</u>		SAMPLE TYPES: ☒ Split Spoon      ▣ Bulk ■ Shelby Tube      □ Rock Core ⊠ Pressuremeter    ▽ DCP	
REMARKS:			

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: B-2	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/21/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.9	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/21/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (ft)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
109.8		A	Asphalt = 3 inches lean clay FILL, with sand and asphalt, moist, black, brown		X	10 26 100/4								
	5				X	1 2 1/1								
	10	B1	LEAN CLAY (CL), moist, brown		X	2 9 7								
98.4		B2	clayey SAND (SC), with gravel, moist, brown		X	11 18 24								
94.6	15		Auger Refusal at 15.3 ft		X	100/4								

GROUND WATER LEVELS: ▽ ENCOUNTERED: <u>11.4</u> ft ELEV. <u>98.5</u>		SAMPLE TYPES: Split Spoon     Bulk Shelby Tube     Rock Core Pressuremeter     DCP	
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REMARKS:

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.





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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-4</b>
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		
OWNER/CLIENT: EwingCole		DRILLER: Walter	DATE STARTED: 5/20/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.4	DRILLING METHOD: 2.25" I.D. HSA	DATE COMPLETED: 5/20/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT							
								20	40	60	80				
108.6			Concrete = 9.5 inches												
	5	A	clayey sand FILL, with gravel, moist, brown		X	8 17 16 28 30 34									
	10														
	15	B1	LEAN CLAY (CL), moist to wet, gray petroleum odor at 13.5 ft.		X	5 7 10									
95.9															
	20	B2	clayey SAND (SC), with gravel, moist, brown		X	5 10 10									
90.9															
89.3			Auger and Spoon Refusal at 20.1 ft			7 13 107 100/1									

GROUND WATER LEVELS:  CAVED: <u>9.4</u> ft ELEV. <u>100.0</u>	SAMPLE TYPES: Split Spoon Shelby Tube Pressuremeter Bulk Rock Core DCP
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REMARKS:

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-5</b>											
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1											
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/21/04											
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.1	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/21/04											
ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT							
108.6			Asphalt = 6 inches			10									
			clayey sand FILL, with gravel, moist, brown			5									
						4									
106.4			Auger and Spoon Refusal at 2.7 ft			3									
						3									
						100/2									
	5														
	10														
	15														
	20														
GROUND WATER LEVELS:								SAMPLE TYPES:							
ENCOUNTERED: <u>None</u>								<input checked="" type="checkbox"/> Split Spoon <input checked="" type="checkbox"/> Bulk <input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> Rock Core <input checked="" type="checkbox"/> Pressuremeter <input type="checkbox"/> DCP							
UPON COMPLETION: <u>Dry</u>															
REMARKS:															

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES, THE TRANSITION MAY BE GRADUAL.

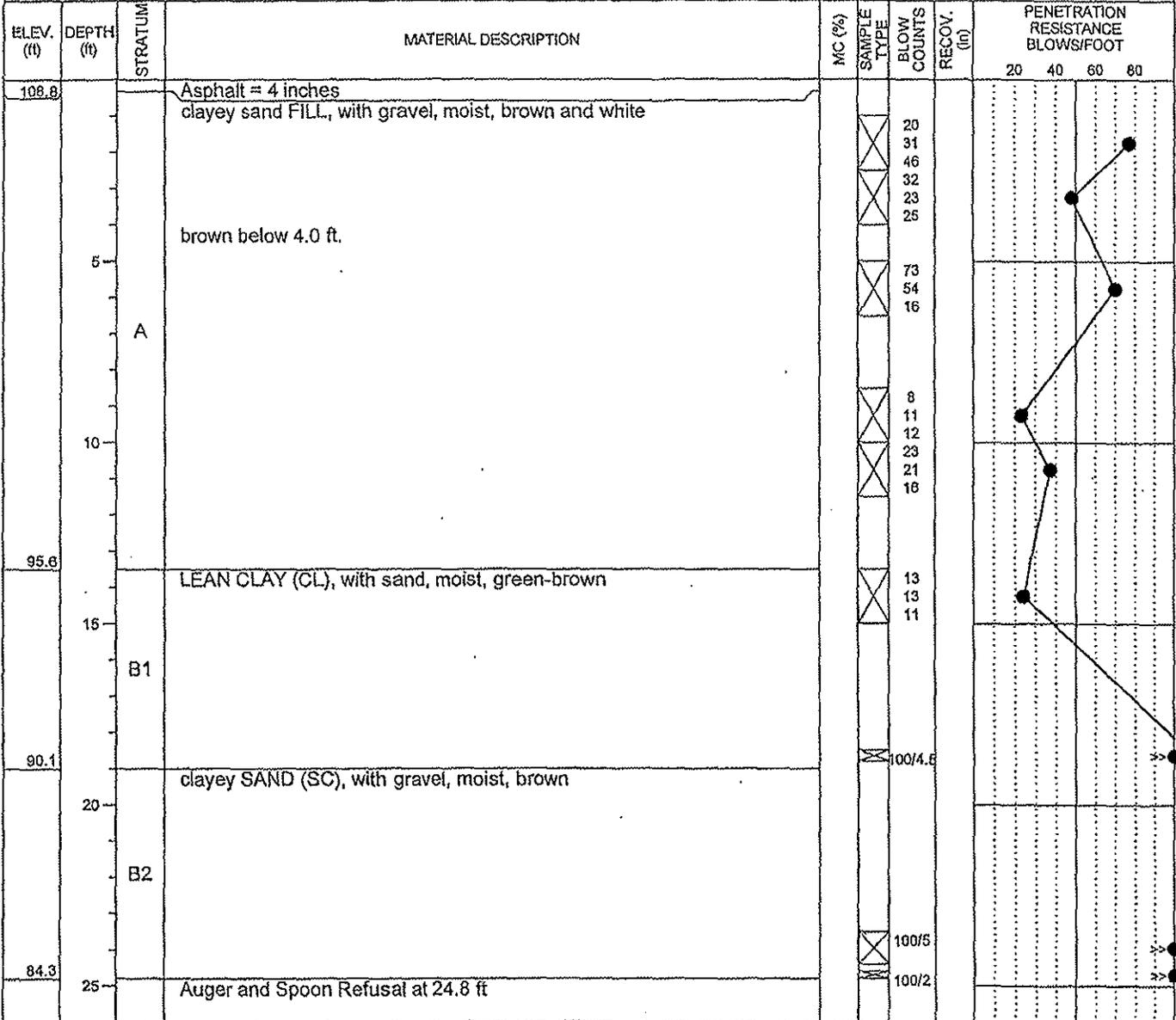


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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: B-5A	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/26/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.1	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/26/04	



GROUND WATER LEVELS:		SAMPLE TYPES:	
ENCOUNTERED: <u>None</u>	UPON COMPLETION: <u>Dry</u>	Split Spoon	Bulk
		Shelby Tube	Rock Core
		Pressuremeter	DCP

REMARKS:

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ, GEOCONCEPTS.GDT 7/6/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-6</b>
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/21/04
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.9	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/21/04

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
109.4		A	Asphalt = 6 inches lean clay FILL, with sand and asphalt, moist, gray-brown											
	5													
101.4		B1	LEAN CLAY (CL), with sand, moist, gray-green and brown											
	10													
98.4			Auger and Spoon Refusal at 13.5 ft			100/0								
	15													
	20													

GROUND WATER LEVELS:				SAMPLE TYPES:			
ENCOUNTERED:	<u>None</u>				Split Spoon		Bulk
UPON COMPLETION:	<u>Dry</u>	CAVED:	<u>8.3</u> ft	ELEV.:	<u>101.6</u>		Shelby Tube
							Rock Core
							Pressuremeter
							DCP

REMARKS:

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-7</b>
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/21/04
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.8	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/21/04

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
109.3		A	Asphalt = 6 inches sandy lean clay FILL, with asphalt, moist, gray-brown		X	4								
106.8			clayey gravel FILL, with sand and brick, moist, brown		X	22								
104.8	5	B2	clayey SAND (SC), moist, gray and brown		X	18								
					X	11								
					X	8								
					X	3								
					X	4								
	10				X	4								
					X	12								
					X	12								
	15				X	7								
					X	7								
					X	14								
91.6	18.2		Auger and Spoon Refusal at 18.2 ft			100/1								

GROUND WATER LEVELS:  
 ▽ ENCOUNTERED: 8.5 ft ELEV. 101.3

SAMPLE TYPES:

	Split Spoon		Bulk
	Shelby Tube		Rock Core
	Pressuremeter		DCP

REMARKS:

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-8</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/19/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.7	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/19/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT							
								20	40	60	80				
109.2			Asphalt = 6 inches												
			sandy lean clay FILL, with asphalt, moist, gray-brown												
107.7		A	clayey sand FILL, moist, brown			8 14 13 10 6 33									
105.5			Auger and Spoon Refusal at 4.2 ft			100/3 100/2									
	5														
	10														
	15														
	20														

GROUND WATER LEVELS:				SAMPLE TYPES:			
ENCOUNTERED:	<u>None</u>			<input checked="" type="checkbox"/>	Split Spoon	<input checked="" type="checkbox"/>	Bulk
UPON COMPLETION:	<u>Dry</u>			<input checked="" type="checkbox"/>	Shelby Tube	<input type="checkbox"/>	Rock Core
▼ 5/21/04	<u>7.6</u> ft	ELEV.	<u>102.1</u>	<input checked="" type="checkbox"/>	Pressuremeter	<input checked="" type="checkbox"/>	DCP

REMARKS:

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard			LOGGED BY: J. Chokeychaitanasin			BORING NUMBER: <b>B-8A</b>		
LOCATION: Kittery, Maine			DRILLING CONTRACTOR: New Hampshire Boring, Inc.			SHEET 1 OF 1		
OWNER/CLIENT: EwingCole			DRILLER: Walter			DATE STARTED: 5/19/04		
PROJECT NUMBER: 24071		GROUND SURFACE ELEVATION (ft): 109.7		DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/19/04		
ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT
			No Sampling to 4.2 ft.					20 40 60 80
105.5	5		very hard, slightly weathered, moderately spaced joints, moderately fractured, moderately open aperture, closed healing, 98% recovered, RQD = 65%, fair QUARTZITE ROCK					
100.5	10	C2	very hard, fresh, moderately spaced joints, slightly fractured, moderately open aperture, closed healing, 100% recovered, RQD = 100%, excellent QUARTZITE ROCK					
95.5	15		Bottom of Boring at 14.2 ft					
	20							
GROUND WATER LEVELS:						SAMPLE TYPES:		
ENCOUNTERED: <u>None</u>						<input checked="" type="checkbox"/> Split Spoon <input checked="" type="checkbox"/> Bulk <input checked="" type="checkbox"/> Shelby Tube <input checked="" type="checkbox"/> Rock Core <input checked="" type="checkbox"/> Pressuremeter <input checked="" type="checkbox"/> DCP		
UPON COMPLETION: <u>Dry</u>								
5/21/04 <u>7.6</u> ft     ELEV. <u>102.1</u>								
REMARKS:								

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-9</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Waiter		DATE STARTED: 5/19/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.5	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/19/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
109.9			Asphalt = 7 inches											
			clayey sand FILL, with gravel and asphalt, moist, gray-brown			9								
						10								
						12								
106.5			lean clay FILL, with sand, moist, brown-orange			57								
						5								
						9								
						16								
	5	A	petroleum odor at 5 ft.			23								
						12								
						34								
						30								
						25								
						4								
						50								
100.6			Auger Refusal at 8.9 ft			86								
						100/4								

GROUND WATER LEVELS:				SAMPLE TYPES:			
▼ ENCOUNTERED:	7.4 ft	ELEV. 102.1		<input checked="" type="checkbox"/> Split Spoon	<input checked="" type="checkbox"/> Bulk		
▼ 5/20/04	7.4 ft	ELEV. 102.1		<input checked="" type="checkbox"/> Shelby Tube	<input checked="" type="checkbox"/> Rock Core		
				<input checked="" type="checkbox"/> Pressuremeter	<input checked="" type="checkbox"/> DCP		
REMARKS:							

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-10</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/18/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.4	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/18/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (ft)	PENETRATION RESISTANCE BLOWS/FOOT							
								20	40	60	80				
108.8			Asphalt = 7 inches												
			sandy lean clay FILL, with gravel and asphalt, moist, gray-brown												
107.3			clayey sand FILL, with gravel, moist, brown		X	13 46									
	5	A			X	8 15 87 30									
101.5			petroleum odor at 7.9 ft. Auger and Spoon Refusal at 7.9 ft			100/0									
	10														
	15														
	20														

GROUND WATER LEVELS:				SAMPLE TYPES:			
ENCOUNTERED:	<u>None</u>			<input checked="" type="checkbox"/>	Split Spoon	<input checked="" type="checkbox"/>	Bulk
UPON COMPLETION:	<u>Dry</u>	CAVED: <u>7.9</u> ft	ELEV. <u>101.5</u>	<input checked="" type="checkbox"/>	Shelby Tube	<input type="checkbox"/>	Rock Core
5/19/04	<u>Dry</u>	CAVED: <u>5.8</u> ft	ELEV. <u>103.7</u>	<input checked="" type="checkbox"/>	Pressuremeter	<input checked="" type="checkbox"/>	DCP

REMARKS:

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.

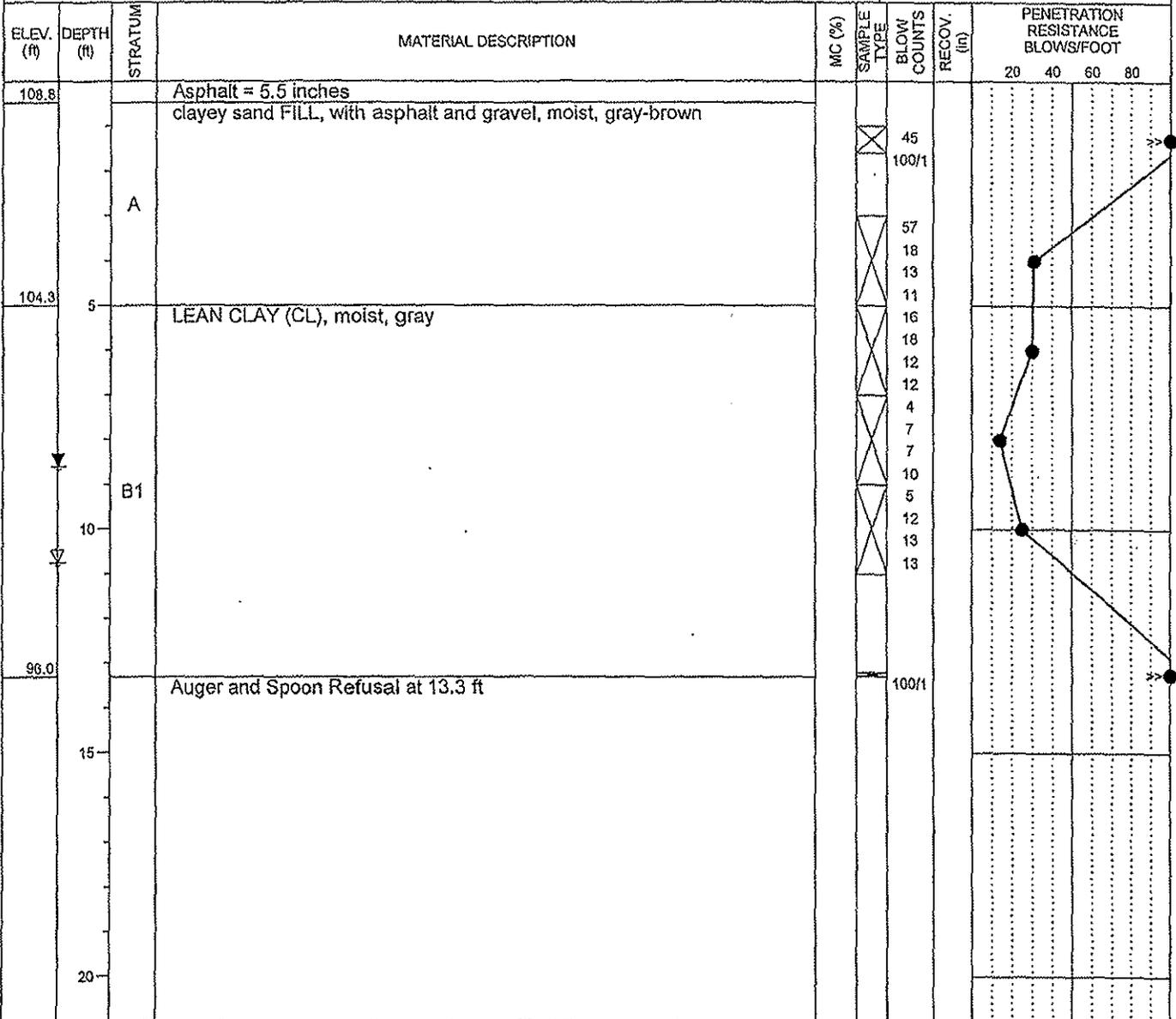


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PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-11</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/19/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.3	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/19/04	



BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/5/04

GROUND WATER LEVELS:				SAMPLE TYPES:			
▽ ENCOUNTERED:	10.8	ft	ELEV. 98.5		Split Spoon		Bulk
▽ 5/20/04	8.6	ft	ELEV. 100.7		Shelby Tube		Rock Core
					Pressuremeter		DCP

REMARKS:

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



# GeoConcepts Engineering, Inc.

604 South King St., Suite 200  
Leesburg, VA 20175

703 443-0309  
703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-12</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/26/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 110.0	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/26/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT					
								20	40	60	80		
109.7		A	Asphalt = 3 inches clayey sand FILL, with gravel, moist, brown			6							
106.5		B2	clayey SAND (SC), moist, brown			10							
104.5	5	B1	LEAN CLAY (CL), with sand, moist, brown			11 23 36							
101.5 101.1		C1	DISINTEGRATED QUARTZITE BEDROCK, moist, gray Auger and Spoon Refusal at 8.9 ft			100/1.5							

GROUND WATER LEVELS:				SAMPLE TYPES:			
ENCOUNTERED:	5.9	ft	ELEV. 104.1		Split Spoon		Bulk
5/27/04	2.1	ft	ELEV. 107.9		Shelby Tube		Rock Core
					Pressuremeter		DCP

REMARKS:

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-13</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/25/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.6	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/25/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
109.4		A	Asphalt = 3 inches clayey sand FILL, with gravel, moist, black-brown		X	14								
			13											
			19											
			10											
			10											
			7											
105.6			Auger Refusal at 4.0 ft			100/5								
	5													
	10													
	15													
	20													

GROUND WATER LEVELS: ENCOUNTERED: <u>None</u> UPON COMPLETION: <u>Dry</u>		SAMPLE TYPES: <input checked="" type="checkbox"/> Split Spoon <input checked="" type="checkbox"/> Bulk <input checked="" type="checkbox"/> Shelby Tube <input checked="" type="checkbox"/> Rock Core <input checked="" type="checkbox"/> Pressuremeter <input checked="" type="checkbox"/> DCP	
---	--	---	--

REMARKS:

BOREHOLE/TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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Leesburg, VA 20175

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703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-13a</b>
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		
OWNER/CLIENT: EwingCole		DRILLER: Walter	DATE STARTED: 5/19/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.6	DRILLING METHOD: 2.25" I.D. HSA	DATE COMPLETED: 5/19/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
			No Sampling to 2.5 ft.											
107.1			Auger and Spoon Refusal at 2.5 ft		100/1									
	5													
	10													
	15													
	20													

GROUND WATER LEVELS:	SAMPLE TYPES:
	<input type="checkbox"/> Split Spoon <input type="checkbox"/> Bulk <input type="checkbox"/> Shelby Tube <input type="checkbox"/> Rock Core <input type="checkbox"/> Pressuremeter <input type="checkbox"/> DCP

REMARKS:

BOREHOLE/TEST PIT: 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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Leesburg, VA 20175

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703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokechaitanasin		BORING NUMBER: <b>B-14</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/24/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.3	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/24/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT									
								20	40	60	80						
108.8			Concrete = 6 inches														
			clayey sand FILL, with gravel, moist, brown														
	5	A				7 8 28 2 100/2.5											
100.8			LEAN CLAY (CL), with sand, moist, gray-brown														
	10	B1				3 3 4											
95.8			clayey SAND (SC), moist, gray														
	15	B2				6 27 30											
			with gravel at 18.5 ft.														
89.1	20		Auger Refusal at 20.2 ft			50 100/5 100/2.5											

GROUND WATER LEVELS:		SAMPLE TYPES:	
V UPON COMPLETION: <u>12.8</u> ft ELEV. <u>96.5</u> CAVED: <u>4.2</u> ft ELEV. <u>105.1</u>		<input type="checkbox"/> Split Spoon <input type="checkbox"/> Bulk <input type="checkbox"/> Shelby Tube <input type="checkbox"/> Rock Core <input type="checkbox"/> Pressuremeter <input type="checkbox"/> DCP	

REMARKS:

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-15</b>	
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		SHEET 1 OF 1	
OWNER/CLIENT: EwingCole		DRILLER: Walter		DATE STARTED: 5/24/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.1	DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/24/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT					
								20	40	60	80		
108.6		A	Asphalt = 6 inches clayey sand FILL, with asphalt and gravel, moist, black-brown			25 22 30 30 19							
	5						11 6 5						
100.6			B1	LEAN CLAY (CL), with sand, moist, brown-gray			4 8 11						
	10							1 8 10					
	15												
80.6		B2	clayey SAND (SC), with gravel, moist, brown			6 12 12							
	20												
87.2			Auger and Spoon Refusal at 21.9 ft			100/2							
	25												

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

GROUND WATER LEVELS: ENCOUNTERED: <u>6.2</u> ft ELEV. <u>102.9</u>		SAMPLE TYPES: Split Spoon     Bulk Shelby Tube     Rock Core Pressuremeter     DCP	
---	--	---	--

REMARKS:

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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Leesburg, VA 20175

703 443-0309  
703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard		LOGGED BY: J. Chokeychaitanasin		BORING NUMBER: <b>B-16</b>
LOCATION: Kittery, Maine		DRILLING CONTRACTOR: New Hampshire Boring, Inc.		
OWNER/CLIENT: EwingCole		DRILLER: Walter	DATE STARTED: 5/27/04	
PROJECT NUMBER: 24071	GROUND SURFACE ELEVATION (ft): 109.9	DRILLING METHOD: 2.25" I.D. HSA	DATE COMPLETED: 5/27/04	

ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (ft)	PENETRATION RESISTANCE BLOWS/FOOT					
								20	40	60	80		
109.6		A	Asphalt = 4 inches clayey sand FILL, with gravel, moist, brown			13 10 12 7 10 13							
104.9	6	B1	LEAN CLAY (CL), moist, gray-brown			10 11 13							
101.4		B2	clayey SAND (SC), with gravel, moist, brown			16							
100.97		C1	DISINTEGRATED QUARTZITE BEDROCK, moist, gray			100/4							
100.3	10		Auger and Spoon Refusal at 9.6 ft			100/2							

GROUND WATER LEVELS:				SAMPLE TYPES:			
∇ ENCOUNTERED:	9.0	ft	ELEV. 100.9		Split Spoon		Bulk
∇ UPON COMPLETION:	8.1	ft	ELEV. 101.8		Shelby Tube		Rock Core
					Pressuremeter		DCP

REMARKS:

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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703 443-0309  
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PROJECT: Portsmouth Naval Shipyard			LOGGED BY: J. Chokechaitanasin			BORING NUMBER: B-17								
LOCATION: Kittery, Maine			DRILLING CONTRACTOR: New Hampshire Boring, Inc.			SHEET 1 OF 1								
OWNER/CLIENT: EwingCole			DRILLER: Walter			DATE STARTED: 5/25/04								
PROJECT NUMBER: 24071		GROUND SURFACE ELEVATION (ft): 109.3		DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/25/04								
ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
109.1		A	Asphalt = 2 inches clayey sand FILL, with asphalt, moist, black-brown		X X X X	13 12 13 13 16								
108.2			Auger Refusal at 3.1 ft		X	100/5								
	5													
	10													
	15													
	20													
GROUND WATER LEVELS:						SAMPLE TYPES:								
ENCOUNTERED: <u>None</u>						<input checked="" type="checkbox"/> Split Spoon <input checked="" type="checkbox"/> Bulk <input checked="" type="checkbox"/> Shelby Tube <input checked="" type="checkbox"/> Rock Core <input checked="" type="checkbox"/> Pressuremeter <input checked="" type="checkbox"/> DCP								
UPON COMPLETION: <u>Dry</u>						CAVED: <u>4.2</u> ft ELEV. <u>105.1</u>								
REMARKS:														

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.



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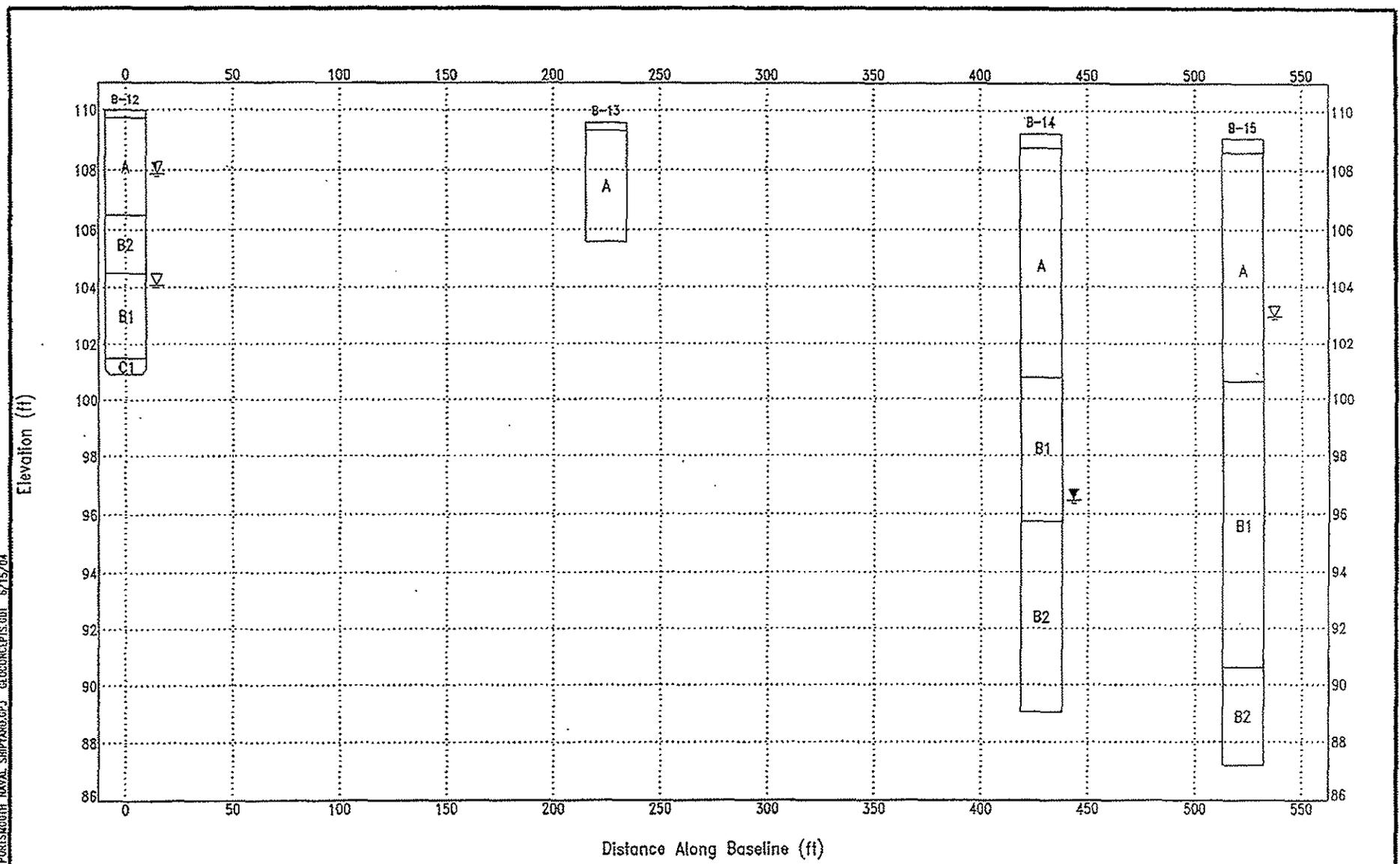
703 443-0309  
703 589-1592 fax

PROJECT: Portsmouth Naval Shipyard			LOGGED BY: J. Chokeychaitanasin			BORING NUMBER: <b>B-17a</b>								
LOCATION: Kittery, Maine			DRILLING CONTRACTOR: New Hampshire Boring, Inc.			SHEET 1 OF 1								
OWNER/CLIENT: EwingCole			DRILLER: Walter			DATE STARTED: 5/25/04								
PROJECT NUMBER: 24071		GROUND SURFACE ELEVATION (ft): 109.3		DRILLING METHOD: 2.25" I.D. HSA		DATE COMPLETED: 5/25/04								
ELEV. (ft)	DEPTH (ft)	STRATUM	MATERIAL DESCRIPTION	MC (%)	SAMPLE TYPE	BLOW COUNTS	RECOV. (in)	PENETRATION RESISTANCE BLOWS/FOOT						
								20	40	60	80			
			No Sampling to 5 ft.											
104.3	5	A	clayey sand FILL, with gravel, moist, brown		X	7								
103.8			clayey SAND (SC), with gravel, moist, brown			4								
		B2				3								
101.3			Auger and Spoon Refusal at 8.0 ft				100/2							
	10													
	15													
	20													
GROUND WATER LEVELS:						SAMPLE TYPES:								
						<input checked="" type="checkbox"/> Split Spoon <input checked="" type="checkbox"/> Bulk <input checked="" type="checkbox"/> Shelby Tube <input checked="" type="checkbox"/> Rock Core <input checked="" type="checkbox"/> Pressuremeter <input checked="" type="checkbox"/> DCP								
REMARKS:														

BOREHOLE TEST PIT 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 7/8/04

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES. THE TRANSITION MAY BE GRADUAL.

STRATIGRAPHY & GW 24071, PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.DWT 5/15/04



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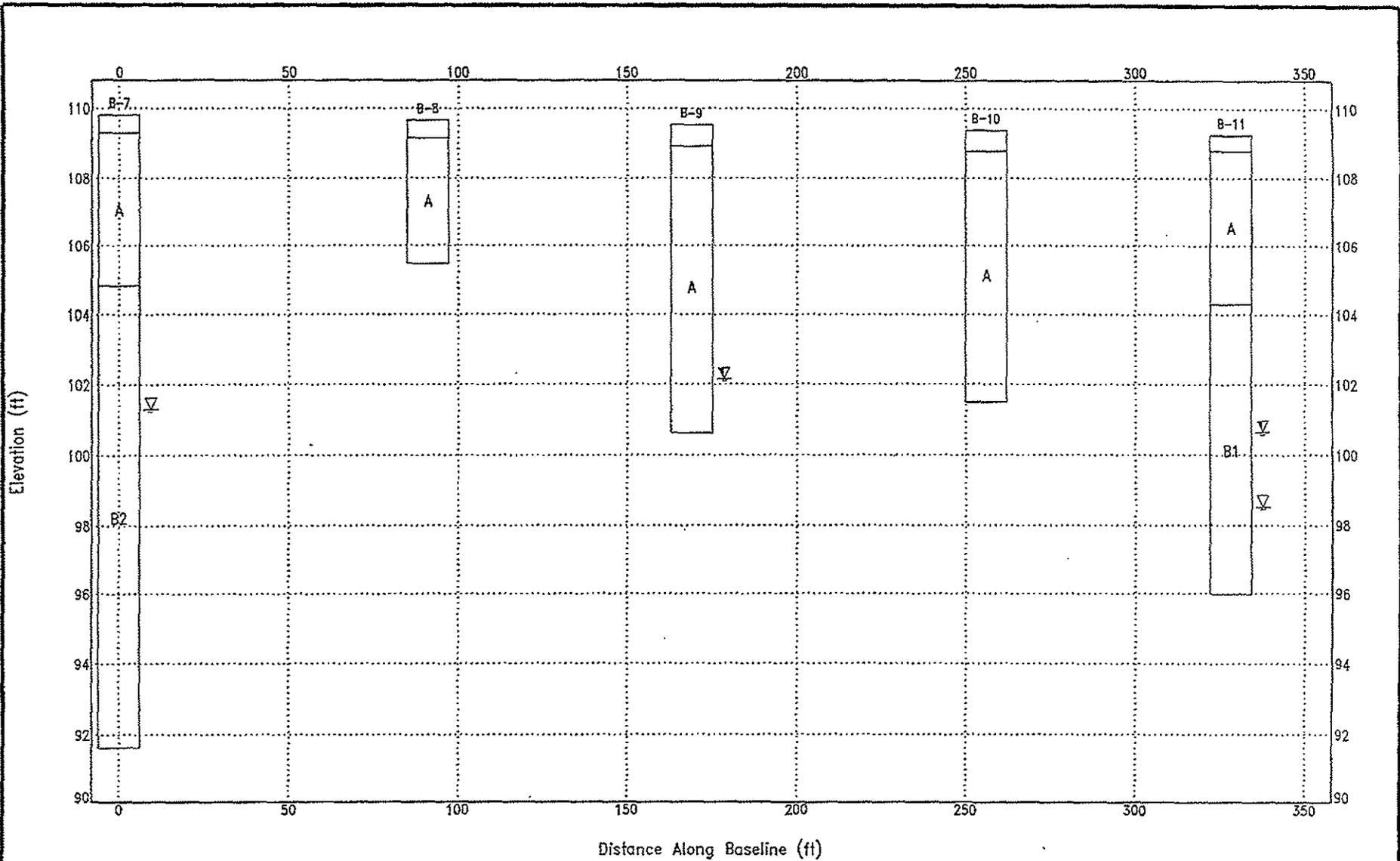
604 South King St., Suite 200 703 443-0309  
Leesburg, VA 20175 703 589-1592 fax

GROUND WATER LEVELS:  
▽ ENCOUNTERED  
▽ UPON COMPLETION  
▽ LONG-TERM

**SUBSURFACE PROFILE A-A'**

Project: Portsmouth Naval Shipyard  
Location: Kittery, Maine  
Owner/Client: EwingCole  
Project No.: 24071

STRATEGIC & GW 24071 PORTSMOUTH NAVAL SHIPYARD.GPJ GEOCONCEPTS.GDT 8/15/04



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Engineering, Inc.**

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Leesburg, VA 20175

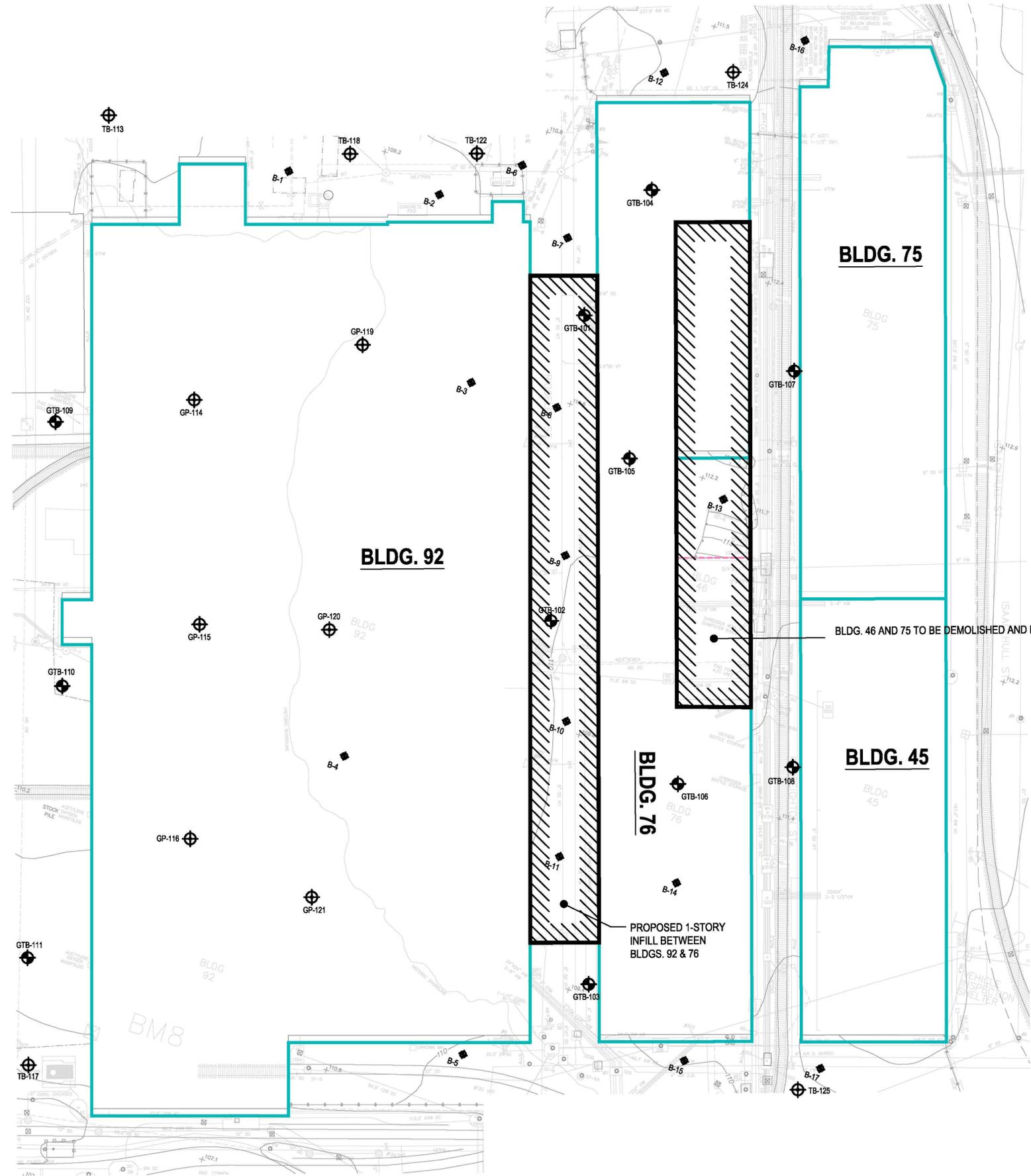
703 443-0309  
703 589-1592 fax

GROUND WATER LEVELS:

- ▽ ENCOUNTERED
- ▽ UPON COMPLETION
- ▽ LONG-TERM

**SUBSURFACE PROFILE B-B'**

Project: Portsmouth Naval Shipyard  
Location: Kittery, Maine  
Owner/Client: EwingCole  
Project No.: 24071



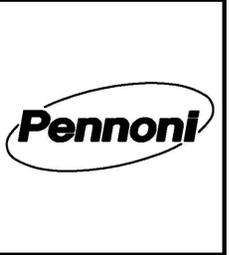
TEST BORING KEY	
◆	GTB-101 GEOTECHNICAL TEST BORING LOCATION (11)
⊕	TB-113 ENVIRONMENTAL TEST BORING LOCATION (6)
⊕	GP-114 GEOPROBE TEST BORING LOCATION (6)
◆	B-1 PREVIOUS TEST BORING LOCATIONS

WATER LEVELS, WHERE SHOWN, ARE THOSE OBSERVED AT THE TIME NOTED AND MAY NOT REFLECT DAILY OR SEASONAL VARIATIONS IN THE GROUND WATER LEVEL.

THE SUBSURFACE CONDITIONS REVEALED BY THIS STUDY REPRESENT CURRENT CONDITIONS AT THE SPECIFIED TEST LOCATIONS ONLY AND MAY NOT BE INDICATIVE OF CONDITIONS AT OTHER LOCATIONS.

1 TEST BORING PLAN  
1"=30'

**Pennoni Associates Inc.** 2041 AVENUE C, SUITE 100, BETHLEHEM, PA 18017  
 Engineers • Surveyors • Planners • Landscape Architects  
 (610) 231-0600 FAX: (610) 231-2033



NO.	DATE	REVISIONS	BY

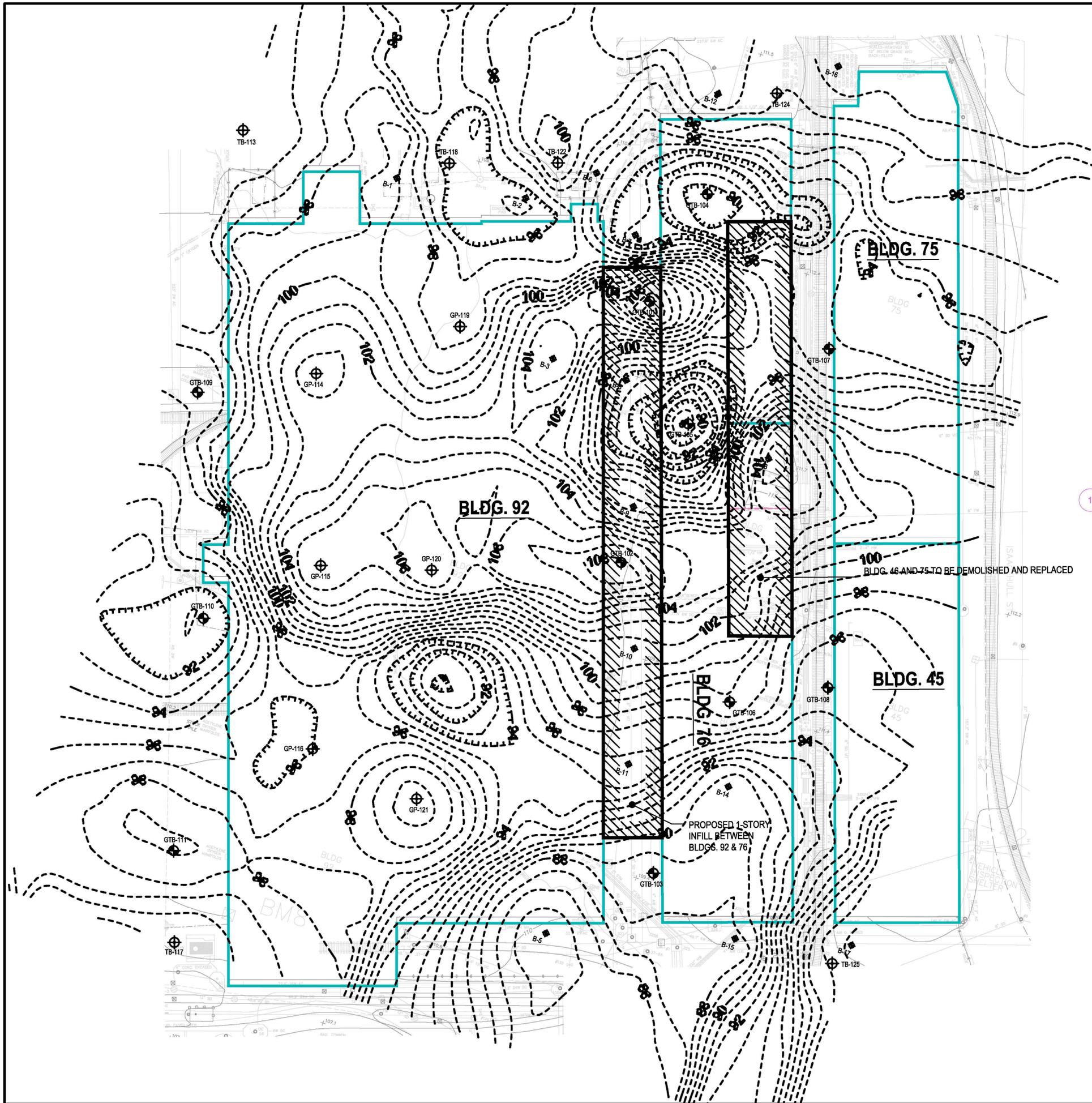
ALL DIMENSIONS MUST BE VERIFIED BY THE FIELD. PENNONI ASSOCIATES WILL NOT BE RESPONSIBLE FOR ANY DISCREPANCIES NOTIFIED TO PENNONI ASSOCIATES BEFORE PROCEEDING WITH THE WORK.

**PORTSMOUTH NAVAL SHIPYARD**  
 KITTERY, MAINE  
**TEST BORING LOCATION PLAN**  
**EWING COLE ARCHITECTS**  
 FEDERAL RESERVE BANK BUILDING, 100 N 6TH STREET  
 PHILADELPHIA, PA 19106-4590

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JOB NUMBER	ECCF 1003
1 OF 1	

SCALE	1"=30'	DRAWING NO.	TB-1
DRAWN BY	JDT		
DATE	12/14/10		
APPROVED			



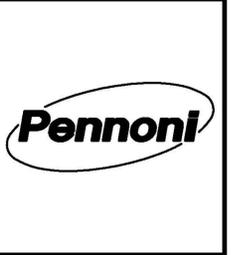
TEST BORING KEY	
◆	GTB-101 GEOTECHNICAL TEST BORING LOCATION (11)
⊕	TB-113 ENVIRONMENTAL TEST BORING LOCATION (6)
⊕	GP-114 GEOPROBE TEST BORING LOCATION (6)
◆	B-1 PREVIOUS TEST BORING LOCATIONS

TOP OF ROCK CONTOURS SHOWN ARE EXTRAPOLATED FROM ELEVATIONS AT SPECIFIC LOCATIONS (BORINGS, PROBES, ETC.) USING ALGORITHMIC SOFTWARE AND MAY VARY BY A COUPLE OF FEET IN SOME AREAS. REFER TO THE INDIVIDUAL TEST BORING LOGS FOR MORE DEFINITIVE DEPTHS/ELEVATIONS AT SPECIFIC LOCATIONS.

GROUND SURFACE ELEVATIONS AT THE BORING LOCATIONS WERE DEVELOPED FROM TOPOGRAPHIC DATA PROVIDED BY OTHERS.

1 TEST BORING PLAN  
1"=30'

**Pennoni Associates Inc.** 2041 AVENUE C, SUITE 100, BETHLEHEM, PA 18017  
 Engineers • Surveyors • Planners • Landscape Architects  
 (610) 231-0600 FAX: (610) 231-2033



DATE	NO.	REVISIONS	BY

ALL DIMENSIONS MUST BE VERIFIED BY THE FIELD. NOTIFY PENNONI ASSOCIATES OF ANY DISCREPANCIES BEFORE PROCEEDING WITH THE WORK.

**PORTSMOUTH NAVAL SHIPYARD**  
 KITTERY, MAINE  
**TOP OF ROCK CONTOUR PLAN**  
**EWING COLE ARCHITECTS**  
 FEDERAL RESERVE BANK BUILDING, 100 N 6TH STREET  
 PHILADELPHIA, PA 19106-4580

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JOB NUMBER	ECCF 1003
	1 OF 1

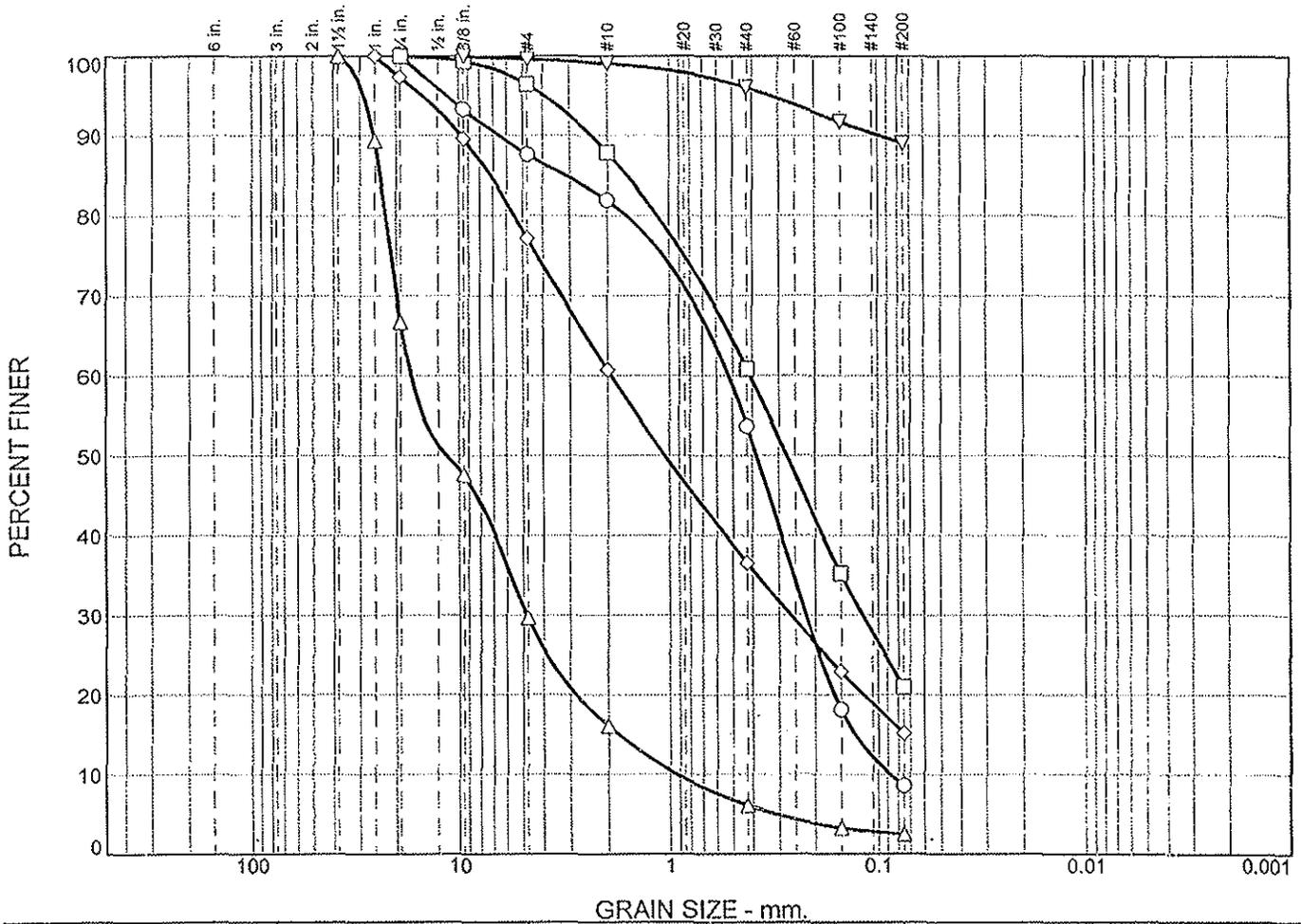
SCALE	1"=30'	DRAWING NO.	TOR-1
DRAWN BY	JDT		
DATE	01/04/11		
APPROVED			

**APPENDIX B**  
**Laboratory Data**





# Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

MATERIAL DATA					
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	GTB-106	S-2	2-4'	FM SAND, LITTLE F GRAVEL, TRACE SILT	SP-SM
□	GTB-106	S-5	8-10'	FNC SAND, SOME SILT, TRACE F GRAVEL	SM
△	GTB-109	S-1	0.5-2'	FC GRAVEL, SOME CMF SAND, TRACE SILT	GW
◇	GTB-109	S-3	4-6'	MFC SAND, SOME FC GRAVEL, LITTLE SILT	SM
▽	GTB-109	S-7	19-21'	SILT, LITTLE FM SAND	

<b>PENNONI ASSOCIATES INC.</b>  Bethlehem, PA	Client: Ewing Cole Architects Project: Structural Shops Add'n PNSY Kittery ME  Project No.: ECCF 1003.01
Figure S-2	



## LABORATORY TESTING PROCEDURES

All testing is either done in accordance with the indicated ASTM Designation-latest edition, or with other standard or generally accepted engineering practice as described:

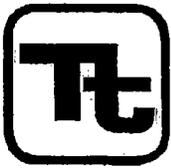
1. Consolidation Test of Soils  
Preparation of samples and testing procedures generally follow the methods described in Lambe, op. Cit. In addition, the time of loading may be selected on the basis of:
  - a. Controlled rate of percent of consolidation
  - b. Controlled pore pressure gradient
  - c. Controlled strain

The method of test is selected to suit the soil type in question and the test is conducted in accordance with generally accepted engineering practice.
2. Atterberg Limits – Plasticity Indices
  - a. Liquid limit of soils, ASTM D 4318
  - b. Plastic limit and plasticity index of soils, ASTM D 4318
  - c. Shrinkage factors of soils, ASTM D 427

(Moisture content is also determined with the Atterberg Limit test, and liquidity index is also computed)
3. Moisture Content of Soil  
ASTM D 2216
4. Particle Size Analysis of Soils  
ASTM D 421, Dry preparation of soil samples;  
ASTM D 422, Sieve and/or hydrometer analysis.
5. Triaxial Compression Test of Soils  
Sample preparation, apparatus, and testing generally follow the procedures outlined in Soil Testing for Engineers, T.W. Lambe, John Wiley & Sons, Inc., New York, 1951 and in The Measurement of Soil Properties in the Triaxial Test, Alan W. Bishop & D.J. Henkel, 2<sup>nd</sup> Edition, St. Martin's Press, New York, 1962
6. Unconfined Compression Strength of Cohesive Soil  
ASTM D 2166
7. Specific Gravity of Soils  
ASTM D 854
8. Unit Weight Determination of Soils  
See ASTM D 2166 for preparation of specimen except that sample size may differ. For moisture content see ASTM D 2216.
9. Visual Identification of Soil Samples  
All soil samples are visually identified and/or classified. The classification system used is shown in Table L-1.
10. Identification of Rock  
Rock core samples are identified by the character and appearance of newly fractured surfaces of unweathered pieces, by core conditions and characteristics, and by the determination of simple physical and chemical properties.
11. Compaction Test of Soils
  - a. Moisture-density relations of soils using 5.5 lb. hammer and 12 in. drop, ASTM D 698
  - b. Moisture-density relations of soils using 10 lb. hammer and 18 in. drop, ASTM D 1557
12. Maximum and Minimum Densities of Granular Soils  
Testing procedures follow D.M. Burmeister, "Suggested Method of Test for Maximum and Minimum Densities of Granular Soils" cited in Proceedings for Testing Soils, Fourth Edition, ASTM, Philadelphia. 1964, pp 175-177.
13. Bearing Ratio of Laboratory Compacted Soils  
ASTM D 1883 (Sometimes called California Bearing Ratio or CBR)
14. Organic Content  
A modified dichromate oxidation method using ferrous ammonium sulfate is employed in determining the percent of organic matter in soil.

**APPENDIX B**

**FIELD DOCUMENTATION FORMS**



**TETRA TECH**  
**FIELD TASK MODIFICATION REQUEST FORM**

Project/Installation Name \_\_\_\_\_ CTO & Project Number \_\_\_\_\_ Task Mod. Number \_\_\_\_\_

Modification To (e.g. Work Plan) \_\_\_\_\_ Site/Sample Location \_\_\_\_\_ Date \_\_\_\_\_

Activity Description: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Reason for Change: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Recommended Disposition: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Field Operations Leader (Signature) \_\_\_\_\_ Date \_\_\_\_\_

Approved Disposition: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Project/Task Order Manager (Signature) \_\_\_\_\_ Date \_\_\_\_\_

Distribution:

Program/Project File – \_\_\_\_\_  
Project/Task Order Manager – \_\_\_\_\_  
Field Operations Leader – \_\_\_\_\_

Other: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_







Tetra Tech

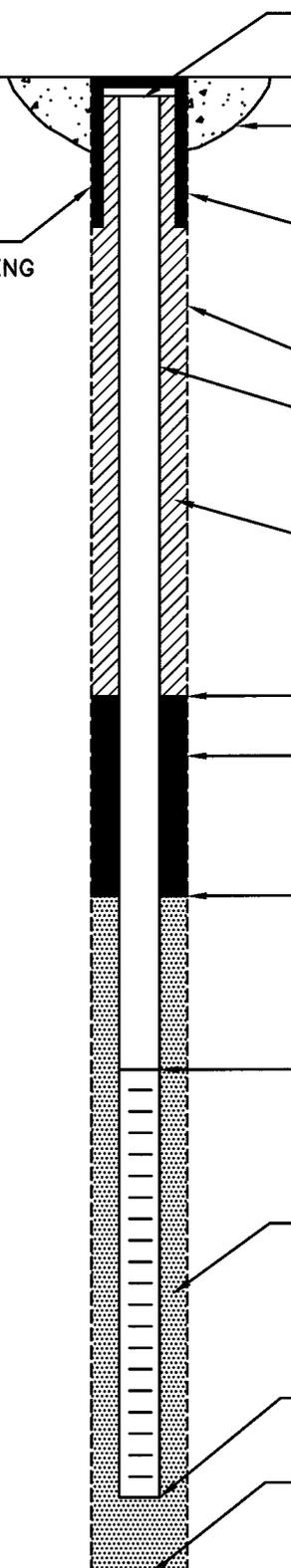
# OVERBURDEN MONITORING WELL SHEET FLUSH - MOUNT

WELL NO.: \_\_\_\_\_

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
DATE BEGUN _____	DATE COMPLETED _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		
GROUND ELEVATION _____	DATUM _____	

ACAD: FORM\_MWFM.dwg 07/20/99 INL

FLUSH MOUNT  
SURFACE CASING  
WITH LOCK



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: \_\_\_\_\_

ELEVATION/DEPTH TOP OF SEAL: \_\_\_\_\_ / \_\_\_\_\_

TYPE OF SEAL: \_\_\_\_\_

ELEVATION/DEPTH TOP OF SAND: \_\_\_\_\_ / \_\_\_\_\_

ELEVATION/DEPTH TOP OF SCREEN: \_\_\_\_\_ / \_\_\_\_\_

TYPE OF SCREEN: \_\_\_\_\_

SLOT SIZE x LENGTH: \_\_\_\_\_

TYPE OF SAND PACK: \_\_\_\_\_

DIAMETER OF HOLE IN BEDROCK: \_\_\_\_\_

ELEVATION / DEPTH BOTTOM OF SCREEN: \_\_\_\_\_ / \_\_\_\_\_

ELEVATION / DEPTH BOTTOM OF SAND: \_\_\_\_\_ / \_\_\_\_\_

ELEVATION/DEPTH BOTTOM OF HOLE: \_\_\_\_\_ / \_\_\_\_\_

BACKFILL MATERIAL BELOW SAND: \_\_\_\_\_









# SOIL & SEDIMENT SAMPLE LOG SHEET

Project Site Name: _____	Sample ID No.: _____
Project No.: _____	Sample Location: _____
<input type="checkbox"/> Surface Soil	Sampled By: _____
<input type="checkbox"/> Subsurface Soil	C.O.C. No.: _____
<input type="checkbox"/> Sediment	Type of Sample:
<input type="checkbox"/> Other: _____	<input type="checkbox"/> Low Concentration
<input type="checkbox"/> QA Sample Type: _____	<input type="checkbox"/> 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:**

Large empty box for observations and notes.

**MAP:**

Large empty box for map.

**Circle if Applicable:**

MS/MSD	Duplicate ID No.:
--------	-------------------

Signature(s):





# QA SAMPLE LOG SHEET

Project Site Name: \_\_\_\_\_ Sample ID Number: \_\_\_\_\_  
 Project Number: \_\_\_\_\_ Sampled By: \_\_\_\_\_  
 Sample Location: \_\_\_\_\_ C.O.C. Number: \_\_\_\_\_  
 QA Sample Type: \_\_\_\_\_  
 Trip Blank  Rinsate Blank  
 Source Water Blank  Other Blank \_\_\_\_\_

SAMPLING DATA:	WATER SOURCE:
----------------	---------------

Date: _____ Time: _____ Method: _____	<input type="checkbox"/> Laboratory Prepared <input type="checkbox"/> Tap <input type="checkbox"/> Purchased <input type="checkbox"/> Fire Hydrant <input type="checkbox"/> Other _____
---	---

PURCHASED WATER INFORMATION (If Applicable as Source or Rinsate Water):	RINSATE INFORMATION (If Applicable):
--	---

Product Name: _____ Supplier: _____ Manufacturer: _____ Order Number: _____ Lot Number: _____ Expiration Date: _____	Media Type: _____ Equipment Used: _____ Equipment Type: <input type="checkbox"/> Dedicated <input type="checkbox"/> Reusable
---	--

SAMPLE COLLECTION INFORMATION:			
--------------------------------	--	--	--

Analysis	Preservative	Container Requirements	Collected
Volatiles	Cool 4°C & HCl		YES / NO
Semivolatiles	Cool 4°C		YES / NO
Pesticide / PCB	Cool 4°C		YES / NO
Metals	Cool 4°C & HNO <sub>3</sub>		YES / NO
Cyanide	Cool 4°C & NaOH		YES / NO

OBSERVATIONS / NOTES:
-----------------------

	<b>Signature(s):</b> _____ _____
--	--

# CHAIN OF CUSTODY RECORD

PROJECT NO.:					SITE NAME:					NO. OF CON- TAINERS	REMARKS				
SAMPLERS (SIGNATURE):															
STATION NO.	DATE	TIME	COMP	GRAB	STATION LOCATION										
RELINQUISHED BY (SIGNATURE):			DATE / TIME:		RECEIVED BY(SIGNATURE):			RELINQUISHED BY (SIGNATURE):			DATE / TIME:		RECEIVED BY(SIGNATURE):		
RELINQUISHED BY (SIGNATURE):			DATE / TIME:		RECEIVED BY (SIGNATURE):			RELINQUISHED BY (SIGNATURE):			DATE / TIME:		RECEIVED BY(SIGNATURE):		
RELINQUISHED BY (SIGNATURE):			DATE / TIME:		RECEIVED FOR LABORATORY BY (SIGNATURE):			DATE / TIME:		REMARKS:					

# Tetra Tech

PROJECT: \_\_\_\_\_  
 LOCATION: \_\_\_\_\_  
 PROJECT MANAGER: \_\_\_\_\_

JOB #: \_\_\_\_\_  
 DATE: \_\_\_\_\_  
 FOL: \_\_\_\_\_

<b>DAILY ACTIVITIES CHECKLIST</b>			
<b>Startup Checklist</b>			
<b>Activity</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>
Pertinent site activities/information entered into site logbook			
All onsite personnel listed in logbook			
Required medical information onsite for all workers (Tetra Tech and Subcontractors)			
Required MSDS's onsite			
Proper equipment calibrations performed (list equipment)			
1 _____			
2 _____			
3 _____			
4 _____			
Calibration logs filled out			
Tailgate H&S meeting held prior to beginning field activities			
Required work permits filled out/signed			
Required utility clearances obtained			
Required PPE onsite and in use			
Information required to be posted is in place (OSHA poster, hospital route, key phone numbers, etc.)			
<b>Exit Checklist</b>			
<b>Activity</b>	<b>Yes</b>	<b>No</b>	<b>N/A</b>
Logbooks completely and comprehensively filled out			
Field forms complete and accounted for/properly filed			
Samples properly packaged/shipped			
COCs faxed to appropriate in-house personnel			
All equipment accounted for, on charge if needed, and properly secured			
All personnel accounted for			
Arrangements made for upcoming work (permits, clearances, equipment, etc.)			
Site properly secured			

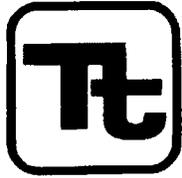
Note - not all items listed apply to every job, and some additional requirements may apply on a job-specific basis.





## **APPENDIX C**

### **FIELD STANDARD OPERATING PROCEDURES**



TETRA TECH

# STANDARD OPERATING PROCEDURES

Number	CT-04	Page	1 of 7
Effective Date	01/2012	Revision	3
Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
SAMPLE NOMENCLATURE

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## 1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) 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 database sample numbers)
- Accommodation of all project-specific requirements
- Accommodation of laboratory sample number length constraints (maximum of 20 characters)

## 2.0 SCOPE

The methods described in this SOP shall be used consistently for all projects requiring electronic data. Other contract- or project-specific sample nomenclature requirements may also be applicable.

## 3.0 GLOSSARY

None.

## 4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

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

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

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

General personnel qualifications for sample nomenclature activities in the field include the following:

- Occupational Safety and Health Administration (OSHA) 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate procedures for field documentation, handling, packaging, and shipping.

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## 5.0 PROCEDURES

### 5.1 INTRODUCTION

The sample identification (ID) system can consist of as few as eight but not more than 20 distinct alphanumeric characters. The sample ID will be provided to the laboratory on the sample labels and chain-of-custody forms. The basic sample ID provided to the laboratory has three segments and shall be as follows, where "A" indicates "alpha," and "N" indicates "numeric":

<b>A or N</b> <b>3 or 4 Characters</b>	<b>AAA</b> <b>2 or 3 Characters</b>	<b>A or N</b> <b>3 to 6 Characters</b>
Site Identifier	Sample Type	Sample Location

Additional segments may be added as needed. For example:

- (1) Soil and sediment sample ID

<b>A or N</b> <b>3 or 4 Characters</b>	<b>AAA</b> <b>2 or 3 Characters</b>	<b>A or N</b> <b>3 to 6 Characters</b>	<b>NNNN</b> <b>4 Characters</b>
Site identifier	Sample type	Sample location	Sample depth

- (2) Aqueous (groundwater or surface water) sample ID

<b>A or N</b> <b>3 or 4 Characters</b>	<b>AAA</b> <b>2 or 3 Characters</b>	<b>A or N</b> <b>3 to 6 Characters</b>	<b>NN</b> <b>2 Characters</b>	<b>-A</b> <b>1 Character</b>
Site identifier	Sample type	Sample location	Round number	Filtered sample only

- (3) Biota sample ID

<b>A or N</b> <b>3 or 4 Characters</b>	<b>AAA</b> <b>2 or 3 Characters</b>	<b>A or N</b> <b>3 to 6 Characters</b>	<b>AA</b> <b>2 Characters</b>	<b>NNN</b> <b>3 Characters</b>
Site identifier	Sample type	Sample location	Species identifier	Sample group number

### 5.2 SAMPLE IDENTIFICATION FIELD REQUIREMENTS

The various fields in the sample ID include but are not limited to the following:

- Site identifier
- Sample type
- Sample location
- Sample depth
- Sampling round number
- Filtered
- Species identifier
- Sample group number

The site identifier must be a three- or four-character field (numeric characters, alpha characters, or a mixture of alpha and numeric characters may be used). A site number is necessary because many

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facilities/sites have multiple individual sites, Solid Waste Management Units (SWMUs), Operable Units (OUs), etc. Several examples are presented in Section 5.3 of this SOP.

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

The sample location must be at least a three-character field but may have up to six characters (alpha, numeric, or a mixture). The six characters may be useful in identifying a monitoring well to be sampled or describing a grid location.

The sample depth field is used to note the depth below ground surface (bgs) at which a soil or sediment sample is collected. The first two numbers of the four-number code specify the top interval, and the third and fourth specify the bottom interval in feet bgs of the sample. If the sample depth is equal to or greater than 100, then only the top interval would be represented and the sampling depth would be truncated to three characters. The depths will be noted in whole numbers only; further detail, if needed, will be recorded on the sample log sheet or boring log, in the logbook, etc.

A two-digit round number will be used to track the number of aqueous samples collected from a particular aqueous sample location. The first sample collected from a location will be assigned the round identifier 01, the second 02, etc. This applies to both existing and proposed monitoring wells and surface water locations.

Aqueous samples that are field filtered (dissolved analysis) will be identified with an "-F" in the last field segment. No entry in this segment signifies an unfiltered (total) sample.

The species identifier must be a two-character alpha field. Several suggested codes are provided in Section 5.3 of this SOP.

The three-digit sample group number will be used to track the number of biota sample groups (a particular group size may be determined by sample technique, media type, the number of individual caught, weight issues, time, etc.) by species and location. The first sample group of a particular species collected from a given location will be assigned the sample group number 001, and the second sample group of the same species collected from the same location will be assigned the sample group number 002.

### 5.3 EXAMPLE SAMPLE FIELD DESIGNATIONS

Examples of each of the fields are as follows:

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

- A01 - Area of Concern (AOC) 1
- 125 - SWMU 125
- 000 - Base- or facility-wide sample (e.g., upgradient well)
- BBG - Base background

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

Sample type - Examples of sample types are as follows:

- AH - Ash Sample
- AS - Air Sample
- BM - Building Material Sample

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- BSB - Biota Sample Full Body
- BSF - Biota Sample Fillet
- CP - Composite Sample
- CS - Chip Sample
- DS - Drum Sample
- DU - Dust Sample
- FP - Free Product
- IDW - Investigation-Derived Waste Sample
- LT - Leachate Sample
- MW - Monitoring Well Groundwater Sample
- OF - Outfall Sample
- RW - Residential Well Sample
- SB - Soil Boring Sample
- SD - Sediment Sample
- SC - Scrape Sample
- SG - Soil Gas Sample
- SL - Sludge Sample
- SP - Seep Sample
- SS - Surface Soil Sample
- ST - Storm Sewer Water Sample
- SW - Surface Water Sample
- TP - Test Pit Sample
- TW - Temporary Well Sample
- WC - Well Construction Material Sample
- WP - Wipe Sample
- WS - Waste/Solid Sample
- WW - Wastewater Sample

Sample location - Examples of the location field are as follows:

- 001 - Monitoring well 1
- N32E92 - Grid location 32 North and 92 East
- D096 - Investigation-derived waste drum number 96

Species identifier - Examples of species identifier are as follows:

- BC - Blue Crab
- GB - Blue Gill
- CO - Corn
- SB - Soybean

#### 5.4 **EXAMPLES OF SAMPLE NOMENCLATURE**

The first round monitoring well groundwater sample collected from existing monitoring well 001 at SWMU 16 for a filtered sample would be designated as 016MW00101-F.

The second round monitoring well groundwater sample collected from existing monitoring well C20P2 at Site 23 for an unfiltered sample would be designated as 023MWC20P202.

The second surface water sample collected from point 01 at SWMU 130 for an unfiltered sample would be designated as 130SW00102.

A surface soil sample collected from grid location 32 North and 92 East at Site 32 at the 0- to 2-foot

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interval would be designated as 032SSN32E920002.

A subsurface soil sample from soil boring 03 at SWMU 32 at an interval of 4 to 5 feet bgs would be designated as 032SB0030405.

A sediment sample collected at SWMU 19 from 0 to 6 inches at location 14 would be designated as 019SD0140001. The sample data sheet would reflect the precise depth at which this sample was collected.

During biota sampling for full-body analysis, the first time a minnow trap was checked at grid location A25 of SWMU 1415, three small blue gills were captured, collected, and designated with the sample ID of 1415BSBA25BG001. The second time blue gill were collected at the same location (grid location A25 at SWMU 1415), the sample ID would be 1415BSBA25BG002.

Note: No dash (-) or spacing is used between the segments with the exception of the filtered segment. The "F" used for a filtered aqueous sample is preceded by a dash (-F).

### 5.5 FIELD QA/QC SAMPLE NOMENCLATURE

Field Quality Assurance (QA)/Quality Control (QC) samples are designated using a different coding system. The QC code will consist of a three- to four-segment alpha-numeric code that identifies the sample QC type, the date the sample was collected, and the number of this type of QC sample collected on that date.

AA	NNNNNN	NN	-F
QC type	Date	Sequence number (per day)	Filtered (aqueous only, if needed)

The QC types are identified as:

TB = Trip Blank  
 RB = Rinsate Blank (Equipment Blank)  
 FD = Field Duplicate  
 AB = Ambient Conditions Blank  
 WB = Source Water Blank

The sampling time recorded on the chain-of-custody form, labels, and tags for duplicate samples will be 0000 so that the samples are "blind" to the laboratory. Notes detailing the sample number, time, date, and type will be recorded on the routine sample log sheets and will document the location of the duplicate sample (sample log sheets are not provided to the laboratory). Documentation for all other QC types (TB, RB, AB, and WB) will be recorded on the QC Sample Log Sheet (see SOP SA-6.3, Field Documentation).

### 5.6 EXAMPLES OF FIELD QA/QC SAMPLE NOMENCLATURE

The first duplicate of the day for a filtered groundwater sample collected on June 3, 2000, would be designated as FD06030001-F.

The third duplicate of the day taken of a subsurface soil sample collected on November 17, 2003, would be designated as FD11170303.

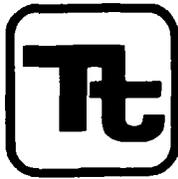
The first trip blank associated with samples collected on October 12, 2000, would be designated as TB10120001.

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The only rinsate blank collected on November 17, 2001, would be designated as RB11170101.

## **6.0 DEVIATIONS**

Any deviation from this SOP must be addressed in detail in the site-specific planning documents.



TETRA TECH

# STANDARD OPERATING PROCEDURES

Number CT-05	Page 1 of 7
Effective Date 01/2012	Revision 3
Applicability Tetra Tech, Inc.	
Prepared Management Information Systems Department	

Subject  
DATABASE RECORDS AND QUALITY ASSURANCE

Approved  
J. Zimmerly

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## 1.0 PURPOSE

The purpose of this document is to specify a consistent procedure for the quality assurance review of electronic and hard copy databases. This SOP outlines the requirements for establishment of a Database Record File, Quality Assurance review procedures, and documentation of the Quality Assurance Review Process.

## 2.0 SCOPE

The methods described in this Standard Operating Procedure (SOP) shall be used consistently for all projects managed by Tetra Tech.

## 3.0 GLOSSARY

Chain-of-Custody Form - A Chain-of-Custody Form is a printed form that accompanies a sample or a group of samples from the time of sample collection to the laboratory. The Chain-of-Custody Form is retained with the samples during transfer of samples from one custodian to another. The Chain-of-Custody Form is a controlled document that becomes part of the permanent project file. Chain-of-Custody and field documentation requirements are addressed in SOP SA-6.1.

Electronic Database - A database provided on a compact laser disk (CD). Such electronic databases will generally be prepared using public domain software such as DBase, RBase, Oracle, Visual FoxPro, Microsoft Access, Paradox, etc.

Hardcopy Database - A printed copy of a database prepared using the software discussed under the definition of an electronic database.

Form I - A printed copy of the analytical results for each sample.

Sample Tracking Summary - A printed record of sample information including the date the samples were collected, the number of samples collected, the sample matrix, the laboratory to which the samples were shipped, the associated analytical requirements for the samples, the date the analytical data were received from the laboratory, and the date that validation of the sample data was completed.

## 4.0 RESPONSIBILITIES

Database Records Custodian - It shall be the responsibility of the Database Records Custodian to update and file the Sample Tracking Summaries for all active projects on a weekly basis. It shall be the responsibility of the Database Records Custodian to ensure that the most recent copies of the Sample Tracking Summaries are placed in the Database Records file. It shall be the responsibility of the Database Records Custodian to ensure that a copy of all validation deliverables is provided to the Project Manager (for placement in the project file). It shall be the responsibility of the Database Records Custodian to ensure that photocopies of all validation deliverables and historical data and reports (as applicable) are placed in the Database Records file.

Data Validation Coordinator - It shall be the responsibility of the Data Validation Coordinator (or designee) to ensure that the Sample Tracking Summaries are maintained by the Database Records Custodian. It shall be the responsibility of the Data Validation Coordinator (or designee) to ensure that photocopies of all data validation deliverables are placed in the applicable Database Records file by the Database Records Custodian.

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**Earth Sciences Department Manager** - It shall be the responsibility of the Earth Sciences Department Manager (or equivalent) to ensure that all field personnel are familiar with the requirements of this Standard Operating Procedure (specifically Section 5.5).

**FOL** - It shall be the responsibility of the FOL (FOL) of each project to ensure that all field technicians or sampling personnel are thoroughly familiar with this SOP, specifically regarding provision of the Chain-of-Custody Forms to the Database Records Custodian. Other responsibilities of the FOL are described in Sections 5.4 and 5.5.

**Management Information Systems (MIS) Manager** - It shall be the responsibility of the MIS Manager to ensure that copies of original electronic deliverables (CDs) are placed in both the project files and the Database Records File. It shall be the responsibility of the MIS Manager (or designee) to verify the completeness of the database (presence of all samples) in both electronic and hardcopy form in the Database Records File. It shall be the responsibility of the MIS Manager to ensure that Quality Assurance Reviews are completed and are attested to by Quality Assurance Reviewers. It shall be the responsibility of the MIS Manager to ensure that records of the Quality Assurance review process are placed in the Database Records File. It shall be the responsibility of the MIS Manager to ensure that both electronic and hardcopy forms of the final database are placed in both the project and the Database Record File. It shall be the responsibility of the MIS Manager to ensure that data validation qualifiers are entered in the database.

Furthermore, it shall be the responsibility of the MIS Manager to participate in project planning at the request of the Project Manager, specifically with respect to the generation of level of effort and schedule estimates. To support the project planning effort, the MIS Manager shall provide a copy of the MIS Request Form included as Attachment A to the project manager. It shall be the responsibility of the MIS Manager to generate level of effort and budget estimates at the time database support is requested if a budget does not exist at the time of the request. The MIS Request Form shall be provided to the Project Manager at the time of any such requests. It shall be the responsibility of the MIS Manager to notify the Project Manager of any anticipated level of effort overruns or schedule noncompliances as soon as such problems arise along with full justification for any deviations from the budget estimates (provided they were generated by the MIS Manager). It shall be the responsibility of the MIS Manager to document any changes to the scope of work dictated by the Project Manager, along with an estimate of the impact of the change on the level of effort and the schedule.

**Program/Department Managers** - It shall be the responsibility of the Department and/or Program Managers (or designees) to inform their respective department's Project Managers of the existence and requirements of this SOP.

**Project Manager** - It shall be the responsibility of each Project Manager to determine the applicability of this SOP 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 FOL is familiar with the requirements regarding Chain-of-Custody Form provision to the Database Records Custodian. It shall be the responsibility of the Project Manager (or designee) to determine which, if any, historical data are relevant and to ensure that such data (including all relevant information such as originating entity, sample locations, sampling dates, etc.) are provided to the Database Records Custodian for inclusion in the Database Records File. It shall be the responsibility of the Project Manager to obtain project planning input regarding the level of effort and schedule from the MIS Manager. It shall be the responsibility of the Project Manager to complete the database checklist (Attachment A) to support the level of effort and schedule estimate and to facilitate database preparation and subroutine execution.

**Risk Assessment Department Manager** - It shall be the responsibility of the Risk Assessment Department Manager to monitor compliance with this Standard Operating Procedure, to modify this SOP as necessary, and to take corrective action if necessary. Monitoring of the process shall be completed on a quarterly basis.

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**Quality Assurance Reviewers** - It shall be the responsibility of the Quality Assurance Reviewers to verify the completeness of the sample results via review of the Chain-of-Custody Forms and Sample Tracking Summaries. It shall be the responsibility of the Quality Assurance Reviewers to ensure the correctness of the database via direct comparison of the hardcopy printout of the database and the hardcopy summaries of the original analytical data (e.g., Form Is provided in data validation deliverables). Correctness includes the presence of all relevant sample information (all sample information fields), agreement of the laboratory and database analytical results, and the presence of data validation qualifiers.

**Quality Manager** - It shall be the responsibility of the Quality Manager to monitor compliance with this Standard Operating Procedure via routine audits.

## 5.0 PROCEDURES

### 5.1 Introduction

Verification of the accuracy and completeness of an electronic database can only be accomplished via comparison of a hardcopy of the database with hardcopy of all relevant sample information. The primary purposes of this SOP are to ensure that 1) all necessary hardcopy information is readily available to Quality Assurance Reviewers; 2) ensure that the Quality Assurance review is completed in a consistent and comprehensive manner, and; 3) ensure that documentation of the Quality Assurance review process is maintained in the project file.

### 5.2 File Establishment

A Database Record file shall be established for a specific project at the discretion of the Project Manager. Initiation of the filing procedure will commence upon receipt of the first set of Chain-of-Custody documents from a FOL or sampling technician. The Database Record Custodian shall establish a project-specific file for placement in the Database Record File. Each file in the Database Record File shall consist of standard components placed in the file as the project progresses. Each file shall be clearly labeled with the project number, which shall be placed on the front of the file drawer and on each and every hanging file folder relevant to the project. The following constitute the minimum components of a completed file:

- Electronic Deliverables
- Sample Tracking Forms
- Chain-of-Custody Forms
- Data Validation Letters
- Quality Assurance Records

### 5.3 Electronic Deliverables

The format of electronic deliverables shall be specified in the laboratory procurement specification and shall be provided by the laboratory. The integrity of all original electronic data deliverables shall be maintained. This shall be accomplished via the generation of copies of each electronic deliverable provided by the laboratory. The original electronic deliverable shall be provided to the project manager for inclusion in the project file. A copy of the original electronic deliverable shall be placed in the Database Record File. The second copy shall be maintained by the MIS Manager (or designee) to be used as a working copy.

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#### **5.4 Sample Tracking Forms**

Updated versions of the sample tracking form for each relevant project shall be maintained by the Database Record Custodian. The Sample Tracking Forms shall be updated any time additional Chain-of-Custody Forms are received from a FOL or sampling technician, or at any time that data are received from a laboratory, or at any time that validation of a given data package (sample delivery group) is completed. The Data Validation Coordinator shall inform the Database Record Custodian of the receipt of any data packages from the laboratory and of completion of validation of a given data package to facilitate updating of the Sample Tracking Form. The Database Record Custodian shall place a revised copy of the Sample Tracking Form in the Database Record File anytime it has been updated. Copies of the updated Sample Tracking Form shall also be provided to the project manager to apprise the project manager of sample package receipt, completion of validation, etc.

#### **5.5 Chain-of-Custody Forms**

The Chain-of-Custody Forms for all sampling efforts will be used as the basis for (1) updating the Sample Tracking Form, and (2) confirming that all required samples and associated analyses have been completed. It shall be the responsibility of the FOL (or sample technician) to provide a photocopy of all Chain-of-Custody Forms to the Database Record Custodian immediately upon completion of a sampling effort. The Database Record Custodian shall then place the copies of the Chain-of-Custody Form(s) in the Database Record File. Upon receipt of a sample data package from an analytical laboratory, the Data Validation Coordinator shall provide a copy of the laboratory Chain-of-Custody Form to the Database Record Custodian. The Database Record Custodian shall use this copy to update the Sample Tracking Summary and shall place the copy of the laboratory-provided Chain-of-Custody Form in the Database Record File. The photocopy of the laboratory-provided Chain-of-Custody Form shall be stapled to the previously filed field copy. Upon receipt of all analytical data, two copies of the Chain-of-Custody will therefore be in the file. Review of the Chain-of-Custody Forms will therefore be a simple mechanism to determine if all data have been received. Chain-of-Custody is addressed in SOP SA-6.1.

#### **5.6 Data Validation Letters**

All data validation deliverables (or raw data summaries if validation is not conducted) shall be provided for inclusion in both the Database Record File and the project file. If USEPA regional- or client-specific requirements are such that Form Is (or similar analytical results) need not be provided with the validation deliverable, copies of such results must be appended to the deliverable. It is preferable, although not essential that the validation qualifiers be hand-written directly on the data summary forms. The data validation deliverables (and attendant analytical summaries) will provide the basis for direct comparison of the database printout and the raw data and qualifiers.

#### **5.7 Historical Data**

At the direction of the Project Manager, historical data may also be included in a project-specific analytical database. In the event that historical data are germane to the project, hardcopy of the historical data must be included in the Database Record File. Historical data may be maintained in the form of final reports or as raw data. The information contained in the historical data file must be sufficient to identify its origin, its collection date, the sample location, the matrix, and any and all other pertinent information. All available analytical data, Chain-of-Custody Forms, boring logs, well construction logs, sample location maps, shall be photocopied by the Project Manager (or designee) and placed in one or more 3-ring binders. All information shall be organized chronologically by matrix. It shall be the responsibility of the Project Manager (or designee) to ensure that all inconsistencies between analytical data, Chain-of-Custody Forms, boring logs, sample log sheets, and field logbooks are identified and corrected. The Project Manager (or designee) shall decide which nomenclature is appropriate and edit, initial and date all

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relevant forms. Data entry may only be performed on information that has undergone the aforementioned editing process, thereby having a direct correlation between hardcopy information and what will become the electronic database.

## 6.0 RECORDS

Records regarding database preparation and quality assurance review include all those identified in the previous section. Upon completion of the database task, records from the file will be forwarded to the Project Manager for inclusion in the project file, or will be placed in bankers boxes (or equivalent) for storage. The final records for storage shall include the following minimum information on placards placed on both the top and end of the storage box:

Database Record File  
PROJECT NUMBER: \_\_\_\_\_  
SITE NAME: \_\_\_\_\_  
DATE FILED: \_\_/\_\_/\_\_\_\_  
SUMMARY OF CONTENTS ENCLOSED  
BOX \_ OF \_

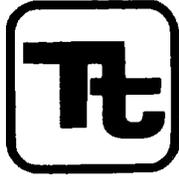
Project- or program-specific record keeping requirements shall take precedence over the record keeping requirements of this SOP.

**ATTACHMENT A**



**MIS REQUEST FORM**

<b>Project Name:</b> _____	<b>Request Date:</b> _____
<b>CTO:</b> _____	<b>Date Data Available for Production:</b> _____
<b>Project Manager:</b> _____	<b>Request in Support of:</b> _____
<b>Requestor:</b> _____	<b>Database Lead:</b> _____
<b>Program/Client:</b> _____	<b>GIS Lead:</b> _____
<b>State/EPA Region:</b> _____	<b>Statistics Lead:</b> _____
	<b>Risk Lead:</b> _____
<b>Site Name(s) (Area, OU, etc.):</b> _____	
<b>Sampling Date(s):</b> _____	
<b>Matrix:</b> <input type="checkbox"/> GW <input type="checkbox"/> SO <input type="checkbox"/> SD <input type="checkbox"/> SW <input type="checkbox"/> Other: _____	
<b>Labels:</b> <input type="checkbox"/> Labels needed for an upcoming sampling event    _____ Total # of Samples	
Estimated Hours _____	Additional Instructions: _____
Due Date _____	
Complete ETS Charge No. _____	
FOL _____	
<b>Data Entry:</b>	
<input type="checkbox"/> Chemical data needs to be entered from hardcopy    _____ Estimated # of Samples	
<input type="checkbox"/> Chemical data needs to be formatted electronically	
<input type="checkbox"/> Field analytical data needs to be entered from hardcopy	
<input type="checkbox"/> Geologic data needs to be entered from hardcopy	
<input type="checkbox"/> Hydrology data needs to be entered from hardcopy	
Estimated Hours _____	Additional Instructions: _____
Due Date _____	
Complete ETS Charge No. _____	
<b>Tables:</b>	
<input type="checkbox"/> Full Data Printout	
<input type="checkbox"/> Summary of Positive Hits	
<input type="checkbox"/> Occurrence and Distribution <input type="checkbox"/> with criteria	
<input type="checkbox"/> Sampling Analytical Summary	
<input type="checkbox"/> Other: _____	
Estimated Hours _____	Additional Instructions: _____
Due Date _____	
Complete ETS Charge No. _____	
<b>GIS:</b>	
<input type="checkbox"/> General Facility Location	
<input type="checkbox"/> Site Location	
<input type="checkbox"/> Potentiometric Contours/Groundwater Flow	
<input type="checkbox"/> Sample Location Proposed	
<input type="checkbox"/> Sample Location Existing	
<input type="checkbox"/> Tag Map Single Round	
<input type="checkbox"/> Tag Map Multiple Round	
<input type="checkbox"/> Isoconcentrations	
<input type="checkbox"/> Chart Map	
<input type="checkbox"/> 3D Visualization	
<input type="checkbox"/> EGIS CD	
<input type="checkbox"/> Other: _____	
Estimated Hours _____	Additional Instructions: _____
Due Date _____	
Complete ETS Charge No. _____	
<b>Statistics:</b> <input type="checkbox"/> Yes	
Estimated Hours _____	Additional Instructions: _____
Due Date _____	
Complete ETS Charge No. _____	
<b>Geostatistics:</b> <input type="checkbox"/> Yes	
Estimated Hours _____	Additional Instructions: _____
Due Date _____	
Complete ETS Charge No. _____	



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject EVALUATION OF EXISTING MONITORING WELLS AND WATER LEVEL MEASUREMENT

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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.

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**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, past sampling dates, 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 and condition of dedicated sampling equipment.
- The presence of a survey mark on the inner 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.

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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) 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 and/or the well has not been sampled in 12 or more months, it 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.

See Attachment A, Monitoring Well Inspection Sheet.

### **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 B), 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. To be useful, the

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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, 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 pressure transducer.

### 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 B):
  - Well number.
  - Water level (to the nearest 0.01 foot). 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.
  - Thickness of free product if present.

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.

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### 5.3.4 Water Level Measuring Devices

#### Electric Water Level Indicators

These are the most commonly used devices and 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 adjacent to the survey mark on the inner well casing. The electric tape is read (to the nearest 0.01 ft.) at the measuring point and recorded where contact with the water surface was indicated.

#### 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.

#### 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.

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### 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 B). 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 and SA-7.1 Decontamination of Field Equipment.

### 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 or FID 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.

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**ATTACHMENT A  
MONITORING WELL INSPECTION SHEET**

**Monitoring Well Inspection Sheet**

Project Name: \_\_\_\_\_ Date: \_\_\_\_\_  
 Location: \_\_\_\_\_ Time: \_\_\_\_\_  
 Tidally Influenced: Y / N Personnel: \_\_\_\_\_

Field Measurements				
Well ID	PID Reading PPM	Depth to Water *	Total Depth *	Flush Mt./ Stick-up

Well Construction Details (Taken from construction logs)		
Total Depth *	Ground Elev.	Top/Btm Screen *

**Check List:**

Riser Pipe Material:
Riser Notched for Surveyors:
Well ID Tag In-place:
Well security:
Photo taken:

**Condition of Well:**

Protective Case:
Riser:
Well Pad:
Other:

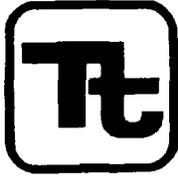
**Presence/Evidence of:**

Standing Water Around Well:
Existing Sampling Equipment:
Sediment build-up in Well Btm:

<p><b>Comments:</b></p>          
---

\* = Measurements are from the top of the inner case to the nearest 0.01'





TETRA TECH

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Approved J. Zimmerly	

Subject  
SOIL AND ROCK DRILLING METHODS

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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

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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:

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- 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
- Rotasonic
- 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

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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:

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- 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).

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- 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.

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- 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

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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 casing 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:

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- 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 includes:

- 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.

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● 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 Ivan 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

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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:

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- 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 dismantled 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.

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### 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'

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### 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

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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.

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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. Rotasonic 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.

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~~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 <u>  </u> / <u>  </u> / <u>  </u>	1 7/8	1	1.875	1.000
BX Wire line <u>  </u> / <u>  </u> / <u>  </u>	2 3/8	1 7/16	2.345	1.437
NX Wire line <u>  </u> / <u>  </u> / <u>  </u>	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 O.D., Inches	Casing Coupling		Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings		O.D., Inches	I.D., Inches				Normal, Inches	Thinwall, Inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	---	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush Joint	No Coupling	1.485	1.160	1.094	---	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	---	5.500			5.650	---	---	---	---
SW	---	6.625			6.790	---	---	---	---
UW	---	7.625			7.800	---	---	---	---
ZW	---	8.625			8.810	---	---	---	---
---	AX <u>    </u> \	---	---	---	---	1.875	1.750	1.000	---
---	BX <u>    </u> \	---	---	---	---	2.345	2.250	1.437	---
---	NX <u>    </u> \	---	---	---	---	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**

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### 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

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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	

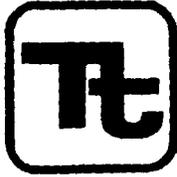
\* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

**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.



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Effective Date	01/2012	Revision	2
Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
BOREHOLE AND SAMPLE LOGGING

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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 (CONTINUED)

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)										
COARSE-GRAINED SOILS More Than Half of Material is LARGER Than No. 200 Sieve Size					FINE-GRAINED SOILS More Than Half of Material is SMALLER Than No. 200 Sieve Size					
FIELD IDENTIFICATION PROCEDURES (Existing Procedures or Their Immediate Neighboring Records as Estimated) (Moist)		GROUP SYMBOL	TYPICAL NAMES		FIELD IDENTIFICATION PROCEDURES (Existing Procedures or Their Immediate Neighboring Records as Estimated) (Moist)			GROUP SYMBOL	TYPICAL NAMES	
Method: (See Identification procedures, see M1)		OC	OC1		Method: (See Identification procedures, see M1)			UC	UC1	
Method: (See Identification procedures, see M1)			OC2		Method: (See Identification procedures, see M1)				UC2	
GRAVELS (G-1 to G-5) 1 to 5% Fines	CLEAN GRAVELS (G-1 to G-2) 1 to 5% Fines	Use: range in grain size and substantial amounts of all intermediate fractions.	OC1	Well graded gravels, poorly graded mixtures, etc. or as they are.	SILT AND CLAY SILT CLAY SILT CLAY	None to High	Low to None	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
	GRAVELS WITH SILT OR CLAY (G-3 to G-5) 1 to 5% Fines	Use: range in grain size and substantial amounts of all intermediate fractions.	OC2	Highly plastic gravels, sandstone, etc. or as they are.		Medium to High	None to Very Low	Medium	CL	Inorganic clays of low to medium plasticity, silty clay, silty clay, clayey silty clay, etc.
	GRAVELS WITH SILT OR CLAY (G-3 to G-5) 1 to 5% Fines	Use: range in grain size and substantial amounts of all intermediate fractions.	OC0	Clayey gravels, poorly graded gravel-sand mixtures.		High to Medium	None	High	CH	Inorganic clays of high plasticity, silty clays.
SANDS (S-1 to S-5) 5 to 50% Fines	CLEAN SANDS (S-1 to S-2) 5 to 50% Fines	Use: range in grain size and substantial amounts of all intermediate fractions.	UC	Well graded sands, poorly graded, etc. or as they are.	SILT AND CLAY SILT CLAY SILT CLAY	High to Very High	None	High	OH	Inorganic clays of high plasticity, silty clays.
	SANDS WITH SILT OR CLAY (S-3 to S-5) 5 to 50% Fines	Use: range in grain size and substantial amounts of all intermediate fractions.	UC2	Highly plastic sands, poorly graded, etc. or as they are.		Medium to High	None to Very Low	Slight to Medium	OH	Organic clays of medium to high plasticity.
	SANDS WITH SILT OR CLAY (S-3 to S-5) 5 to 50% Fines	Use: range in grain size and substantial amounts of all intermediate fractions.	UC0	Clayey sands, poorly graded sand mixtures.		High to Very High	None	Slight to Medium	OH	Organic clays of medium to high plasticity.
					HYDROLYZABLE SILTS	Readily disintegrated by color, odor, taste, etc. and frequently by blow resistance.				

Boundary and field symbols: Soil consistency characteristics when reported as Symbol by Unified Soil Classification. For example, (U)MH, well graded medium sand with clay content. All data in this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS	
DESIGNATION	STANDARD PENETRATION TEST (SPT) BLOW COUNT
Very Loose	4-8
Loose	10-15
Medium Dense	15-30
Dense	30-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS			
CONSISTENCY	LINE COVERED BY STANDARD PENETRATION TEST (SPT) BLOW COUNT	STANDARD PENETRATION TEST (SPT) BLOW COUNT	FIELD IDENTIFICATION SYMBOL
Very Stiff	Less than 15	1 to 3	Easily penetrated or eroded by thumb.
Stiff	15 to 30	3 to 6	Easily penetrated or eroded by thumb.
Medium Stiff	30 to 45	6 to 10	Can be penetrated or eroded by thumb.
Soft	45 to 60	10 to 15	Easily sheared by thumb.
Very Soft	60 to 75	15 to 20	Easily sheared by thumb.
Flow	More than 75	Over 20	Flowing or extruding by thumb.

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)			ROCK BROKENNESS		
Fracture Type	Description of Rock	Hardness Index	Fracture Type	Description	Spacing
Soft	Can be crushed	Crushed when pressed with hammer	Very Break	(V)	1'-3"
Medium Soft	Can be crushed	Breaks into small, sharp edges	Break	(B)	3'-6"
Medium Hard	Can be crushed	Breaks into small, sharp edges	Break	(B)	6'-12"
Hard	Can be crushed	Breaks into small, sharp edges	Medium	(M)	12'-24"

LEGEND:

SOIL SAMPLES - TYPES  
 1" - 1" Splitter Sample  
 6" - 6" Splitter Sample  
 O - Other Sample, Splitter Sample

ROCK SAMPLES - TYPES  
 X - X (or other) Core 1" - 1" O.D.  
 O - O (or other) Core 1" - 1" O.D.  
 2 - Other Core, Splitter Sample

LOG SCALE  
 1" - 1" Splitter Sample  
 6" - 6" Splitter Sample  
 O - Other Sample, Splitter Sample

1" - 1" Splitter Sample  
 6" - 6" Splitter Sample  
 O - Other Sample, Splitter Sample

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### 5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in 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 inch $\Phi$ -1/2 inch $\Phi$ )" 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

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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

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**FIGURE 2**

**CONSISTENCY FOR COHESIVE SOILS**

<b>Consistency</b>	<b>Standard Penetration Resistance (Blows per Foot)</b>	<b>Unconfined Compressive Strength (Tons/Sq. Foot by pocket penetration)</b>	<b>Field Identification</b>
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

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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

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**FIGURE 3**

**BEDDING THICKNESS CLASSIFICATION**

<b>Thickness (metric)</b>	<b>Thickness (Approximate English Equivalent)</b>	<b>Classification</b>
> 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)

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### 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<sub>3</sub>). 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.

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**FIGURE 4**

**GRAIN SIZE CLASSIFICATION FOR ROCKS**

<b>Particle Name</b>	<b>Grain Size Diameter</b>
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

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### 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

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(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.

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- 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
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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**

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

Sample No. and Type or RQD	Depth (FL) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/FL) or Screened Interval	MATERIAL DESCRIPTION			U S C S *	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole #	Driller BZ*
S-1 e	0.0 0800	7 9	1.5/2.0 10		M DENSE	BRN TO BLK	SILTY SAND - SOME ROCK FR. - TR BRICKS (FILL)	SM	MOIST SL. ORG. ODOR FILL TO 4'±	5	0	0	0
	4.0			4.0									
S-2 e	2.0 0810	5 7	2.9/2.0 8		M DENSE	BRN	SILTY SAND - TR FINE GRAVEL	SM	MOIST - W ODOR NAT. MATL. TOOK SAMPLE SBOI-0406 FOR ANALYSIS	10	0	-	-
	8.0			7.9 ± 8.0									
S-3 e	6.0 0820	6 8	1.9/2.0 16		DENSE	TAN BRN	FINE TO COARSE SAND TR. F. GRAVEL	SW	WET HIT WATER = 7'±	0	0	0	0
	12.0			12.0									
S-4 e	8.0 0830	7 5	1.6/2.0 8		STIFF	GRAY	SILTY CLAY	CL	MOIST → WET AUGER REF @ 15'	0	-5	-	-
	15.0			15.0									
	16.0			16.0	M HARD	BRN	SILTSTONE	VER	WEATHERED LO & JNTS @ 15.5 WATER STAINS @ 16.5, 17.1, 17.5	0	0	0	0
	19.0			19.0					LOSING SOME				
	20.0			20.0	HARD	GRAY	SANDSTONE - SOME SILTSTONE	BR	DRILL H2O @ 17'± SET TEMP 6" CAS TO 15.5				
	25.0			25.0					SET 2"Ø PVC SCREEN 16-25 SAND 14-25 PELLETS 12-14	0	0	0	0

\* When rock coring, enter rock brokenness.

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

Remarks: CME-55 RIG, 4 1/4" ID HSA - 9" OD ±  
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP  
NX CORE IN BEDROCK RUN (1) = 25 min, RUN (2) = 15 min

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

Drilling Area Background (ppm): 0

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- 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.

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- 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., 70E 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

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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**

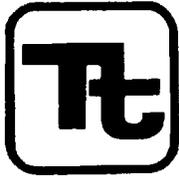
Unified Soil Classification System (USCS).

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.



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
IN-SITU HYDRAULIC CONDUCTIVITY TESTING

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## 1.0 PURPOSE

This guideline is intended to describe procedures for performing in-situ hydraulic conductivity testing (slug testing) in boreholes and monitoring wells, and provide a short description of commonly used evaluation techniques for the data generated. Slug tests are used to provide data regarding the hydraulic properties of the formation tested. A variation of the slug test, called a constant-head test, is also briefly described.

## 2.0 SCOPE

Slug tests are short-term tests designed to provide approximate hydraulic conductivity values for the portion of a formation immediately surrounding the screened/open interval of a well or boring. These tests are much less accurate than pumping tests, as a much more localized area is involved. Therefore, a number of slug tests are typically performed and averaged to determine a representative hydraulic conductivity value for the formation tested. Performance of slug tests may be preferable to pumping tests in situations where handling of large volumes of contaminated water is a concern or when time/budget constraints preclude the more expensive and time-consuming setup and performance of a pumping test.

Constant-head tests also are used to determine hydraulic conductivity values and are similar to slug tests with regard to the quality of data obtained and time/cost considerations. A disadvantage of constant-head tests is that a significant volume of water may be added to high-permeability formations, potentially affecting short-term water quality.

## 3.0 GLOSSARY

Hydraulic Conductivity (K) - A quantitative measure of the ability of a porous material to transmit water, defined as the volume of water that will flow through a unit cross-sectional area of porous material per unit time under a head gradient of 1. Hydraulic conductivity is dependent upon properties of the medium and fluid. Common units of expression include centimeters per second (cm/sec), feet per day (ft/day), and gallons per day per foot<sup>2</sup> (gpd/ft<sup>2</sup>).

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

Slug Test - A rising head or falling head test used to measure hydraulic conductivity. A slug test consists of instantaneously changing the water level within a well and measuring the rate of recovery of the water level to equilibrium conditions. Slug tests are performed by either withdrawing a slug of water (rising head test) or adding a slug of water (falling head test), then measuring recovery over time. A solid slug of known volume can be used to displace a volume of water, thereby simulating the addition or removal of water.

## 4.0 RESPONSIBILITIES

Project Hydrogeologist - The project hydrogeologist, in conjunction with the Project Manager, shall evaluate the type(s) and extent of hydraulic testing required for a given project during the planning process, and design the field program accordingly. The project hydrogeologist also shall ensure that field personnel have the necessary training and guidance to properly perform the tests, and shall oversee data reduction activities, including selecting the appropriate evaluation techniques and checking calculations for accuracy.

Field Geologist - The field geologist is responsible for performing the planned field tests as specified in the project planning documents, (or approved modifications thereto). The field geologist also generally assists in the data evaluation process. The field geologist shall be knowledgeable in the testing

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methodologies used and is responsible for obtaining the necessary support equipment required to perform the field tests. All applicable data regarding testing procedures, equipment used, well construction, and geologic/hydrogeologic conditions shall be recorded by the field geologist. The field geologist shall be familiar enough with testing procedures/requirements to be able to recommend changes in methodology, should unanticipated field conditions be encountered.

## 5.0 PROCEDURES

### 5.1 In-situ Hydraulic Conductivity Testing in Wells

Slug tests are commonly performed in completed wells. Prior to testing, the well shall be thoroughly developed and allowed to stabilize, in order to obtain accurate results. Once the water level within the well has stabilized at its static level, it shall be quickly raised or lowered and the rate of recovery measured.

One of the basic assumptions of slug testing is that the initial change in water level is instantaneous; therefore, an effort shall be made to minimize the time involved in raising or lowering the water level initially. Various methods can be used to induce instantaneous (or nearly instantaneous) changes in water level within the well. A rise in water levels can be induced by pouring water into the well. A solid slug of known volume, quickly lowered below the water level within the well, will displace an equivalent volume of water and raise the water level within the well. The slug can be left in place until the water level restabilizes at the static water level, then suddenly removed to create a drop in water level within the well. An advantage of using a solid cylinder of known volume (slug) to change the water level is that no water is removed or added to the monitoring well. This eliminates the need to dispose of contaminated water and/or add water to the system. A bailer or pump can be used to withdraw water from the well. If a pump is used, pumping shall not continue for more than several seconds so that a cone of depression is not created which would adversely impact testing results. The pump hose shall also be removed from the well during the recovery period, as data analysis techniques involve volume of recovery versus time, and leaving the hose within the well would distort the calculated testing results by altering the apparent volume of recovery. Falling head slug tests should only be performed in wells with fully submerged screens, while rising head slug tests can be performed in wells with either partially or fully submerged screens/open intervals.

Other methods that can be used to change water levels within a well include creating a vacuum or a high pressure environment within the well. The vacuum method will raise water levels within the well, while the pressure method will depress the water level in the well. These methods are particularly useful in highly permeable formations where other methods are ineffective in creating measurable changes in water levels. Both of these methods are limited to wells which have completely submerged screens.

Rate of recovery measurements shall be obtained from time zero (maximum change in water level) until water level recovery exceeds 90 percent of the initial change in water level. In low permeability formations, the test may be cut-off short of 90 percent recovery due to time constraints. Time intervals between water level readings will vary according to the rate of recovery of the well. For a moderately fast recovering well, water level readings at 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, 1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 4.0, . . . minutes may be required. With practice, readings at down to 0.05-minute (3 seconds) time intervals can be obtained with reasonable accuracy, using a pressure transducer and hand held readout. For wells which recover very fast, a pressure transducer and data logger may be required to obtain representative data. Time intervals between measurements can be extended for slow recovering wells. A typical schedule for measurements for a slow recovering well would be 0, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0, 15.0, 20.0, 30.0, . . . minutes from the beginning the test. Measurements shall be taken from the top of the well casing.

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Water level measurements can be obtained using an electric water level indicator, popper, or pressure transducer. Steel tape coated with chalk or water sensitive paste although very accurate, is a slower method of obtaining water levels and is generally not recommended for use due to the frequency at which water level measurements need to be obtained during the performance of a slug test.

Time/recovery should be field-plotted on semilog graph paper to determine the data quality. The data set should plot along a sloped, straight line. If excessive data scatter is observed, the test should be rerun until acceptable results are obtained.

The following data shall be recorded when performing slug tests in wells or borings:

- Well/boring ID number
- Total depth of well/boring
- Screened/open interval depth and length
- Gravel pack interval depth and length
- Well stickup above ground surface
- Gravel pack radius
- Static water level
- Aquifer thickness
- Depth to confining layer
- Time/recovery data

A variation of the slug test, called a constant-head test, is a test in which water is added to the well at a measured rate sufficient to maintain the water level in the well at a constant height above the static water level. Once a stable elevated water level has been achieved, discharge (pumping) rate measurements are recorded in place of time/recovery data for approximately 10 to 20 minutes. The hydraulic conductivity is then calculated from this information. The constant-head test is generally not recommended for monitoring wells as large volumes of water may be introduced into the screened formation, potentially impacting later sampling events.

## **5.2 In-situ Hydraulic Conductivity Testing in Borings**

Slug tests can be performed in borings while the boring is being advanced. This permits testing of formations at different depths throughout the drilling process. Boreholes to be tested shall be drilled using casing, so that discrete depths may be investigated. Various tests and testing methods are described below. The most appropriate test and testing method to be used in a situation varies and shall be selected after a careful evaluation of drilling, geologic, and general site conditions.

Rising head or falling head slug tests can be performed in saturated and unsaturated formations during drilling. There are two ways that the tests can be performed. One way entails setting the casing flush with the bottom of the boring when the desired testing depth has been reached. The hole is then cleaned out to remove loose materials, the drill bit and rods are carefully withdrawn from the boring, and a few feet of sand (of higher permeability than the surrounding formation) is added to the bottom of the boring. After the water level in the boring has stabilized (for saturated formations), the static water level is measured and recorded. The water level is then raised (falling head test) or lowered (rising head test) and the change in water level is measured at time intervals determined by the field hydrogeologist. Only falling head tests can be performed for depth intervals within the unsaturated (vadose) zone. As described for wells, time intervals for water level measurements will vary according to the formation's hydraulic conductivity. The faster the rate of recovery expected, the shorter the time intervals between measurements shall be. The rate of change of water level will be used to calculate hydraulic conductivity. The test is to be conducted until the water level again stabilizes, or for a minimum of 20 minutes. In low permeability formations, it is not always practical to run the test until the water level stabilizes, as it may

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take a long time to do so. The top of the casing shall be used as the reference point for all water level measurements.

The second method for conducting a slug test during drilling consists of placing a temporary well with a short screen into the cleaned-out boring, pulling the drilling casing back to expose the screen, allowing the formation to collapse around the screen (or placing a sand/gravel pack around the screen), and performing the appropriate hydraulic conductivity test in the well, as described for the first method. Again, the test shall be conducted until the water level stabilizes or for a minimum of 20 minutes. This method allows for testing a larger section of the formation and results in more reliable hydraulic conductivity estimates.

Constant-head tests may also be performed in borings. As described for monitoring wells, once a stable elevated level has been achieved, the discharge rate into the boring is measured for a period of time, usually 10 to 20 minutes, and the hydraulic conductivity is calculated from this. This method is the most accurate method depicted in this section, and shall be given preference over others if the materials are available to perform the test and the addition of water to the boring does not adversely impact project objectives. Once the test is over, additional information can be gathered by measuring the rate of the drop in water level in the boring (for saturated formations). A limitation of the constant-head test is that foreign water is introduced into the formation which must be removed from the well area by natural or artificial means, before a representative groundwater sample can be obtained.

Detailed descriptions regarding the performance of borehole hydraulic conductivity tests and subsequent data analysis techniques are provided in Ground Water Manual (1981).

### **5.3 Data Analysis**

There are a number of data analysis methods available to reduce and evaluate slug testing data. The determination of which method is most appropriate shall be made based on the testing conditions (including physical setup of the well/boring tested, hydrogeologic conditions, and testing methodology) and the limitations of each test analysis method. Well construction details, aquifer type (confined or unconfined), and screened/open interval (fully or partially penetrating the aquifer) shall be taken into account in selecting an analysis method. Cooper, et al. (1967), and Papadapulos, et al. (1973) have developed test interpretation procedures for fully penetrating wells in confined aquifers. Hvorslev (1951) developed a relatively simple analytical procedure for point piezometers in an infinite isotropic medium. In Cedergren (1967), Hvorslev presents a number of analytical procedures which cover a wide variety of hydrogeologic conditions, testing procedures, and well/boring/piezometer configurations. Bouwer and Rice (1976) developed an analytical technique applicable to both unconfined and confined conditions, which factors in partial/full penetration and discusses well screen gravel pack considerations. The Ground Water Manual (1981) presents a number of testing and test analysis procedures for wells and borings open above or below the water table, and for both falling head and constant-head tests. The methods described above do not represent a complete listing of test analysis methods available, but are some of the more commonly used and accepted methods. Other methods can be used, at the discretion of the project hydrogeologist and in concurrence with the Project Manager and client.

One consideration to be noted during data analysis is the determination of the screened/open interval of a tested well. If a well with a fully submerged screen is installed in a relatively low permeability formation, and a gravel pack which is significantly more permeable is installed around the screen, the length of the gravel pack (if longer than the screened interval) should be used as the screened/open length, rather than the screen length itself. In situations where the formation permeability is judged to be comparable to the gravel pack permeability (within about an order of magnitude) this adjustment is not required.

All data analysis applications and calculations shall be reviewed by technical personnel thoroughly familiar with testing and test analysis procedures. Upon approval of the calculations and results, the

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calculation sheets shall be initialed and dated by the reviewer. Distribution copies shall be supplied to appropriate project personnel and the original copy stored in the project central file.

## 6.0 REFERENCES

Cedergren, H. R., 1967. Seepage, Drainage, and Flow Nets. John Wiley and Sons Inc., New York, pp. 78-76.

Cooper, H. H., Jr., J. D. Bredehoeft, and I. S. Papadopoulos, 1967. Response of a Finite-Diameter Well to an Instantaneous Change of Water. Water Resources Research, V. 3, No. 1, pp. 263-269.

Hvorslev, M. J., 1951. Time Lag and Soil Permeability in Ground Water Observations. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, D.C., Bull. No. 36.

Papadopoulos, I. S., J. D. Bredehoeft, and H. H. Cooper, 1973. On the Analysis of Slug Test Data. Water Resources Research, V. 9, No. 4, pp. 1087-1089.

Bouwer, H. and R. C. Rice, 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." Water Resources Research, 12:423-28.

United States Department of the Interior, 1981. Ground Water Manual. U.S. Government Printing Office, Denver, Colorado.

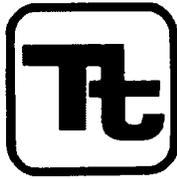
## 7.0 RECORDS

Field data shall be recorded on the data sheet included as Attachment A (or equivalent). 1 Any notes regarding testing procedures, problems encountered, and general observations not included on the data sheet shall be noted in the bound site logbook or field notebook. The boring log and well construction diagrams for each well/boring tested shall be used as references during testing and data analysis activities. Original data sheets shall be placed in the project file, along with the logbook/notebook.

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1 If an automated data recorder is used, the data may be displayed using the printer output from the unit. Such printouts should be annotated to include the relevant data form, or attached to the form shown as Attachment A.





TETRA TECH

# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
GROUNDWATER MONITORING WELL INSTALLATION

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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.

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## 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 (hard hats, safety glasses, etc.) 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.

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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.

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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.

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### 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 sand. 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.

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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~~

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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, turbidity, 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

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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.

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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.

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**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 <sup>7</sup> | 5 | Lo-Carbon Steel  |
| 2  | Stainless Steel 316 | 6 | Galvanized Steel |
| 3. | Stainless Steel 304 | 7 | Carbon Steel     |
| 4  | PVC 1               |   |                  |

\* 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 <sup>7*</sup>	Silicone	Neoprene	Teflon <sup>7*</sup>
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 <sup>7</sup>    | 5 | PE Conventional        |
| 2  | Polypropylene (PP)     | 6 | Plexiglas/Lucite (PMM) |
| 3. | PVC Flexible/PE Linear | 7 | Silicone/Neoprene      |
| 4  | Viton <sup>7</sup>     |   |                        |

\* Trademark of DuPont

Source: Barcelona et al., 1983

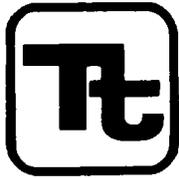
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### ATTACHMENT B

#### COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength 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.



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Health & Safety		
Approved	J. Zimmerly		

Subject  
UTILITY LOCATING AND EXCAVATION CLEARANCE

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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 this policy, to present the acceptable procedures pertaining to utility locating and excavation clearance activities, and to present requirements and restrictions relevant to these types of activities. This SOP must be reviewed by any employee potentially involved with underground or overhead utility locating and avoidance activities.

## 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 and avoidance of contact with 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 initiation of any such activities on a specific project. This SOP is not intended to provide a detailed description of methodology and instrument operation. Specialized expertise during both planning and execution of several of the methods presented 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.

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#### 4.0 RESPONSIBILITIES

Project Manager (PM)/Task Order Manager (TOM) - Responsible for ensuring that all field activities are conducted in accordance with this procedure.

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. 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 and this SOP.

Site Personnel – Responsible for performing their work activities in accordance with this SOP and the TtNUS Health and Safety 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. This procedure must be followed prior to beginning any subsurface probing or 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 scars and patches, and topographical depressions. Note the location of any emergency shut off switches. Any additional information regarding utility

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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 safe and effective methods such as passive and intrusive surveys, or the use of non-conductive hand tools. Also, in situations where such hand tools are used, they should always be used in conjunction with suitable detection equipment, such as the items described in Section 6.0 of this SOP. Each method has advantages and disadvantages including complexity, applicability, and price. It also should be noted that in some 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 using a device such as a tile probe which is made of non-conductive material such as fiberglass. 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.

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**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 through conductive materials, tools, or equipment.

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

<u>Nominal Voltage</u>	<u>Minimum Clearance</u>
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**

A variety of supplemental utility locating approaches are available and can be applied when additional assurance is needed. The selection of the appropriate method(s) to employ is site-specific and should be tailored to the anticipated conditions, site and project constraints, and personnel capabilities.

**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.

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## 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

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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 Excavation**

When the identification and location of underground utilities cannot be positively confirmed through document reviews and/or other methods, borings and excavations may be cleared via the use of non-conductive hand tools. This should always be done in conjunction with the use of detection equipment. This would be required for all locations where there is a potential to impact buried utilities. The minimum hand-excavation 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 excavation depths must be at least to the frost line depth (see Attachment 2) plus two (2) feet, but never less than 4 feet below ground surface (bgs). For hand excavation, the hole created must be reamed large enough to be 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 excavation. It is important to note that a post-hole digger must not be used in this type of hand excavation activity.

### **Tile Probe Surveys**

For some soil types, site conditions, and excavation requirements, non-conductive tile probes may be used. A tile probe is a "T"-handled rod of varying lengths that can be pushed into the soil to determine if any obstructions exist at that location. Tile probes constructed of fiberglass or other nonconductive material are readily-available from numerous vendors. Tile probes must be performed to the same depth requirements as previously specified. As with other types of hand excavating activities, the use of a non-conductive tile probe, should always be in conjunction with suitable utility locating detection equipment.

## **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 surface 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. Implement supplemental utility detection techniques as necessary and appropriate to conform utility locations or the absence thereof.

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5. 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

OSHA Letter of Interpretation, Mr. Joseph Caldwell, Attachment 4  
 OSHA 29 CFR 1926(b)(2)  
 OSHA 29 CFR 1926(b)(3)  
 Tt Utility Locating and Clearance Policy  
 Tt SOP GH-3.1; Resistivity and Electromagnetic Induction  
 Tt SOP GH-3.2; Magnetic and Metal Detection Surveys  
 Tt SOP GH-3.4; Ground-penetrating Radar Surveys

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**ATTACHMENT 1  
LISTING OF UNDERGROUND UTILITY CLEARANCE RESOURCES**



**American Public Works Association**  
2345 Grand Boulevard, Suite 500, Kansas City, MO 64108-2625  
Phone (816) 472-6100 • Fax (816) 472-1610  
Web [www.apwa.net](http://www.apwa.net) • E-mail [apwa@apwa.net](mailto:apwa@apwa.net)

**ONE-CALL SYSTEMS INTERNATIONAL  
CONDENSED DIRECTORY**

**Alabama**  
Alabama One-Call  
1-800-292-8525

**Alaska**  
Locate Call Center of Alaska, Inc.  
1-800-478-3121

**Arizona**  
Arizona Blue Stake  
1-800-782-5348

**Arkansas**  
Arkansas One Call System, Inc.  
1-800-482-8998

**California**  
Underground Service Alert North  
1-800-227-2600  
Underground Service Alert of Southern  
California  
1-800-227-2600

**Colorado**  
Utility Notification Center of Colorado  
1-800-922-1987

**Connecticut**  
Call Before You Dig  
1-800-922-4455

**Delaware**  
Miss Utility of Delmarva  
1-800-282-8555

**Florida**  
Sunshine State One-Call of Florida, Inc.  
1-800-432-4770

**Georgia**  
Underground Protection Center, Inc.  
1-800-282-7411

**Hawaii**  
Underground Service Alert North  
1-800-227-2600

**Idaho**  
Dig Line Inc.  
1-800-342-1585  
Kootenai County One-Call  
1-800-428-4950  
Shoshone - Benewah One-Call  
1-800-398-3285

**Illinois**  
JULIE, Inc.  
1-800-892-0123  
Digger (Chicago Utility Alert Network)  
312-744-7000

**Indiana**  
Indiana Underground Plant Protection  
Service  
1-800-382-5544

**Iowa**  
Iowa One-Call  
1-800-292-8989

**Kansas**  
Kansas One-Call System, Inc.  
1-800-344-7233

**Kentucky**  
Kentucky Underground Protection Inc.  
1-800-752-6007

**Louisiana**  
Louisiana One Call System, Inc.  
1-800-272-3020

**Maine**  
Dig Safe System, Inc.  
1-888-344-7233

**Maryland**  
Miss Utility  
1-800-257-7777  
Miss Utility of Delmarva  
1-800-282-8555

**Massachusetts**  
Dig Safe System, Inc.  
1-888-344-7233

**Michigan**  
Miss Dig System, Inc.  
1-800-482-7171

**Minnesota**  
Gopher State One Call  
1-800-252-1166

**Mississippi**  
Mississippi One-Call System, Inc.  
1-800-227-6477

**Missouri**  
Missouri One-Call System, Inc.  
1-800-344-7483

**Montana**  
Utilities Underground Protection Center  
1-800-424-5555  
Montana One Call Center  
1-800-551-8344

**Nebraska**  
Diggers Hotline of Nebraska  
1-800-331-5666

**Nevada**  
Underground Service Alert North  
1-800-227-2600

**New Hampshire**  
Dig Safe System, Inc.  
1-888-344-7233

**New Jersey**  
New Jersey One Call  
1-800-272-1000

**New Mexico**  
New Mexico One Call System, Inc.  
1-800-321-2537  
Las Cruces- Dona Ana Blue Stakes  
1-888-526-0400

**New York**  
Dig Safely New York  
1-800-962-7962  
New York City- Long Island One Call  
Center  
1-800-272-4480

**North Carolina**  
The North Carolina One-Call Center,  
Inc.  
1-800-532-4949

**North Dakota**  
North Dakota One-Call  
1-800-795-0555

**Ohio**  
Ohio Utilities Protection Service  
1-800-362-2764  
Oil & Gas Producers Underground  
Protect'n Svc  
1-800-925-0988

**Oklahoma**  
Call Okie  
1-800-522-6543

**Oregon**  
Oregon Utility Notification Center/One  
Call Concepts  
1-800-332-2344

**Pennsylvania**  
Pennsylvania One Call System, Inc.  
1-800-242-1776

**Rhode Island**  
Dig Safe System, Inc.  
1-888-344-7233

**South Carolina**  
Palmetto Utility Protection Service Inc.  
1-888-721-7877

**South Dakota**  
South Dakota One Call  
1-800-781-7474

**Tennessee**  
Tennessee One-Call System, Inc.  
1-800-351-1111

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**ATTACHMENT 1 (Continued)**

**Texas**

Texas One Call System  
1-800-245-4545  
Texas Excavation Safety System, Inc.  
1-800-344-8377  
Lone Star Notification Center  
1-800-669-8344

**Utah**

Blue Stakes of Utah  
1-800-662-4111

**Vermont**

Dig Safe System, Inc.  
1-888-344-7233

**Virginia**

Miss Utility of Virginia  
1-800-552-7001  
Miss Utility (Northern Virginia)  
1-800-257-7777

**Washington**

Utilities Underground Location Center  
1-800-424-5555  
Northwest Utility Notification Center  
1-800-553-4344  
Inland Empire Utility Coordinating  
Council  
509-456-8000

**West Virginia**

Miss Utility of West Virginia, Inc.  
1-800-245-4848

**Wisconsin**

Diggers Hotline, Inc.  
1-800-242-8511

**Wyoming**

Wyoming One-Call System, Inc.  
1-800-348-1030  
Call Before You Dig of Wyoming  
1-800-849-2476

**District of Columbia**

Miss Utility  
1-800-257-7777

**Alberta**

Alberta One-Call Corporation  
1-800-242-3447

**British Columbia**

BC One Call  
1-800-474-6886

**Ontario**

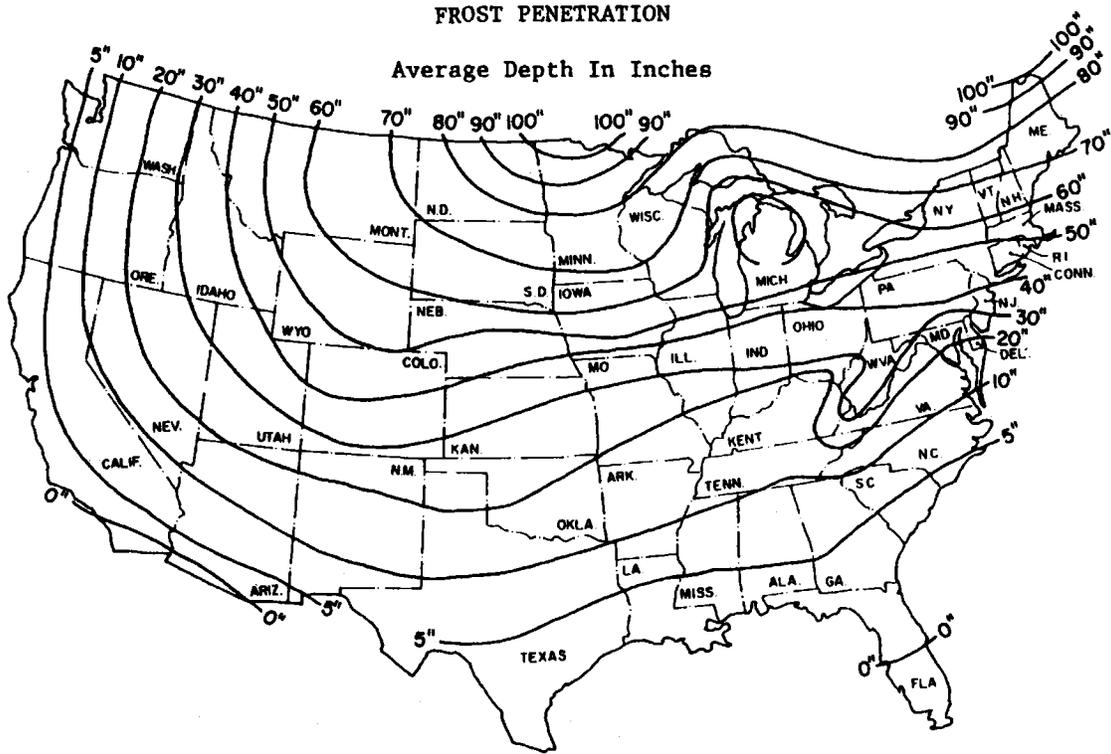
Ontario One-Call System  
1-800-400-2255

**Quebec**

Info-Excavation  
1-800-663-9228

**ATTACHMENT 2**

**FROST LINE PENETRATION DEPTHS BY GEOGRAPHIC LOCATION**



Courtesy U.S. Department Of Commerce

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**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 yes no N/A  
 Name \_\_\_\_\_ Telephone: \_\_\_\_\_ Date: \_\_\_\_\_
  - g) State One-Call agency called? yes no N/A  
 Caller: \_\_\_\_\_  
 Ticket Number: \_\_\_\_\_ Date: \_\_\_\_\_
  - h) Geophysical survey performed? yes no N/A  
 Survey performed by: \_\_\_\_\_  
 Method: \_\_\_\_\_ Date: \_\_\_\_\_
  - i) Hand excavation performed (with concurrent use of utility  
 detection device)? yes no N/A  
 Completed by: \_\_\_\_\_  
 Total depth: \_\_\_\_\_ feet Date: \_\_\_\_\_
  - j) Trench/excavation probed? yes no N/A  
 Probing completed by: \_\_\_\_\_  
 Depth/frequency: \_\_\_\_\_ Date: \_\_\_\_\_

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

Subject UTILITY LOCATING AND EXCAVATION CLEARANCE	Number HS-1.0	Page 13 of 15
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**ATTACHMENT 4  
OSHA LETTER OF INTERPRETATION**

Mr. Joseph Caldwell  
Consultant  
Governmental Liaison  
Pipeline Safety Regulations  
211 Wilson Boulevard  
Suite 700  
Arlington, Virginia 22201

Re: Use of hydro-vacuum or non-conductive hand tools to locate underground utilities.

Dear Mr. Caldwell:

In a letter dated July 7, 2003, we responded to your inquiry of September 18, 2002, regarding the use of hydro-vacuum equipment to locate underground utilities by excavation. After our letter to you was posted on the OSHA website, we received numerous inquiries that make it apparent that aspects of our July 7 letter are being misunderstood. In addition, a number of industry stakeholders, including the National Utility Contractors Association (NUCA), have provided new information regarding equipment that is available for this work.

To clarify these issues, we are withdrawing our July 7 letter and issuing this replacement response to your inquiry.

***Question:** Section 1926.651 contains several requirements that relate to the safety of employees engaged in excavation work. Specifically, paragraphs (b)(2) and (b)(3) relate in part to the safety of the means used to locate underground utility installations that, if damaged during an uncovering operation, could pose serious hazards to employees.*

*Under these provisions, what constitutes an acceptable method of uncovering underground utility lines, and further, would the use of hydro-vacuum excavation be acceptable under the standard?*

**Answer**

Background

Two sections of 29 CFR 1926 Subpart P (Excavations), 1926.651(Specific excavation requirements), govern methods for uncovering underground utility installations. Specifically, paragraph (b)(2) states:

When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours \* \* \* or cannot establish the exact location of these installations, the employer may proceed, provided the employer does so with caution, and provided detection equipment or other acceptable means to locate utility installations are used. (emphasis added).

Paragraph (b)(3) provides:

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#### ATTACHMENT 4 (Continued)

When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means. (emphasis added).

Therefore, “acceptable means” must be used where the location of the underground utilities have not been identified by the utility companies and detection equipment is not used.

Subpart P does not contain a definition of either “other acceptable means” or “safe and acceptable means.” The preambles to both the proposed rule and the final rule discussed the rationale behind the wording at issue. For example, the preamble to the proposed rule, 52 Fed. Reg. 12301 (April 15, 1987), noted that a 1972 version of this standard contained language that specified “careful probing or hand digging” as the means to uncover utilities. The preamble then noted that an amendment to the 1972 standard later deleted that language “to allow other, *equally effective means* of locating such installations.” The preamble continued that in the 1987 proposed rule, OSHA again proposed using language in section (b)(3) that would provide another example of an acceptable method of uncovering utilities that could be used where the utilities have not been marked and detection equipment is not being used – “probing with hand-held tools.” This method was rejected in the final version of 29 CFR 1926. As OSHA explained in the preamble to the final rule, 54 Fed. Reg. 45916 (October 31, 1989):

OSHA received two comments \* \* \* and input from ACCSH [OSHA’s Advisory Committee on Construction Safety and Health] \* \* \* on this provision. All commenters recommended dropping ‘such as probing with hand-held tools’ from the proposed provision, because this could create a hazard to employees by damaging the installation or its insulation.

In other words, the commenters objected to the use of hand tools being used unless detection equipment was used in conjunction with them. OSHA then concluded its discussion relative to this provision by agreeing with the commentators and ultimately not including any examples of “acceptable means” in the final provision.

#### Non-conductive hand tools are permitted

This raises the question of whether the standard permits the use of hand tools alone -- without also using detection equipment. NUCA and other industry stakeholders have recently informed us that non-conductive hand tools that are appropriate to be used to locate underground utilities are now commonly available.

Such tools, such as a “shooter” (which has a non-conductive handle and a snub nose) and non-conductive or insulated probes were not discussed in the rulemaking. Since they were not considered at that time, they were not part of the class of equipment that was thought to be unsafe for this purpose. Therefore, we conclude that the use of these types of hand tools, when used with appropriate caution, is an “acceptable means” for locating underground utilities.

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#### ATTACHMENT 4 (Continued)

##### Hydro-vacuum excavation

It is our understanding that some hydro-vacuum excavation equipment can be adjusted to use a minimum amount of water and suction pressure. When appropriately adjusted so that the equipment will not damage underground utilities (especially utilities that are particularly vulnerable to damage, such as electrical lines), use of such equipment would be considered a "acceptable means" of locating underground utilities. However, if the equipment cannot be sufficiently adjusted, then this method would not be acceptable under the standard.

##### Other technologies

We are not suggesting that these are the only devices that would be "acceptable means" under the standard. Industry stakeholders have informed us that there are other types of special excavation equipment designed for safely locating utilities as well.

We apologize for any confusion our July 7 letter may have caused. If you have further concerns or questions, please feel free to contact us again by fax at: U.S. Department of Labor, OSHA, Directorate of Construction, Office of Construction Standards and Compliance Assistance, fax # 202-693-1689. You can also contact us by mail at the above office, Room N3468, 200 Constitution Avenue, N.W., Washington, D.C. 20210, although there will be a delay in our receiving correspondence by mail.

Sincerely,

Russell B. Swanson, Director  
Directorate of Construction

**NOTE:** OSHA requirements are set by statute, standards and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at <http://www.osha.gov>.



**TETRA TECH**

# STANDARD OPERATING PROCEDURES

Number SA-1.1	Page 1 of 34
Effective Date 01/2012	Revision 8
Applicability Tetra Tech, Inc.	
Prepared Earth Sciences Department	
Approved J. Zimmerly	

Subject  
GROUNDWATER SAMPLE ACQUISITION AND  
ONSITE WATER QUALITY TESTING

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## 1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the process to be used for purging groundwater monitoring wells prior to sampling, for collecting groundwater samples, and for measuring groundwater quality parameters.

## 2.0 SCOPE

This document provides information on proper sampling equipment, onsite water quality testing, safety measures to ensure the safety of the field technician(s), and techniques for groundwater sampling. All personnel are encouraged to review the information contained herein to facilitate planning of the field sampling effort. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require modifications to methodology.

## 3.0 GLOSSARY

Conductivity – Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions and their total concentration, mobility, valence, and relative concentrations and on temperature. Conductivity is highly dependent on temperature and should be reported at a particular temperature, i.e., 20.2 microSiemens per centimeter (mS/cm) at 14°C.

Dissolved Oxygen (DO) – DO levels in natural and wastewater depend on the physical, chemical, and biochemical activities in the water sample.

Groundwater Sample – A quantity of water removed from the ground, usually via a monitoring well that may or may not be lined with a well casing.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode immersed in water, as referenced against a reference electrode. A reference electrode commonly used in the field is the silver/silver chloride electrode, which has a voltage offset of about 210 mV from the standard hydrogen electrode (SHE). To convert field ORP measurements to equivalent SHE values, approximately 210 mV must be added to the ORP values obtained using the silver/silver chloride electrode. The actual offset depends on the concentration of the potassium chloride (KCl) in the field reference electrode and the temperature. Offsets typically range from 199 (saturated KCl) to 205 (3.5 Molar KCl) to 222 mV (1 Molar KCl) at 25°C and are greater at lower temperatures.

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

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

Representativeness – A qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been collected.

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Salinity – The measurement of dissolved salts in a given mass of solution. Note: most field meters determined salinity automatically from conductivity and temperature. The value will be displayed in either parts per thousand (ppt) or percent (e.g., 35 ppt equals 3.5 percent). The parts per thousand symbol ( $^{\circ}/_{00}$ ) is not the same as the percent symbol (%).

Turbidity – Turbidity in water is caused by suspended matter such as clay, silt, and fine organic and inorganic matter. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

#### 4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - The Project Manager is responsible for determining the sampling objectives, initial sampling locations, and field procedures used in the collection of groundwater samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager identifies sampling locations.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan (HASP). This includes but is not limited to performing air quality monitoring during sampling, boring and excavation activities, and ensuring that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO or SSO designee may also be required to advise the FOL on other safety-related matters regarding sampling, such as mitigative measures to address potential hazards from hazardous objects or conditions.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of samples in accordance with this SOP or other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, boring logs, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

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

Field Operations Leader (FOL) – This individual is primarily responsible for the execution of the planning document containing the Sampling and Analysis Plan (SAP). This is accomplished through management of a field sampling team for the proper acquisition of samples. He or she is responsible for the supervision of onsite analyses; ensuring proper instrument calibration, care, and maintenance; sample collection and handling; the completion and accuracy of all field documentation; and making sure that custody of all samples obtained is maintained according to proper procedures. When appropriate and as directed by the FOL, such responsibilities may be performed by other qualified personnel (e.g., field technicians) where credentials and time permit. The FOL is ultimately responsible for adherence to Occupational Safety and Health Administration (OSHA) regulations during these operations through self acquisition or through the management of a field team of samplers.

General personnel qualifications for groundwater sample collection and onsite water quality testing include the following:

- Occupational Safety and Health Administration (OSHA) 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.

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- Familiarity with appropriate procedures for sample documentation, handling, packaging, and shipping.

## 5.0 HEALTH AND SAFETY

Specific safety and health precautions are identified throughout this SOP. In addition to those precautions, the following general hazards may be incurred during sampling activities:

- Knee injuries from kneeling on hard surfaces
- Slips, trips, and falls
- Cuts and lacerations
- Traffic hazards associated with sampling in parking areas and roadways and along highways.

Methods of avoiding these hazards are provided below.

**Knee injuries** – Many monitoring wells are installed as flush mounts. Personnel are required to kneel to open these wells and to take groundwater level measurements, etc. This could result in knee injuries from kneeling on stones/foreign objects and general damage due to stress on the joints. To combat this hazard:

- Clear any foreign objects from the work area.
- Wear hard-sided knee pads.

**Slips, Trips, and Falls** – These hazards exist while traversing varying terrains carrying equipment to sample wells. To minimize these hazards:

- Pre-survey well locations. Eliminate, barricade, or otherwise mark physical hazards leading to the locations.
- Carry small loads that do not restrict the field of vision.
- Travel the safest and clearest route (not necessarily the shortest).

**Cuts and Lacerations** – To prevent cuts and lacerations associated with groundwater sampling, the following provisions are required:

- Always cut away from yourself and others when cutting tubing or rope. This will prevent injury to yourself and others if the knife slips.
- Do not place items to be cut in your hand or on your knee.
- Change blades as necessary to maintain a sharp cutting edge. Many accidents result from struggling with dull cutting attachments.
- Whenever practical, wear cut-resistant gloves (e.g., leather or heavy cotton work gloves) at least on the hand not using the knife.
- Keep cutting surfaces clean and smooth.

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- Secure items to be cut -- do not hold them against the opposing hand, a leg, or other body part.
- When transporting glassware, keep it in a hard-sided container such as a cooler so that if there is a fall, you will be less likely to get cut by broken glass.
- DO NOT throw broken glass or glass ampoules into garbage bags. Place broken glass and glass ampoules in hard-sided containers such as a cardboard box or directly into a dumpster. DO NOT reach into garbage bags to retrieve any item accidentally thrown away. Empty the contents onto a flat surface to avoid punctures and lacerations from reaching where you cannot see.

**Vehicular and Foot Traffic Hazards** – When sampling along the roadway or near traffic patterns, follow the following precautions:

- Motorists may be distracted by onsite activities – ASSUME THEY DO NOT SEE YOU OR MEMBERS OF YOUR FIELD CREW.
- DO NOT place obstructions (such as vehicles) along the sides of the road that may cause site personnel to move into the flow of traffic to avoid your activities or equipment or that will create a blind spot.
- **Provide a required free space of travel.** Maintain at least 6 feet of space between you and moving traffic. Where this is not possible, use flaggers and/or signs to warn oncoming traffic of activities near or within the travel lanes.
- Face Traffic. Whenever feasible, if you must move within the 6 feet of the required free space or into traffic, attempt to face moving traffic at all times. Always leave yourself an escape route.
- Wear high-visibility vests to increase visual recognition by motorists.
- Do not rely on the vehicle operator's visibility, judgment, or ability. Make eye contact with the driver. Carefully and deliberately use hand signals so they will not startle or confuse motorists or be mistaken for a flagger's direction before moving into traffic.
- Your movements may startle a motorist and cause an accident, so move deliberately. Do not make sudden movements that might confuse a motorist.

## 6.0 PROCEDURES

### 6.1 General

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

#### **CAUTION**

A closed well may generate and accumulate gases due to biological degradation, evolution of volatile chemicals from groundwater into the air, or other chemical actions. These gases may also be artificially generated, such as in the case of air sparging or

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extraction wells, which may take several days to depressurize. See Section 6.6.2 for safety measures to be employed to protect sampling personnel.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air or nitrogen, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water sample due to external influences of the sampling technique(s). In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. Concentration gradients resulting from mixing and dispersion processes, layers of variable geologic permeability, and the presence of separate-phase product (e.g., floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase contaminant concentrations in the collected sample compared to what is representative of the integrated water column as it naturally occurs at that point, resulting in the collection of a non-representative sample. To safeguard against collecting non-representative samples, the following approach shall be followed prior to sample acquisition:

**CAUTION**

Mechanical agitation of well water may cause off-gas generation of volatile contaminants, creating an inhalation exposure to the sampler(s). Where avoiding an inhalation exposure is not possible and mechanical agitation is possible, pump into closed-top containers to control potential air emissions.

1. If possible, position yourself (and the sampling equipment) upwind of the well head.
2. Purge the monitoring well to be sampled prior to obtaining any samples from it. Evacuation of three to five well volumes is recommended prior to sampling, unless low-flow purging and sampling methods are utilized as described in Section 6.7 (Consult the site-specific SAP for exact purging parameters). In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical as it is in a low-yielding well or in wells containing stagnant water.
3. For wells with low yields that are purged dry during sampling, evacuate the well and allow it to recover to 75 percent of full capacity prior to sample acquisition. If the recovery rate is fairly rapid (generally 300 mL per minute or greater), attempt to continue evacuation until the number of well volumes specified in the SAP is achieved. If this cannot be accomplished, allow recovery to 75 percent of capacity and begin sampling.

**CAUTION**

For moderate to high-yielding monitoring wells, an evacuation rate that does not cause excessive turbulence in the well should be selected. There is no absolute safeguard against contaminating the sample with stagnant water; hence, special techniques are required for purging to minimize the potential for sample contamination (see below).

4. For moderate to high-yielding monitoring wells, use one of the following purge techniques:
  - Place a submersible pump or the intake line of a surface pump or bailer just below the water surface when removing the stagnant water.

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- While purging and as the water level decreases, lower the pump or intake line as the water level drops in the well. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. After this is accomplished, a bailer or other approved device may be used to collect the sample for analysis.
- Unless otherwise directed, place the intake line of the sampling pump (or the submersible pump itself) near the center of the screened section, and pump approximately one casing volume of water from the well at a low purge rate equal to the well's recovery rate (low-flow sampling).

## 6.2 Sampling, Monitoring, and Evacuation Equipment

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

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

- Sample packaging and shipping equipment – Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler materials, ice, labels, and chain-of-custody documents.
- Field tools and instrumentation
  - Multi-parameter water quality meter with an in-line sample chamber capable of measuring ORP, pH, temperature, DO, specific conductance, turbidity, and salinity, or individual meters (as applicable)
  - pH Paper
  - Camera and film (if appropriate)
  - Appropriate keys (for locked wells)
  - Water level indicator and/or oil-water interface probe if separate-phase product is expected
- Pumps
  - Shallow-well pumps: Centrifugal, bladder, suction, or peristaltic pumps with drop lines and air-lift apparatus (compressor and tubing) where applicable.
  - Deep-well pumps: Submersible pump and electrical power-generating unit, or bladder pumps where applicable.
- Other sampling equipment – Bailers, graduated cylinder, stopwatch, and inert line with tripod-pulley assembly (if necessary).
- Pails – Plastic, graduated.
- Clean paper or cotton towels for cleaning equipment.
- Buckets with lids for collecting purge water.

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- Decontamination solutions – Deionized water, potable water, phosphate-free laboratory-grade detergent, and analytical-grade solvent (e.g., pesticide-grade isopropanol), as required.

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

### 6.3 Calculations of Well Volume

To ensure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to know the volume of standing water in the well pipe (including well screen where applicable). This volume can be easily calculated by the following method. Calculations shall be entered in the site logbook or field notebook or on a sample log sheet form or equivalent electronic form(s) (see SOP SA-6.3):

1. Obtain all available information on well construction (location, casing, screen, etc.).
2. Determine well or inner casing diameter.
3. Measure and record static water level (depth below ground level or top of casing reference point).
4. Determine depth of well by sounding using a clean, decontaminated, weighted tape measure or water level indicator.
5. Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).
6. Calculate one static well volume in gallons  $V = (0.163)(T)(r^2)$

where: V = Static volume of well in gallons.  
T = Linear feet of water in the well.  
r = Inside radius of well casing in inches.  
0.163 = Conversion factor (compensates for conversion of casing radius from inches to feet and cubic feet to gallons and pi.

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

Measuring devices may become contaminated when gathering the above information if they are submerged in contaminated water. Decontamination of the tape or water level indicator must be conducted between measurements in different wells as follows:

1. Saturate a paper towel or clean cotton towel with deionized water.
2. As the measuring device is extracted, wipe the tape, changing the cleaning surface frequently.
3. After it is extracted, rinse the probe or tape using a spray bottle of deionized water over a bucket or similar collection container.

Based on the contaminant (oily, etc), it may be necessary to use a soap and water wash and rinse to remove contaminants. Isopropanol can be used on the probe/tape. However, it is recommended that the use of solvents on the tape be minimized because they could degrade the protective covering or possibly

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remove the scale designations. If isopropanol (or some other solvent) is used, assure that the manufacturer/supplier Material Safety Data Sheet (MSDS) is obtained, kept on site at a readily available location with other MSDSs, and reviewed by personnel prior to the first usage of the solvent. Also, add the substance to the site-specific Hazardous Chemical Inventory list (see Section 5 of the TtNUS Health and Safety Guidance Manual [HSGM], Hazard Communication Program and OSHA Standard 29 CFR 1910.1200).

#### **6.4 Evacuation of Static Water – Purging**

##### **6.4.1 General**

The amount to be purged from each well will be determined prior to sample collection. This amount will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of the aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately, the well can be pumped until parameters such as temperature, specific conductance, pH, and turbidity (as applicable) have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook or field notebook or on standardized data sheets or an equivalent electronic form(s).

##### **6.4.2 Evacuation Devices**

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

##### **Bailers**

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of tubing equipped with a base plate and ball check-valve at the bottom. Bailers are comprised of stainless steel and plastic. They come in a variety of sizes, but the two most often used are 2 inches and 4 inches in diameter. An inert non-absorbent line such as polyethylene rope is used to lower and then raise the bailer to retrieve the sample. As the bailer is lowered into the water column, the ball is pushed up allowing the tube to be filled. When the bailer is pulled upward, the ball seats in the base plate preventing water from escaping.

Advantages of bailers include the following:

- There are few limitations on size and materials used.
- No external power source is needed.
- Bailers are inexpensive and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.

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- Splashing the bailer into the water or transfer of sample may cause aeration.
- The use of a bailer does not permit constant in-line monitoring of groundwater parameters.
- Use of bailers is physically demanding, especially in warm temperatures at personal protection equipment (PPE) levels above Level D.

Safety concerns using a bailer include the following:

- Muscle stress and strain, especially when using 4-inch bailers and when pulling from excessively deep wells.
- Entanglement, possible hand/finger injuries, and rope burns during a sudden release of the bailer back down the well.
- Direct contact with contaminants of concern and sample preservatives when discharging the bailer contents because there is not a high level of control during a direct pour, and splashing and indirect contact with contaminants/preservatives could occur.

Control measures for these hazards are provided in Section 6.6.2.

#### Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, and peristaltic pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low-volume pump that uses rollers to squeeze flexible tubing to create suction. This tubing can be dedicated to a well to prevent cross-contamination from well to well. Suction pumps are all portable, inexpensive, and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause loss of dissolved gases and volatile organics. Another limitation of these pumps is that they require a secondary energy source to drive them. Electrically driven pumps may require portable generators as energy sources. Air diaphragm pumps require air compressors and/or compressed gas cylinders to drive them. The advantage of the peristaltic pump is that it will operate from a portable battery source. Safety measures associated with these pumps are provided below.

#### Air-Lift and Gas-Lift Samplers

This group of pump samplers uses gas pressure either in the annulus of the well or in a venturi to force groundwater up a sampling tube. These pumps are also relatively inexpensive. Air- or gas-lift samplers are more suitable for well development than for sampling because the samples may be aerated as a result of pump action. Aeration can cause pH changes and subsequent trace metal precipitation or loss of volatile organics.

#### Submersible Pumps

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

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Limitations of this class of pumps include the following:

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

#### Compressed Gases

Safety concerns using compressed gases as an energy source in these pumps are numerous. The nitrogen gas or compressed air is provided in a compressed gas cylinder at a pressure of approximately 2,000 psi. If damaged, these cylinders can become dangerous projectiles. Additionally, a sudden release of a cylinder's contents can involve considerable force that could cause significant damage to the eyes and/or skin. Protective measures include the following:

- Always wear safety impact glasses when handling compressed gases.
- Always administer compressed gases through an appropriate pressure-reducing regulator.
- When clearing the cylinder connection port, open the cylinder valve only enough to clear foreign debris. During this process, always position the cylinder valve so that it faces away from you and others.
- If the cylinder is designed to accept a valve protection cap, always keep that protection cap in place, except the cylinder is connected for use.
- When using the cylinder, lay the cylinder on its side to avoid the potential of it falling and knocking the valve off (and becoming a missile).
- DO NOT use the compressed nitrogen or air to clean clothing or to spray off the skin. Small cuts in the protective layer of the skin may permit the gas to enter into the bloodstream, presenting the potential danger of an embolism.

See the project-specific HASP for additional direction concerning cylinder safe handling procedures pertaining to the safe handling, transportation, and storage of compressed gas cylinders.

#### Electrical Shock

Even in situations where portable batteries are used, the potential for electrical shock exists. This potential risk is increased in groundwater sampling activities because of the presence of groundwater near the batteries. This potential is also increased in (prohibited) situations where jury-rigging of electrical connections is performed. Other potential hazards occur when field samplers open the hood of a running car to access the battery as a power source. To control these hazards:

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- If you are unfamiliar with electrical devices, do not experiment, get help, and get the proper equipment necessary to power your device.
- Use the proper portable power inverters for cigarette lighter connections to minimize the need to access the battery under the hood of your vehicle.
- Use of electrical generators may pose a number of hazards including noise, those associated with fueling, and indirect sample influence.

To minimize or eliminate electrical generator hazards:

- Inspect the generator before use. Ensure that the generator and any extension cords are rated for the intended operation and have a Ground Fault Circuit Interrupter (GFCI) in line to control potential electrical shock.
- Fuel the generator before purging and sampling to avoid loss of power during sampling.
- Fuel engines only when they are turned OFF and have cooled sufficiently to prevent a fire hazard.
- Place the generator and any fuel source at least 50 feet from the well to be sampled to avoid indirect influence to the sample from fuel vapors or emission gases.

#### Lifting Hazards

This hazard may be experienced when moving containers of purge water, equipment, cylinders, etc. To control these potential hazards:

- Do not fill purge buckets to more than 80 percent of their capacity.
- Obtain a gas cylinder of sufficient size to complete the designated task but not too large to handle. K-size cylinders weigh approximately 135 pounds and are difficult to handle. M-size cylinders weigh approximately 50 pounds and are easier to handle and move.
- When necessary, get help lifting and moving gas cylinders and other heavy objects. Minimize twisting and turning while lifting. If it is necessary to move these cylinders or generators over significant distance, use mechanical means (carts, etc.).
- Use proper lifting techniques as described in Section 4.4 of the HSGM.

### 6.5 Onsite Water Quality Testing

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

- pH
- Specific conductance
- Temperature
- DO
- ORP
- Turbidity
- Salinity

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

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Because instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use. Most meters used to measure field parameters require calibration on a daily basis. Refer to SOP SA-6.3 for an example equipment calibration log.

### 6.5.1 Measurement of pH

#### 6.5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken and recorded on the groundwater sample log sheet (Attachment B) or equivalent electronic form.

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

#### 6.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or alkalinity determination) and specific, or narrower range, pH range paper.

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

#### 6.5.1.3 Equipment

The following equipment is to be used for obtaining pH measurements:

- A stand-alone portable pH meter or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).

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- Combination electrode with polymer body to fit the above meter. Alternately, a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs.
- Buffer solutions, as specified by the manufacturer. If the buffer solutions are considered hazardous per 29 Code of Federal Regulations (CFR) 1910.1200 (Hazard Communication) or the volumes used are greater than consumer commodity levels, the SSO shall obtain MSDSs from the manufacturer for the specific buffer solutions (see Section 4 of the HSGM regarding the Hazard Communication Program)
- pH indicator paper to cover the pH range 2 through 12.
- Manufacturer's operation manual. All personnel must be familiar with the equipment operation to ensure that the integrity of samples is preserved and that the equipment is operated safely.

#### 6.5.1.4 Measurement Techniques for Field Determination of pH

##### pH Meter

The following procedure shall be used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

1. Inspect the instrument and batteries prior to initiation of the field effort.
2. Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.
3. If applicable, make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
4. Calibrate the meter and electrode(s) on a daily use basis (or as recommended by manufacturer) following manufacturer's instructions. Record calibration data on a water quality meter calibration log sheet (Attachment C) or equivalent electronic form.
5. Immerse the electrode(s) in the sample. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. The failure of the measurements to stabilize must be clearly noted in the logbook or equivalent electronic form.
6. Read and record the pH of the sample. pH shall be recorded to the nearest 0.01 pH standard unit. Also record the sample temperature (unless otherwise specified in the SAP, record temperatures to the nearest whole degree Fahrenheit or 0.5 degree Celsius).
7. Rinse the electrode(s) with deionized water.
8. Store the electrode(s) in an accordance with manufacturer's instructions when not in use.

Any visual observation of conditions that may interfere with pH measurement, such as oily materials or turbidity, shall be noted and avoided as much as possible.

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## pH Paper

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

1. Collect a small portion of sample into a clean container.
2. Dip the pH paper into this small portion of sample.
3. Compare the color of the paper to the color chart that is provided with the pH paper and read the corresponding pH from the chart.
4. Record the pH value from the chart on the sampling log sheet.
5. Discard the used pH paper as trash.
6. Discard the small volume of sample that was used for the pH measurement with the other investigative derived waste.

### **6.5.2 Measurement of Specific Conductance**

#### 6.5.2.1 General

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

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

It is important to obtain a specific conductance measurement soon after taking a sample because temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect specific conductance. Most conductivity meters in use today display specific conductance in units of mS/cm, which is the conductivity normalized to a temperature of 25°C. These are the required units to be recorded on the groundwater sample log field form or equivalent electronic form.

#### 6.5.2.2 Principles of Equipment Operation

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

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also

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be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on the ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell, which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

#### 6.5.2.3 Equipment

The following equipment is needed for taking specific conductance measurements:

- Stand-alone portable conductivity meter or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available that may also be used to monitor salinity and temperature. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirements of the sampling program.

#### 6.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are as follows (calibration shall be conducted according to manufacturer's instructions):

1. Check batteries and calibrate instrument before going into the field.
2. Calibrate on a daily use basis (or as recommended by manufacturer), according to the manufacturer's instructions and record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used for calibration.
3. Rinse the cell with one or more portions of the sample to be tested or with deionized water and shake excess water from the cell.
4. Immerse the electrode in the sample and measure the conductivity.
5. Read and record the results in a field logbook or on a sample log sheet or equivalent electronic form.
6. Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for troubleshooting assistance.

### 6.5.3 Measurement of Temperature

#### 6.5.3.1 General

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

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### 6.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury-filled, dial-type thermometers or combination meters equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22). In addition, various meters such as specific conductance or DO meters that have temperature measurement capabilities may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

### 6.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample, use the following procedure:

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

If a temperature meter or probe is used:

1. Calibrate the instrument according to manufacturer's recommendations prior to use.
2. Immerse the meter/probe in the sample until temperature equilibrium is obtained (1 to 3 minutes). To avoid the possibility of cross-contamination, the meter/probe shall not be inserted into samples that will undergo subsequent chemical analysis.
3. Record values in a field logbook or on a sample log sheet or equivalent electronic form.

## 6.5.4 Measurement of Dissolved Oxygen

### 6.5.4.1 General

DO levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. In addition, the growth of many aquatic organisms and the rate of corrosivity are dependent on DO concentrations. Thus, analysis for DO is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in situ because concentrations may show a large change in a short time if the sample is not adequately preserved.

The monitoring method discussed herein is limited to the use of DO meters. Chemical methods of analysis (i.e., Winkler methods) are available but require more equipment and greater sample manipulation. Furthermore, DO meters using a membrane electrode are suitable for highly polluted waters because the probe is completely submersible and is not susceptible to interference caused by color, turbidity, or colloidal material or suspended matter.

### 6.5.4.2 Principles of Equipment Operation

DO probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH<sup>-</sup>) occurs at the cathode surface. An electrical

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current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode. This rate is proportional to the oxygen concentration in the water being measured.

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

DO probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases such as chlorine or with gases such as hydrogen sulfide that are not easily depolarized from the indicating electrode. If a gaseous interference is suspected, it shall be noted in the field logbook and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer. This compensation can counteract some of the temperature effects but not all of them.

#### 6.5.4.3 Equipment

The following equipment is needed to measure DO concentrations:

- A stand-alone portable DO meter or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

#### 6.5.4.4 Measurement Techniques for Dissolved Oxygen Determination

DO probes differ as to instructions for use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure DO concentrations:

1. Check the DO meter batteries before going to the field.
2. Condition the probe in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
3. Calibrate the instrument in the field according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature.
4. Record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form.
5. Rinse the probe with deionized water.
6. Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells may be moved up and down to achieve the required mixing.

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7. Record the DO content and temperature of the sample in a field logbook or on a sample log sheet or equivalent electronic form.
8. Rinse the probe with deionized water.
9. Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable because sample handling is not involved. This however may not always be practical.

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

### **6.5.5 Measurement of Oxidation-Reduction Potential**

#### 6.5.5.1 General

ORP provides a measure of the tendency of organic or inorganic chemicals to exist in an oxidized state. The ORP parameter therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of reduced to oxidized species in the sample.

#### 6.5.5.2 Principles of Equipment Operation

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

#### 6.5.5.3 Equipment

The following equipment is needed for measuring the ORP of a solution:

- A combination meter with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

#### 6.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring ORP:

1. Check the equipment using the manufacturer's recommended reference solution and check its batteries before going to the field.
2. Thoroughly rinse the electrode with deionized water.

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3. If the probe does not respond properly to the recommended reference solution, verify the sensitivity of the electrodes by noting the change in millivolts when the pH of a test solution is altered. The ORP will increase when the pH of a test solution decreases, and the ORP will decrease when the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note that the ORP drops sharply when the caustic is added (i.e., pH increases) thus indicating that the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions or the probe should be replaced.
4. Record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form.

### **6.5.6 Measurement of Salinity**

#### 6.5.6.1 General

Salinity is a unitless property of industrial and natural waters. It is the measurement of dissolved salts in a given mass of solution. Most field meters determine salinity automatically from conductivity and temperature. The displayed value will be displayed in either parts per thousand (ppt) or percent (e.g., 35 ppt equals 3.5 percent).

#### 6.5.6.2 Principles of Equipment Operation

Salinity is determined automatically from the meter's conductivity and temperature readings according to algorithms (such as are found in Standard Methods for the Examination of Water and Wastewater). Depending on the meter, the results are displayed in either ppt or percent. The salinity measurements are carried out in reference to the conductivity of standard seawater (corrected to salinity = 35 ppt).

#### 6.5.6.3 Equipment

The following equipment is needed for salinity measurements:

- A multi-parameter water quality meter capable of measuring conductivity and temperature and converting them to salinity (e.g., Horiba U-22 or YSI 600 series).
- Calibration solution as specified by the manufacturer.
- Manufacturer's operation manual.

#### 6.5.6.4 Measurement Techniques for Salinity

The steps involved in taking salinity measurements are as follows (standardization shall be conducted according to manufacturer's instructions):

1. Check the expiration date of the solutions used for field calibration and replace them if they are expired.
2. Check batteries and calibrate the meter before going into the field.

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3. Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form.
4. Rinse the cell with the sample to be tested. This is typically accomplished as the probe is placed in line during the collection of the purge water up to the time of sample acquisition.
5. Immerse the multi-probe in the sample and measure the salinity. Read and record the results in a field logbook or on a sample log sheet or equivalent electronic form.
6. Rinse the probes with deionized water.

### **6.5.7 Measurement of Turbidity**

#### **6.5.7.1 General**

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Turbidity in water is caused by suspended matter such as clay, silt, or other finely divided organic and inorganic matter and microscopic organisms including plankton.

It is important to obtain a turbidity reading immediately after taking a sample because irreversible changes in turbidity may occur if the sample is stored too long.

#### **6.5.7.2 Principles of Equipment Operation**

Turbidity is measured by the Nephelometric Method, which is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidimeter. Therefore, nephelometric turbidity units (NTUs) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

#### **6.5.7.3 Equipment**

The following equipment is needed for turbidity measurements:

- A turbidity meter (e.g., LaMotte 2020) that calibrates easily using test cells with standards of 0.0, 1.0, and 10 NTUs, or a combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Calibration solution and sample tubes, as specified by the manufacturer.
- Manufacturer's operation manual.

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#### 6.5.7.4 Measurement Techniques for Turbidity

The steps involved in taking turbidity measurements utilizing an electrode (e) or light meter (l) are listed below (standardization shall be done according to manufacturer's instructions):

1. Check the expiration date of the solutions used for field calibration and replace them if they are expired.
2. Check batteries and calibrate the instrument before going into the field.
3. Calibrate on a daily basis according to the manufacturer's instructions, and record all pertinent information on a turbidity meter calibration log sheet (Attachment C) or equivalent electronic form.
4. When using the YSI and/or Horiba U-22, rinse the electrode with one or more portions of the sample to be tested or with deionized water.
5. When using the Lamotte 2020, fill the light meter's glass test cell with approximately 5 mL of sample, screw on the cap, wipe off glass to remove all residue that could intercept the instrument's light beam, place the test cell in the light meter, and close the lid.
6. Immerse the electrode in the sample and measure the turbidity.
7. The reading must be taken immediately because suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.
8. Read and record the results in a field logbook or on a sample log sheet or equivalent electronic form. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.
9. Rinse the electrode or test cell with deionized water.

### 6.6 Sampling

#### 6.6.1 Sampling Plan

The sampling approach consisting of the following shall be developed as part of the project planning documents approved prior to beginning work in the field:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
- Intended number, sequence, volumes, and types of samples. If the relative degree of contamination between wells is insignificant, a sampling sequence that facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells. In situations where the well is not well-characterized and the nature or extent of airborne contamination is unknown, it is recommended that head space analysis using a photoionization detector (PID) or flame ionization detector (FID) is performed to rate the wells, sampling from least contaminated to most contaminated.

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Refer to the project-specific HASP for appropriate information and direction on air monitoring requirements.

- Sample preservation requirements.
- Work schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirements for split samples, access problems, location of keys, etc.
- The FOL shall ensure that the sampling method(s) to be employed is accurately represented in the HASP, indicating the types of sampling to be employed and the hazards. If the methods are not accurately represented, the FOL should rectify this with the HASP author.
- The FOL shall ensure that sampling teams understand the sampling approach that they are to follow. Where sampling teams are made up of personnel from multiple locations, personal sampling experiences may vary. Therefore the FOL shall review project-specific requirements, SOPs, and protocol to be followed. The FOL will conduct periodic surveys to ensure that these methods are being completed per his/her direction.

#### **6.6.2 Sampling Methods as Related to Low-Flow Sampling**

The collection of a groundwater sample consists of the following steps:

1. Ensure the safety of the sample location. Take a few minutes to evaluate the area for physical hazards (trip hazards, uneven ground, overhanging branches, etc.) and natural hazards (snakes, bees, spiders, etc.) that may exist in the area or that may have constructed nests in the well head. Snakes often like to sun themselves on concrete well pads. Follow provisions in the project-specific HASP and/or HSGM for addressing natural hazards.
2. As indicated earlier, some monitoring wells have the potential to contain pressurized headspace (e.g., through the generation of gases from contaminated groundwater, due to biological processes, degradation of contaminants, or simply based on location such as near a landfill or in areas that intersect lithological abnormalities) or through intentional artificial means such as those associated with air sparging systems. Injection or extraction wells may be artificially pressurized and may remain so for several days after the system has been turned off. This presents a hazard to people opening these wells. The Field Sampling Technician shall employ the following practices to minimize these hazards:
  - Wear safety glasses to protect the eyes. If site-specific observations and conditions indicate that the wells may be pressurized, wear a full-face shield over the safety impact eye protection.
  - DO NOT place your face or any other part of your body over the well when opening because this may place you in a strike zone.
  - Open the well cover at arms length, then step away and allow the well to off gas and stabilize.

Follow directions provided in the project-specific HASP, Work Plan and/or Sampling Plan pertaining to the use of volatile chemical detection equipment (PID or FID) within the breathing zone of the

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sampler during sampling to determine the need to retreat from the work area and/or for the use of respiratory protection (as specified in the HASP).

3. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data on a groundwater sampling log sheet or equivalent electronic form; then calculate the fluid volume in the well pipe (as previously described in this SOP). It is imperative that downhole equipment be adequately decontaminated between wells to prevent cross-contamination. Just as sampling occurs from the least contaminated to the most contaminated, it is also recommended that groundwater level measurements be taken in this manner.
4. Calculate volume of well water to be removed as described in Section 6.3.
5. Select the appropriate purging equipment (see Attachment A to this SOP) or as designated within your Work Plan/Sampling Plan. If an electric submersible pump with packer is chosen, go to Step 10.
6. Lower the purging equipment or intake into the well to a short distance below the water level or mid-screen as indicated in project-specific documentation and begin water removal. Remember that some contaminants are "bottom dwellers," and in these cases, project-specific direction may specify placing the intake just above (1 to 2 feet) the well bottom. Secure the pump intake at the well and secure the effluent at the collection container and begin pumping. The pumping rate will be determined based on the decrease in the water level (see Section 6.7) or as directed in your project-specific documents or this SOP. Purge water is generally collected in a 5-gallon bucket or similar open- or closed-top container. To minimize the potential for spills and back injuries, do not fill 5-gallon buckets beyond approximately 80 percent of their capacity. Dispose of purge water as indicated in the planning document(s). Where necessary, slow the pumping rate or lower the pump intake as required to maintain submergence.
7. Estimate the approximate rate of discharge frequently and record it on the Low Flow Purge Data Sheet (see Attachment D). Estimate flow rate by noting the amount of discharge in a bucket or graduated cylinder per unit time using a watch with a second hand or a stopwatch.
8. Observe the peristaltic pump tubing intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics.
9. Purge a minimum of three to five casing volumes before sampling (or as directed by the site-specific SAP). In low-permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recover to 75 percent of initial water level before sampling. Do not overfill purge containers because this increases the potential for spills and lifting injuries.
10. If sampling using a submersible pump, lower the pump intake to mid-screen (or the middle of the open section in uncased wells) and collect the sample. If sampling with a bailer, lower the bailer to just below the water surface.
11. For pump and packer assemblies only: Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. Purge a volume equal to at least twice the screened interval (or unscreened open section volume below the packer) before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
12. If the recovery time of the well is very slow (e.g., 24 hours or greater), sample collection can be delayed until the following day. If the well has been purged early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record

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this occurrence in the site logbook or equivalent electronic form. When this occurs, contact the analytical laboratory to alert them that a reduced sample volume(s) will be submitted for analysis.

13. Fill sample containers and preserve and label them as described in SOP SA-6.1. Many sample bottles will contain preservative when they are shipped to the field. In those cases, do not add preservative.
14. Replace the well cap and lock it as appropriate. Make sure the well is readily identifiable as the source of the sample.
15. Process sample containers as described in SOP SA-6.1.
16. Decontaminate equipment as described in SOP SA-7.1.

## **6.7 Low-Flow Purging and Sampling**

### **6.7.1 Scope and Application**

Low-flow purging and sampling techniques may be required for groundwater sampling activities. The purpose of low-flow purging and sampling is to collect groundwater samples that contain "representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at or near natural flow conditions. This minimum-stress procedure emphasizes negligible water level drawdown and low pumping rates to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 1 inch or more and a saturated screen length, or open interval, of 10 feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semivolatile organic compounds, pesticides, polychlorinated biphenyls [PCBs], metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This low-flow procedure is not designed for collection of non-aqueous phase liquid samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs).

This procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 10 NTUs and to achieve a water level drawdown of less than 0.3 foot during purging and sampling. If these goals cannot be achieved, sample collection can take place provided that the remaining criteria in this procedure are met.

### **6.7.2 Equipment**

The following equipment is required (as applicable) for low-flow purging and sampling:

- Adjustable rate submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon).
- Disposable clear plastic bottom-filling bailers to be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing – Teflon, Teflon-lined polyethylene, polyethylene, polyvinyl chloride (PVC), Tygon, or stainless steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device with 0.01-foot accuracy (electronic devices are preferred for tracking water level drawdown during all pumping operations).

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- Interface probe.
- Flow measurement supplies.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments – pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional indicators - ORP, salinity, and DO. A flow-through cell (also referred to as an in-line sample chamber) is required.
- Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s) and other forms (see Attachments B through D) or equivalent electronic form(s).
- Sample bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags and/or labels.
- Well construction data, location map, field data from last sampling event (if available).
- Field Sampling Plan.
- PID or FID instrument for measuring volatile organic compounds (VOCs) per the HASP.

### **6.7.3 Purging and Sampling Procedure**

1. Open the monitoring well as stated earlier and step away. Prepare sampling equipment while allowing 3 to 5 minutes to allow the water level to reach equilibrium. In situations where VOCs are the primary contaminants of concern, air monitoring of the samplers' breathing zone areas may be required by the HASP (typically with a PID or FID).
2. Measure the water level immediately prior to placing the pump in the well and record the water level on the Low-Flow Purge Data Form or equivalent electronic form immediately prior to placing the pump or tubing into the well.
3. Lower the measuring device further into the well to collect the total depth measurement. Again wait 3 to 5 minutes to allow the well to equilibrate to the initial water level prior to placing the pump or pump intake in the well.
4. Record the total well depth on the Low-Flow Purge Data Form or equivalent electronic form immediately prior to placing the pump or tubing into the well
5. Lower the pump or tubing slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible, keep the pump intake at least 2 feet above the bottom of the well to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbidity-free water samples may be difficult if there is 3 feet or less of standing water in the well.

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6. Start with the initial pump rate set at approximately 0.1 liter per minute. Use a graduated cylinder and stopwatch to measure the pumping rate. Adjust the pumping rates as necessary to prevent drawdown from exceeding 0.3 foot during purging. If no drawdown is noted, the pump rate may be increased (to a maximum of 0.4 liter per minute) to expedite the purging and sampling event. The pump rate will be reduced if turbidity is greater than 10 NTUs after all other field parameters have stabilized. If groundwater is drawn down below the top of the well screen, purging shall cease or the well shall be pumped to dryness and then allowed to recover before purging continues. Well recovery to 75 percent is necessary prior to sampling. Slow-recovering wells should be identified and purged at the beginning of the workday to maximize field work efficiency. If possible, samples should be collected from these wells within the same workday and no later than 24 hours after the end of purging.
  7. Measure the water level in the well every 5 to 10 minutes using the water level meter. Record the well water level on the Low Flow Purge Data Form (Attachment D) or equivalent electronic form.
  8. Record on the Low Flow Purge Data Form every 5 to 10 minutes the water quality parameters (pH, specific conductance, temperature, turbidity, ORP, DO, and salinity or as specified by the approved site-specific planning document) measured by the water quality meter and turbidity meter. If the cell needs to be cleaned during purging operations, continue pumping (allow the pump to discharge into a container) and disconnect the cell. Rinse the cell with distilled/deionized water. After cleaning is completed, reconnect the flow-through cell and continue purging. Document the cell cleaning on the Low-Flow Purge Data Form or equivalent electronic form.
  9. Estimate the flow rate by noting the amount of discharge in a graduated cylinder per unit time using a watch with a second hand. Remeasure the flow rate any time the pump rate is adjusted and periodically during purging. This will determine if a reduction in rate has occurred due to possible battery depletion.
  10. During purging, check for the presence of bubbles in the flow-through cell. The presence of bubbles is an indication that connections are not tight. If bubbles are observed, check for loose connections and tighten, repair, or replace them as necessary to achieve a tight connection.
  11. Wait until stabilization is achieved, or a minimum of two saturated screen volumes have been removed and three consecutive readings, taken at 5 to 10 minute intervals, are within the following limits, then begin sampling:
    - pH  $\pm 0.2$  standard units
    - Specific conductance  $\pm 10\%$
    - Temperature  $\pm 10\%$
    - Turbidity less than 10 NTUs
    - DO  $\pm 10\%$
  12. If the above conditions have not been met after the well has been purged for 4 hours, purging will be considered complete and sampling can begin. Record the final well stabilization parameters from the Low-Flow Purge Data Form onto the Groundwater Sample Log Form or equivalent electronic form.
- NOTE:** VOC samples are preferably collected first, directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.
13. If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples:

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- Collect samples for non-VOC analyses first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample for VOCs, and record the new flow rate.
- Reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel) or clamp, which should reduce the flow rate by constricting the end of the tubing. Proceed with sample collection.
- Insert a narrow-diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, then collect the sample from the narrow diameter tubing.
- Prepare samples for shipping as per SOP SA-6.1.

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Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level <25 feet	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>			
	Water Level >25 feet	<b>X</b>			<b>X</b>				
2-Inch	Water level <25 feet	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>		
	Water Level >25 feet	<b>X</b>			<b>X</b>		<b>X</b>		
4-Inch	Water level <25 feet	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
	Water Level >25 feet	<b>X</b>			<b>X</b>		<b>X</b>	<b>X</b>	<b>X</b>
6-Inch	Water level <25 feet				<b>X</b>	<b>X</b>		<b>X</b>	<b>X</b>
	Water Level >25 feet				<b>X</b>			<b>X</b>	<b>X</b>
8-Inch	Water level <25 feet				<b>X</b>	<b>X</b>		<b>X</b>	<b>X</b>
	Water Level >25 feet				<b>X</b>			<b>X</b>	<b>X</b>

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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/L ength (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	\$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	<1.0/NA	(not submersible) Tygon®, silicone Viton®	0-30	670 mL/min with 7015-20 pump head	\$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	Portable; venturi	<1.5 or <2.0/NA	PP, PE, PVC, SS, Teflon®, Tefzel®	0-100	0-500 mL/min depending on lift	\$400-700	AC, DC, or gasoline-driven motors available; must be primed.
Geltek Corp.	Bailer 219-4	Portable; grab (positive displacement)	1.66/38	Teflon®	No limit	1,075 mL	\$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton®	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	\$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon®, Viton®	0-250	0-2,800 mL/min	\$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon®	No limit	850 mL sample volume	\$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2600 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon®, PP, PE, Detrin®, acetal	0-150	0-7,500 mL/min	\$990	Requires compressed gas (40 psi minimum).
Keck Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-160	0-4,500 mL/min	\$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3,500 mL/min	\$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin®	No limit	Approximately 250 mL	\$125-160	Other materials and models available; for measuring thickness of "floating" contaminants.
Q.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.66/36	PVC	0-230	0-2,000 mL/min	\$300-400	Requires compressed gas; piezometric level indicator; other materials available.

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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/L ength (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	Portable; peristaltic (suction)	<0.5/NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	\$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 180	Portable; piston (positive displacement)	1.8/22	SS, Teflon®, Delrin® PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	\$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 514124 Pneumatic Water Sampler	Portable; gas drive (positive displacement)	1.9/18	PVC, nylon	0-1,100	250 mL/flushing cycle	\$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	5W Water Sampler	Portable; grab (positive displacement)	1.9/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	\$1,300-1,800	Requires compressed gas; custom models available.
TIMCO Mfg. Co., Inc.	Std. Bailer	Portable; grab (positive displacement)	1.66/Custom	PVC, PP	No limit	250 mL/ft of bailer	\$20-60	Other sizes, materials, models available; optional bottom-emptying device available; no solvents used.
TIMCO	Air or Gas Lift Sampler	Portable; gas drive (positive displacement)	1.66/30	PVC, Tygon®, Teflon®	0-150	350 mL/flushing cycle	\$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tole Devices Co.	Sampling Pump	Portable; bladder (positive displacement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	\$800-1,000	Compressed gas required; DC control module; custom built.

## Construction Material Abbreviations:

PE Polyethylene  
 PP Polypropylene  
 PVC Polyvinyl chloride  
 SS Stainless steel  
 PC Polycarbonate  
 EPDM Ethylene-propylene diene (synthetic rubber)

## Other Abbreviations:

NA Not applicable  
 AC Alternating current  
 DC Direct current

NOTE: Other manufacturers market pumping devices which could be used for groundwater sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication. No skimmer, scavenger-type, or high-capacity pumps are included.

Source: Barcelona et al., 1983.

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# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
SOIL SAMPLING

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## 1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures to be used to collect surface, near-surface, and subsurface soil samples. Additionally, it describes the methods for sampling of test pits and trenches to determine subsurface soil and rock conditions and for recovery of small-volume or bulk samples from pits.

## 2.0 SCOPE

This document applies to the collection of surface, near-surface, and subsurface soil samples exposed through hand digging, hand augering, drilling, or machine excavating at hazardous substance sites for laboratory testing, onsite visual examination, and onsite testing.

## 3.0 GLOSSARY

Composite Sample - A composite sample is a combination of more than one grab sample from various locations and/or depths and times that is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples shall not be collected for volatile organics analysis.

Confined Space - As stipulated in 29 Code of Federal Regulations (CFR) 1910.146, a confined space means a space that: (1) is large enough and so configured that an employee can bodily enter and perform assigned work; (2) has limited or restricted means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, pits, and excavations); and (3) is not designed for continuous employee occupancy. Tetra Tech considers all confined space as permit-required confined spaces.

Grab Sample - One sample collected at one location and at one specific time.

Hand Auger - A sampling device used to extract soil from the ground.

Representativeness – A qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been collected.

Sample for Non-Volatile Analyses - Includes all chemical parameters other than volatile organics (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-barrel sampler is typically available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-barrel samplers commonly range in size from 2 to 3.5 inches OD. The larger sizes are commonly used when a larger volume of sample material is required (see Attachment B).

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher, excavator, or bulldozer).

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Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

#### 4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - The Project Manager is responsible for determining the sampling objectives, selecting proposed sampling locations, and selecting field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan. This will include (but not be limited to) performing air quality monitoring during sampling, boring, and excavation activities and to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation, and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - This individual is primarily responsible for the execution of the planning document containing the Sampling and Analysis Plan (SAP). This is accomplished through management of a field sampling team for the proper acquisition of samples. He or she is responsible for the supervision of onsite analyses; ensuring proper instrument calibration, care, and maintenance; sample collection and handling; the completion and accuracy of all field documentation; and making sure that custody of all samples obtained is maintained according to proper procedures. When appropriate and as directed by the FOL, such responsibilities may be performed by other qualified personnel (e.g., field technicians) where credentials and time permit. The FOL is responsible for finalizing the locations for collection of surface, near-surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits, and trenches and for adherence to Occupational Safety and Health Administration (OSHA) regulations during these operations through self acquisition or through the management of a field team of samplers.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of samples in accordance with this SOP and/or other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

General personnel qualifications for groundwater sample collection and onsite water quality testing include the following:

- Occupational Safety and Health Administration (OSHA) 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate procedures for sample documentation, handling, packaging, and shipping.

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## 5.0 HEALTH AND SAFETY

Health and safety precautions are identified for individual sample collection procedures throughout this SOP. In addition to those precautions, the following general hazards may be incurred during sampling activities:

- Knee injuries from kneeling on hard or uneven surfaces
- Slips, trips, and falls
- Cuts and lacerations
- Traffic hazards associated with sampling in parking areas, along roadways and highways.

Methods of avoiding these hazards are provided below.

**Knee injuries** – If kneeling is required during soil sampling, this could result in knee injuries from stones/foreign objects and general damage due to stress on the joints. To minimize this hazard:

- Clear any foreign objects from the work area.
- Wear hard-sided knee pads.
- Stretch ligaments, tendons and muscles before, during and after. Take breaks as frequently as necessary.
- Report pre-existing conditions to the SSO if you feel this activity will aggravate an existing condition.

**Slips, Trips, and Falls** – These hazards exist while traversing varying terrains carrying equipment to sample locations. To minimize these hazards:

- Pre-survey sampling locations. Eliminate, barricade, or otherwise mark physical hazards leading to the locations.
- Carry small loads that do not restrict the field of vision.
- Travel the safest and clearest route (not necessarily the shortest).

**Cuts and Lacerations** - To prevent cuts and lacerations associated with soil sampling, the following provisions are required:

- Always cut away from yourself and others when cutting tubing or rope. This will prevent injury to yourself and others if the knife slips.
- Do not place items to be cut in your hand or on your knee.
- Change blades as necessary to maintain a sharp cutting edge. Many accidents result from struggling with dull cutting attachments.
- Whenever practical, wear cut-resistant gloves (e.g., leather or heavy cotton work gloves) at least on the hand not using the knife.

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- Keep cutting surfaces clean and smooth.
- Secure items to be cut – do not hold them against the opposing hand, a leg, or other body part.
- When transporting glassware, keep it in a hard-sided container such as a cooler so that if there is a fall, you will be less likely to get cut by broken glass.
- DO NOT throw broken sample jars or glass ampoules into garbage bags. Place broken glass and glass ampoules in hard-sided containers such as a cardboard box or directly into a dumpster. DO NOT reach into garbage bags to retrieve any item accidentally thrown away. Empty the contents onto a flat surface to avoid punctures and lacerations from reaching where you cannot see.

**Vehicular and Foot Traffic Hazards** – When sampling along the roadway or near traffic patterns, follow the following precautions:

- Motorists may be distracted by onsite activities – ASSUME THEY DO NOT SEE YOU OR MEMBERS OF YOUR FIELD CREW.
- DO NOT place obstructions (such as vehicles) along the sides of the road that may cause site personnel to move into the flow of traffic to avoid your activities or equipment or that will create a blind spot.
- **Provide a required free space of travel.** Maintain at least 6 feet of space between you and moving traffic. Where this is not possible, use flaggers and/or signs to warn oncoming traffic of activities near or within the travel lanes.
- Face Traffic. Whenever feasible, if you must move within the 6 feet of the required free space or into traffic, attempt to face moving traffic at all times. Always leave yourself an escape route.
- Wear high-visibility vests to increase visual recognition by motorists.
- Do not rely on the vehicle operator's visibility, judgment, or ability. Make eye contact with the driver. Carefully and deliberately use hand signals so they will not startle or confuse motorists or be mistaken for a flagger's direction before moving into traffic.
- Your movements may startle a motorist and cause an accident, so move deliberately. Do not make sudden movements that might confuse a motorist.

## 6.0 PROCEDURES

The following procedures address surface and subsurface sampling.

**CAUTION**

Each situation must be evaluated individually to determine the applicability and necessity for obtaining a utility clearance ticket/dig permit. Common sense dictates, prior to digging or boring with power equipment, no matter what the depth, or digging by hand in a manner that could damage unprotected underground utilities, that a dig permit is required. See SOP HS-1.0, Utility Locating and Excavation Clearance, for additional clarification. If you do not know or are unsure as to whether a ticket is necessary – **Get the Ticket.**

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## 6.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they migrate to the water table, and can establish the amount of contamination absorbed or adsorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can affect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during sampling operations, particularly noting sampling locations, depths, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. Certain vegetation species can create degradation products that can alter contaminant concentrations in soil. This is why vegetation types and extent of degradation of this foliage must be recorded. To prevent degradation, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers, and be analyzed as soon as possible after collection. In addition, to the extent possible, vegetation should be removed from the sample.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. It is the intent of this document to present the most commonly employed soil sampling methods used at hazardous waste sites.

## ~~6.2 Soil Sample Collection~~

### ~~6.2.1 Procedure for Preserving and Collecting Soil Samples for Volatile Organic Compound Analysis~~

~~Samples collected using traditional methods such as collection in a jar with no preservation have been known to yield non-representative samples due to loss of volatile organic compounds (VOCs). To prevent such losses, preservation of samples with methanol or sodium bisulfate may be used to minimize volatilization and biodegradation. This preservation may be performed either in the field or laboratory, depending on the sampling methodology employed. Because of the large number of sampling methods and associated equipment required, careful coordination between field and laboratory personnel is needed.~~

~~Soil samples to be preserved by the laboratory are currently being collected using Method SW-846, 5035. For samples preserved in the field, laboratories are currently performing low-level analyses (sodium bisulfate preservation) and high- to medium-level analyses (methanol preservation) depending on the needs of the end user.~~

~~The following procedures outline the necessary steps for collecting soil samples to be preserved at the laboratory, and for collecting soil samples to be preserved in the field with methanol or sodium bisulfate.~~

#### ~~6.2.1.1 Soil Samples to be Preserved at the Laboratory~~

~~Soil samples collected for volatile organic analysis that are to be preserved at the laboratory shall be obtained using a hermetically sealed sample vial such as an EnCore™ sampler. Each sample shall be~~

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obtained using a reusable sampling handle (T-handle) that can be provided with the EnCore™ sampler when requested and purchased. Collect the sample in the following manner for each EnCore™ sampler:

1. Scene Safety - Evaluate the area where sampling will occur. Ensure that the area is safe from physical, chemical, and natural hazards. Clear or barricade those hazards that have been identified.
2. Wear the appropriate personal protective equipment (PPE). This will include, at a minimum, safety glasses and nitrile surgeon's gloves. If you must kneel on the ground or place equipment on the surface being sampled, cover the ground surface with plastic to minimize surface contamination of your equipment and clothing. Wear knee pads to protect your knees from kneeling on hard or uneven surfaces.
3. Load the Encore™ sampler into the T-handle with the plunger fully depressed.
4. Expose the area to be sampled using a hand trowel or similar device to remove surface debris.
5. Press the T-handle against the freshly exposed soil surface, forcing soil into the sampler. The plunger will be forced upward as the cavity fills with soil.
6. When the sampler is full, rotate the plunger and lock it into place. If the plunger does not lock, the sampler is not full. This method ensures there is no headspace. Soft soil may require several plunges or forcing soil against a hard surface such as a sample trowel to ensure that headspace is eliminated.
7. Use a paper towel to remove soil from the side of the sampler so a tight seal can be made between the sample cap and the rubber O-ring.
8. With soil slightly piled above the rim of the sampler, force the cap on until the catches hook the side of the sampler.
9. Remove any surface soil from the outside of the sampler and place in the foil bag provided with the sampler. Good work hygiene practices and diligent decontamination procedures prevents the spread of contamination even on the outside of the containers.
10. Label the bag with appropriate information in accordance with SOP SA-6.3.
11. Place the full sampler inside a lined cooler with ice and cool to 4°C ± 2 °C. Make sure any required trip blanks and temperature blanks are also in the cooler. Secure custody of the cooler in accordance with SOP SA-6.3.
12. Typically, collect three Encore™ samplers at each location. Consult the SAP or laboratory to determine the required number of Encore™ samplers to be collected.
13. The T-handle shall be decontaminated before moving to the next interval or location using a soap and water wash and rinse, and where applicable, the selected solvent as defined in the project planning documents.

Using this type of sampling device eliminates the need for field preservation and the shipping restrictions associated with preservatives. A complete set of instructions is included with each Encore™ sampler.

After the Encore™ samples are collected, they should be placed on ice immediately and delivered to the laboratory within 48 hours (following the chain-of-custody and documentation procedures outlined in SOP SA-6.1). Samples must be preserved by the laboratory within 48 hours of sample collection.

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### 2.1.2 Soil Samples to be Preserved in the Field

Soil samples preserved in the field may be prepared for analyses using both the low-level (sodium bisulfate preservation) and high- to medium-level (methanol preservation) methods.

#### **Safety Reminder**

When using chemicals in the field to preserve samples, the FOL and/or SSO must ensure that Materials Safety Data Sheets (MSDSs) have been provided with the chemicals to be used. They also must ensure that these chemicals have been added to the Chemical Inventory List contained within Section 5.0, Hazard Communication, of your Health and Safety Guidance Manual (HSGM). Lastly, but most importantly, the FOL and/or SSO must review the hazards with personnel using these chemicals and ensure that provisions are available for recommended PPE and emergency measures (e.g., eyewash, etc.).

#### **Methanol Preservation (High to Medium Level):**

Bottles may be pre-spiked with methanol in the laboratory or prepared in the field. Soil samples to be preserved in the field with methanol shall utilize 40 to 60 mL glass vials with septum-lined lids. Each sample bottle shall be filled with 25 mL of demonstrated analyte-free purge-and-trap grade methanol. The preferred method for adding methanol to the sample bottle is by removing the lid and using a pipette or scaled syringe to add the methanol directly to the bottle.

#### **CAUTION**

NEVER attempt to pipette by mouth

In situations where personnel are required to spike the septum using a hypodermic needle, the following provisions for handling sharps must be in place:

- Training of personnel regarding methods for handling of sharps
- Hard-sided containers for the disposal of sharps
- Provisions for treatment in cases where persons have received a puncture wound

Soil shall be collected with the use of a decontaminated (or disposable), small-diameter coring device such as a disposable tube/plunger-type syringe with the tip cut off. The outside diameter of the coring device must be smaller than the inside diameter of the sample bottle neck.

A small electronic balance or manual scale will be necessary for measuring the volume of soil to be added to the methanol-preserved sample bottle. Calibration of the scale shall be performed prior to use and intermittently throughout the day according to the manufacturer's requirements.

The sample should be collected as follows:

1. Weigh the unused syringe and plunger to the nearest 0.01 gram.
2. Pull the plunger back and insert the syringe into the soil to be sampled.
3. Collect 8 to 12 grams of soil by pushing the syringe barrel into the soil.
4. Weigh the sample and adjust until obtaining the required amount of sample.

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5. Record the sample weight to the nearest 0.01 gram in the field logbook and/or on the sample log sheet.
6. Extrude the weighed soil sample into the methanol-preserved sample bottle taking care not to contact the sample container with the syringe.
7. If dirty, wipe soil particles from the threads of the bottle and cap. Cap the bottle tightly.
8. After capping the bottle, swirl the sample (do not shake) in the methanol and break up the soil such that all of the soil is covered with methanol.
9. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

**Sodium Bisulfate Preservation (Low Level):**

**CAUTION**

Care should be taken when adding the soil to the sodium bisulfate solution. A chemical reaction of soil containing carbonates (limestone) may cause the sample to effervesce or the vial to possibly explode. To avoid this hazard or hazards of this type, a small sample aliquot should be subjected to the sample preservative. If it effervesces in an open air environment, utilize an alternative method such as Encore™ or 2-ounce jar.

Bottles may be prepared in the laboratory or in the field with sodium bisulfate solution. Samples to be preserved in the field using the sodium bisulfate method are to be prepared and collected as follows:

1. Add 1 gram of sodium bisulfate to 5 mL of laboratory-grade deionized water in a 40 to 60 mL glass vial with septum-lined lid.
2. Collect the soil sample and record the sample weight to the nearest 0.01 gram in the field logbook or on the sample log sheet as described for methanol preservation
3. Add the weighed sample to the sample vial.
4. Collect duplicate samples using the methanol preservation method on a one-for-one sample basis because it is necessary for the laboratory to perform both low-level and medium-level analyses.
5. Place the samples on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

**NOTE**

If lower detection limits are necessary, an option to field preserving with sodium bisulfate may be to collect EnCore™ samplers at a given sample location. Consult the planning documents to determine whether this is required. If it is, collect samples in accordance with the Encore™ sampling procedure above and then send all samplers to the laboratory to perform the required preservation and analyses.

**6.2.2 Procedure for Collecting Soil Samples for Non-Volatile Analyses**

Samples collected for non-volatile analyses may be collected as either grab or composite samples as follows:

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1. With a stainless steel trowel or other approved tool, transfer a portion of soil to be sampled to a stainless steel bowl or disposable inert plastic tray.
2. Remove roots, vegetation, sticks, and stones larger than the size of a green pea.
3. Thoroughly mix the soil in the bowl or tray to obtain as uniform a texture and color as practicable. The soil type, moisture content, amount of vegetation, and other factors may affect the amount of time required to obtain a properly mixed sample. In some cases, it may be impossible to obtain a uniform sample appearance. Use the field logbook to describe any significant difficulties encountered in obtaining a uniform mixture.
4. Transfer the mixed soil to the appropriate sample containers and close the containers.
5. Label the sample containers in accordance with SOP SA-6.3.
6. Place the containers in a cooler of ice as soon after collection as possible.
7. Prepare the sample shipment and ship the samples in accordance with SOP SA-6.1.

**NOTE**  
Cooling may not be required for some samples depending on the scheduled analyses. Consult the planning documents if in doubt regarding correct sample preservation conditions. When in doubt – Cool to 4° C.

**NOTE**  
Head space is permitted in soil sample containers for non-volatile analyses to allow for sample expansion.

**6.2.3 Procedure for Collecting Undisturbed Soil Samples**

**NOTE**  
Use of thin-walled undisturbed tube samplers is restricted by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soil with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dennison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soil. Using these devices normally increases sampling costs, and therefore their use should be weighed against the need for acquiring an undisturbed sample. These devices are not discussed in this SOP because they are not commonly used.

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) shall be employed using the following collection procedure:

1. In preparation for sampling utilizing a drill rig, field personnel must complete the following activities:
  - Ensure that all subsurface drilling activities are preceded by a utility clearance for the area to be investigated. This includes activities described in SOP HS-1.0, Utility Location and Excavation Clearance, as well as any location-specific procedures that may apply.

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**REMEMBER**

If you are digging near a marked utility (within the diameter of an underground utility that has been marked plus 18 inches), you must first locate the utility through vacuum extraction or hand digging to ensure that your activities will not damage the utility.

- Complete an Equipment Inspection Checklist for the drill rig or direct-push technology (DPT) rig. This checklist will be provided in the HASP.
  - Review the Safe Work Permit prior to conducting the activity.
  - Review the activity to be conducted.
2. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and/or clean out the borehole to the desired sampling depth. Be careful to minimize potential disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

**CAUTION**

The use of bottom-discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Only the use of side-discharge bits is permitted.

3. Determine whether a stationary piston-type sampler is required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used.
4. Prior to inserting the tube sampler into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal. In addition, the check valve maintains a positive suction within the tube to help retain the sample.
5. A stainless steel tube sampler is typically used to minimize chemical reaction between the sample and the sampling tube.
6. With the sampling tube resting on the bottom of the hole and the water level in the boring at groundwater level or above, push the tube into the soil with a continuous and rapid motion, without impacting or twisting. If the soil is too hard to penetrate by pushing alone, careful hammering may be used by minimizing drop distance (tapping) of the hammer. Before pulling the tube, turn it at least one revolution to shear the sample off at the bottom. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.
7. Upon removal of the sampling tube from the hole, measure the length of sample in the tube and also the length penetrated.
8. Remove disturbed material in the upper end of the tube and measure the length of sample again.
9. After removing at least 1 inch of soil from the lower end, place enough packing material (clean inert material such as paper or cloth) tightly in each end of the Shelby tube and then pour melted wax into each end to make at least a ½-inch wax plug and then add more packing material to fill the voids at both ends.

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10. Place plastic caps on the ends, tape the caps in place, and dip the ends in wax to prevent loss of soil.
11. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label.
12. Mark the "up" direction on the side and upper end of the tube with indelible ink.
13. Complete a chain-of-custody form (see SOP SA-6.3) and other required forms (including Attachment A of this SOP).
14. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

**CAUTION**

To preserve sample integrity do not allow tubes to freeze, and store the samples vertically with the same orientation they had in the ground, (i.e., top of sample is up) in a cool place out of the sun at all times.

**CAUTION**

A primary concern in the preparation of the wax plugs is the potential for the heat source and melted wax to cause a fire and/or burns. Follow the directions below to prevent injury or fire.

**Electrical Heating**

Using hot plates to melt the wax is acceptable. In an outdoor setting, make sure a Ground Fault Circuit Interrupter (GFCI) is employed within the electrical circuit. If a portable generator is used, ensure that the generator is an adequate distance from the sampling operation (at least 50 feet). Ensure that the extension cord is rated for the intended load and for outdoor use and is free from recognizable damage. Ensure flammable preservatives are not employed or stored near the hot plate. Although a Hot Work Permit is not required, scene safety evaluation by site personnel of the above elements is. As always, if a fire potential exists, the provisions for extinguishing must be immediately accessible as well as any provisions for first aid measures.

**Open Flame**

If an open flame is used, the following provisions are necessary:

- Complete a Hot Work Permit and any local permit required for elevated temperature applications. The Hot Work Permit, provided in your HASP, will aid the FOL and/or the SSO in ensuring that fire protection provisions (extinguishers, fire watches, etc.) are in place as well as ensuring that local requirements have been addressed.
- Ensure that water is available to address any wax splashes or contact. If possible, immerse the contacted area. Where this is not possible, run water over the area and apply cold compresses. The need for medical attention or first aid shall be determined on site under the direction of the SSO.

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**6.3 Surface Soil Sampling**

The simplest, most direct method of collecting surface soil samples for subsequent analysis is by use of a stainless steel shovel, hand auger, soil corer, or stainless steel or disposable plastic trowel.

**NOTE**

Multiple depth intervals are used to describe surface soil. Sometimes surface soil is defined as soil from 0 to 2 inches below ground surface (bgs), and sometimes it is defined as soil from other depths such as 0 to 2 feet bgs. Ensure that the definition of surface soil depth is clear before collecting surface soil samples.

For the purposes of instruction, the terms "surface soil" and "near-surface soil" are used in this SOP as follows:

- Surface soil - 0 to 6 inches bgs
- Near-surface soil - 6 to 18 inches bgs

If these intervals are defined differently in the planning documents, substitute the appropriate depth ranges.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel or pre-cleaned disposable trowel.
- Stainless steel hand auger, soil corer, or shovel.
- Real-time air monitoring instrument (e.g., PID, FID) as directed in project planning document.
- Required PPE.
  - Nitrile surgeon's or latex gloves may be used, layered as necessary.
  - Safety glasses
  - Other – Items identified on the Safe Work Permit may be required based on location-specific requirements such as hearing protection, steel-toed work boots, and a hard hat when working near a drill rig. These provisions will be listed in the HASP or directed by the FOL and/or SSO.

**Safety Reminder**

The use of latex products may elicit an allergic reaction in some people. Should this occur, remove the latex gloves, treat for an allergic reaction, and seek medical attention as necessary.

- Required paperwork (see SOP SA-6.3 and Attachment A of this SOP)
- Required decontamination equipment
- Required sample container(s)
- Wooden stakes or pin flags

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- Sealable polyethylene bags (e.g., Ziploc® baggies)
- Heavy duty cooler
- Ice
- Chain-of-custody records and custody seals

When acquiring surface soil samples, use the following procedure:

1. Place padding or use knee pads when kneeling near the sample location. If necessary, place plastic sheeting to provide a clean surface for sample equipment to avoid possible cross- contamination.
2. Carefully remove vegetation, roots, twigs, litter, etc. to expose an adequate soil surface area to accommodate sample volume requirements.
3. Using a precleaned syringe or EnCore™ samplers, follow the procedure in Section 6.2.1 for collecting surface soil samples for volatile analysis. Surface soil samples for volatile organic analysis should be collected deeper than 6 inches bgs because shallower material has usually lost most of the volatiles through evaporation. Ensure that the appropriate surface soil depth is being analyzed in accordance with the planning document.
4. Using decontaminated sampling tools, thoroughly mix in place a sufficient amount of soil to fill the remaining sample containers. See Section 6.5 of this procedure for hand auger instruction, as needed.
5. Transfer the sample into those containers utilizing a stainless steel trowel.
6. Cap and securely tighten all sample containers.
7. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.
8. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.
9. Site restoration – Whenever removing sample materials, always restore the surface. It is our intent to leave the area better than we found it. Do NOT create trip hazards in areas when pedestrian traffic may exist.

#### **6.4 Near-Surface Soil Sampling**

Collection of samples from near the surface (depth of 6 to 18 inches) can be accomplished with tools such as shovels, hand auger, soil corers, and stainless steel or pre-cleaned disposable trowels and the equipment listed under Section 6.5 of this procedure.

To obtain near-surface soil samples, the following protocol shall be used:

1. With a clean shovel, make a series of vertical cuts in the soil to the depth required to form a square approximately 1 foot by 1 foot.
2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel or pre-cleaned disposable trowel to remove any loose soil.

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3. Follow steps 1 through 9 of Section 6.3.

### 6.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of stainless steel bucket bits (approximately 6.5 inches long and 2, 2.75, 3.25, and 4 inches in diameter), series of extension rods (available in 2-, 3-, 4- and 5-inch lengths), and a T-handle connected to extension rods and to the auger bucket. A larger-diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then it is withdrawn. The larger-diameter bit is then replaced with a smaller-diameter bit, lowered down the hole, and slowly turned into the soil to the completion depth (approximately 6 inches). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil either from the surface, or to depths in excess of 12 feet. However, the presence of subsurface rocks and landfill material and collapse of the borehole normally limit sampling depth.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes)
- Stainless steel mixing bowls
- The equipment listed in Section 6.3
- Miscellaneous hand tools as required to assemble and disassemble the hand auger units

#### **CAUTION**

Potential hazards associated with hand augering include:

- Muscle strain and sprain due to over twisting and/or over compromising yourself.
- Equipment failure due to excessive stress on the T-handle or rods through twisting. Failure of any of these components will result in a sudden release and potential injury due to that failure.

As in all situations, any intrusive activities that could damage underground utilities shall be preceded by a Dig/Excavation permit/ticket. Call the Utility Locating service in the area or your Project Health and Safety Officer for more information. When in doubt – **Get the Ticket!**

To obtain soil samples using a hand auger, use the following procedure:

1. Wearing designated PPE, attach a properly decontaminated bucket bit to a clean extension rod and attach the T-handle to the extension rod.
2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).
3. Twist the bucket into the ground while pushing vertically downward on the auger. The cutting shoes fill the bucket as it is advanced into the ground.
4. As the auger bucket fills with soil, periodically remove any unneeded soil.

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5. Add rod extensions as necessary to extend the reach of the auger. Also, note (in a field notebook, boring log, and/or on a standardized data sheet) any changes in the color, texture or odor of the soil as a function of depth. The project-specific planning document (SAP, HASP, etc.) describe requirements for scanning the soil with a real-time air monitoring instrument (e.g., PID, FID, etc.) and recording the measurements.
6. After reaching the desired depth (e.g., the top of the interval to be sampled), slowly and carefully withdraw the apparatus from the borehole to prevent or minimize movement of soil from shallower intervals to the bottom of the hole.
7. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is to be smaller in diameter than the bucket bit employed to initiate the borehole.
8. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.
9. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.
10. Discard the top of the core (approximately 1 inch), which represents any loose material collected by the bucket bit before penetrating the sample material.
11. Using a precleaned syringe or EnCore™ samplers, follow the procedure in Section 6.2.1 for collecting a soil sample for volatile compound analysis directly from the bucket bit.
12. Utilizing a properly decontaminated stainless steel trowel or dedicated disposable trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl.
13. Homogenize the sample material as thoroughly as practicable then fill the remaining sample containers. Refer to Section 6.2.2.
14. Follow steps 4 through 7 listed in Section 6.3.

#### 6.5.1 Sampling Using Stainless Steel Soil Corers

A soil corer is a stainless steel tube equipped with a cutting shoe and sample window in the side. The soil corer is advanced into the soil by applying downward pressure (body weight). The soil is unloaded by then forcing a ram towards the cutting shoe, which results in the discharge of the soil core through a window in the sleeve.

Use, application, and sample protocol is the same as for hand augering provided above, but without necessarily rotating the corer while advancing it.

#### **SAFETY REMINDER**

Hand augering and soil corer sampling can be physically demanding based on the type of geology and subsurface encumbrances encountered. Soil coring has some added hazards such the corer collapsing under your weight. To reduce the potential for muscle strain and damage, the following measures will be incorporated:

- Stretch and limber your muscles before heavy exertion. This hazard becomes more predominant in the early morning hours (prior to muscles becoming limber) and later in the day (as a result of fatigue).

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- Job rotation – Share the duties so that repetitive actions do not result in fatigue and injury.
- Increase break frequencies as needed, especially as ambient conditions of heat and/or cold stress may dictate.
- Do not force the hand tools or use choker pipes or similar devices to bypass an obstruction. Move to another location near the sampling point. Exerting additional forces on the sampling devices can result in damage and/or failure that could potentially injure someone in the immediate vicinity.
- Do not over compromise yourself when applying force to the soil corer or hand auger. If there is a sudden release, it could result in a fall or muscle injury due to strain.

#### 6.6 Subsurface Soil Sampling with a Split-Barrel Sampler

A split-barrel (split-spoon) sampler consists of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment B). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-pound or larger casing driver.

#### **Safety Reminder**

It is intended through the Equipment Inspection for Drill Rigs form provided in the HASP that the hammer and hemp rope, where applicable, associated with this activity will be inspected (no physical damage is obvious), properly attached to the hammer (suitable knots or sufficient mechanical devices), and is in overall good condition.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (2-inch OD, 1-3/8-inch ID, either 20 inches or 26 inches long); Larger OD samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-pound weight, driving head, and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Equipment listed in Section 6.3.

The following steps shall be followed to obtain split-barrel samples (Steps 1 through 4 are typically performed by the drilling subcontractor):

1. Attach the split-barrel sampler to the sampling rods.

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2. Lower the sampler into the borehole inside the hollow stem auger bits.
3. Advance the split-barrel sampler by hammering the length (typically 18 or 24 inches) of the split-barrel sampler into the soil using 140-pound or larger hammer.
4. When the desired depth is achieved, extract the drill rods and sampler from the augers and/or borehole.
5. Detach the sampler from the drill rods.
6. Place the sampler securely in a vise so it can be opened using pipe wrenches.

**CAUTION**

Pipe wrenches are used to separate the split spoon into several components. The driller's helper should not apply excessive force through the use of cheater pipes or push or pull in the direction where, if the wrench slips, hands or fingers will be trapped against an immovable object.

7. Remove the drive head and nosepiece with the wrenches, and open the sampler to reveal the soil sample.
8. Immediately scan the sample core with a real-time air monitoring instrument (e.g., FID, PID, etc.) (as project-specific planning documents dictate). Carefully separate (or cut) the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.
9. If elevated vapor readings were observed, collect the sample scheduled for volatile analysis from the center of the core where elevated readings occurred. If no elevated readings were encountered, the sample material should be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact) (refer to Section 6.2.1).
10. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl.
11. Homogenize the sample material as thoroughly as practicable then fill the remaining sample containers (refer to Section 6.2.2).
12. Follow steps 4 through 7 in Section 6.3.

**6.7      Subsurface Soil Sampling Using Direct-Push Technology**

Subsurface soil samples can be collected to depths of 40+ feet using DPT. DPT equipment, responsibilities, and procedures are described in SOP SA-2.5.

~~**6.8      Excavation and Sampling of Test Pits and Trenches**~~

~~**6.8.1      Applicability**~~

~~This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.~~

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**CAUTION**

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise from the method of excavation. No personnel shall enter any test pit or excavation over 4 feet deep except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart F - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden, steel, or aluminum support structures or through sloping and benching. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments; therefore, monitoring will be conducted by the Competent Person to determine if it is safe to enter. Any entry into a trench greater than 4 feet deep will constitute a Confined Space Entry and must be conducted in conformance with OSHA standard 29 CFR 1910.146. In all cases involving entry, substantial air monitoring, before entry, appropriate respiratory gear and protective clothing determination, and rescue provisions are mandatory. There must be at least three people present at the immediate site before entry by one of the field team members. This minimum number of people will increase based on the potential hazards or complexity of the work to be performed. The reader shall refer to OSHA regulations 29 CFR 1926.650, 29 CFR 1910.120, 29 CFR 1910.134, and 29 CFR 1910.146. High-hazard entries such as this will be supported by members of the Health Sciences Group professionally trained in these activities.

Excavations are generally not practical where a depth of more than about 15 to 20-feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If soil data at depths greater than 15-feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

### **6.8.2 Test Pit and Trench Excavation**

Test pits or trench excavations are constructed with the intent that they will provide an open view of subsurface lithology and/or disposal conditions that a boring will not provide. These procedures describe the methods for excavating and logging test pits and trenches installed to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented (see Attachment C).

Test pits and trenches may be excavated by hand or power equipment to permit detailed descriptions of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration
- The space required for efficient excavation
- The chemicals of concern
- The economics and efficiency of available equipment

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Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table provides guidelines for design consideration based on equipment efficiencies.

Equipment	Typical Widths, in Feet
Trenching machine	0.25 to 1.0
Backhoe/Track Hoe	2 to 6

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, the following field conditions may necessitate revisions to the initial plans:

- Subsurface utilities
- Surface and subsurface encumbrances
- Vehicle and pedestrian traffic patterns
- Purpose for excavation (e.g., the excavation of potential ordnance items)

The final depth and construction method shall be collectively determined by the FOL and designated Competent Person. The actual layout of each test pit, temporary staging area, and spoils pile may further be predicated based on site conditions and wind direction at the time the test pit is excavated. Prior to excavation, the area may be surveyed by magnetometer or metal detector or other passive methods specified in SOP HS1.0, Utility Location and Excavation Clearance, to identify the presence of underground utilities or drums. Where possible, the excavator should be positioned upwind and preferably within an enclosed cab.

No personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is required, OSHA requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be placed for every 25 feet of lateral travel and extended 3 feet above ground surface). A temporary guard rail or vehicle stop must be placed along the surface of the hole before entry in situations where the excavation may be approached by traffic. Spoils will be stockpiled no closer than 2 feet from the sidewall of the excavation. The excavation equipment operator shall be careful not to undercut sidewalls and will, where necessary, bench back to increase stability. The top cover, when considered clean, will be placed separately from the subsurface materials to permit clean cover. It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example, samples of leachate, groundwater, or sidewall soil can be collected with telescoping poles or similar equipment.

Dewatering and watering may be required to ensure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation stable. This is an important consideration for excavations in cohesionless material below the groundwater table and for excavations left open greater than a day. Liquids removed as a result of dewatering operations must be handled as potentially

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contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

Where possible excavations and test pits shall be opened and closed within the same working day. Where this is not possible, the following engineering controls shall be put in place to control access:

- Trench covers/street plates
- Fences encompassing the entire excavation intended to control access
- Warning signs warning personnel of the hazards
- Amber flashing lights to demarcate boundaries of the excavation at night

Excavations left open will have emergency means to exit should someone accidentally enter.

### **6.8.3 Sampling in Test Pits and Trenches**

#### **6.8.3.1 General**

Log test pits and trenches as they are excavated in accordance with the Test Pit Log presented in Attachment C. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable health and safety and OSHA requirements have been met as stated above. These provisions will be reiterated as appropriate in the project-specific HASP.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information includes soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples that can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

#### **6.8.3.2 Sampling Equipment**

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks, hand augers, and stainless steel trowels/disposable trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottle ware for chemical or geotechnical analysis samples.

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- Polyethylene bags for enclosing sample containers; buckets.
- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps, and right angle adapter for conduit (see Attachment D).

#### 6.8.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 6.8.3.4.

- Excavate the trench or pit in several 0.5- to 1.0-foot depth increments. Where soil types support the use of a sand bar cutting plate, use of this device is recommended to avoid potentially snagging utilities with the excavator teeth. It is recommended that soil probes or similar devices be employed where buried items or utilities may be encountered. This permits the trench floor to be probed prior to the next cut.
- After each increment:
  - the operator shall wait while the sampler inspects the test pit from grade level
  - the sampler shall probe the next interval where this is considered necessary. Practical depth increments for lithological evaluations may range from 2 to 4 feet or where lithological changes are noted.
- The backhoe operator, who will have the best view of the test pit, shall immediately cease digging if:
  - Any fluid phase, including groundwater seepage, is encountered in the test pit
  - Any drums, other potential waste containers, obstructions, or utility lines are encountered
  - Distinct changes of material being excavated are encountered

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending on the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Use the backhoe to remove loose material from the excavation walls and floor to the greatest extent possible.
- Secure the walls of the pit, if necessary. (There is seldom any need to enter a pit or trench that would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)
- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material after it has been deposited on the ground, as follows:
  - a. The sampler or FOL shall direct the backhoe operator to remove material from the selected depth or location within the test pit/trench.
  - b. The backhoe operator shall bring the bucket over to a designated location on the sidewall a sufficient distance from the pit (at least 5 feet) to allow the sampler to work around the bucket.

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- c. After the bucket has been set on the ground, the backhoe operator shall either disengage the controls or shut the machine down.
  - d. When signaled by the operator that it is safe to do, the sampler will approach the bucket.
  - e. The soil shall be monitored with a photoionization or flame ionization detector (PID or FID) as directed in the project -specific planning documents.
  - f. The sampler shall collect the sample from the center of the bucket or pile in accordance with surface soil sampling procedures of Section 6.3 or 6.4, as applicable. Collecting samples from the center of a pile or bucket eliminates cross-contamination from the bucket or other depth intervals.
- If a composite sample is desired, several depths or locations within the pit/trench will be selected, and the bucket will be filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

**CAUTION**

Care must be exercised when using the remote sampler described in the next step because of potential instability of trench walls. In situations where someone must move closer than 2 feet to the excavation edge, a board or platform should be used to displace the sampler's weight to minimize the chance of collapse of the excavation edge. Fall protection should also be employed when working near the edges or trenches greater than 6 feet deep. An immediate means to extract people who have fallen into the trench will be immediately available. These means may include ladders or rope anchor points.

- Using the remote sampler shown in Attachment D, samples can be taken at the desired depth from the sidewall or bottom of the pit as follows:
  - a. Scrape the face of the pit/trench using a long-handled shovel or hoe to remove the smeared zone that has contacted the backhoe bucket.
  - b. Collect the sample directly into the sample jar, by scraping with the jar edge, eliminating the need for sample handling equipment and minimizing the likelihood of cross-contamination.
  - c. Cap the sample jar, remove it from the remote sampler assembly, and package the sample for shipment in accordance with SOP SA-6.3.
- Complete documentation as described in SOP SA-6.3 and Attachment C of this SOP.

6.8.3.4 In-Pit Sampling

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soil or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

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In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There are no practical alternative means of obtaining such data.
- The SSO and Competent Person determine that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of oxygen concentration, flammable gases, and toxic compounds, in that order). Action levels will be provided in project-specific planning documents.
- A company-designated Competent Person determines that the pit/trench is stable through soil classification evaluation/inspections or is made stable (by cutting/grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements shall be strictly observed.

If these conditions are satisfied, only one person may enter the pit/trench. On potentially hazardous waste sites, this individual shall be dressed in selected PPE as required by the conditions in the pit. He/she shall be affixed to a harness and lifeline and continuously monitored while in the pit.

A second and possible third individual shall be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations to support self rescue or assisted self rescue. The individual entering the pit shall remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon.

#### 6.8.3.5 Geotechnical Sampling

In addition to the equipment described in Section 6.8.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., thin-walled tube samplers), that can be pushed or driven into the floor of the test pit.
- Suitable driving (e.g., sledge hammer) or pushing (e.g., backhoe bucket) equipment used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soil in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification: larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soil using thin-walled tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability, and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe,

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rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the tube when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 6.8.3.4 shall be followed. The thin-walled tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate because the sample will not have the correct orientation.

A sledge hammer or backhoe may be used to drive or push the tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. When using a sledge hammer, it is recommended that the sampler be stabilized using a rope/strap wrench or pipe wrench to remove the person's hands holding the sampler from the strike zone. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hook the sampler to the excavator or backhoe and extract. This means an alternative head will be used as a connection point or that multiple choke hitches will be applied to extract the sampler. If this fails and the excavator can dig deeper without potentially impacting subsurface utilities, excavate the sampler. If this fails or if the excavator cannot be used due to subsurface utilities, hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry into the test pit, the requirements in Section 6.8.3.4 must be followed. Prepare the sample as described in Steps 9 through 13 in Section 6.2.3, and label, pack and transport the sample in the required manner, as described in SOPs SA-6.3 and SA-6.1.

#### **6.8.4 Backfilling of Trenches and Test Pits**

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non-working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew may photograph, if required by the project-specific work plan, all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL. Backfill should be returned to the trench or test pit in 6-inch to 1-foot lifts and compacted with the bucket. Remote controlled tampers or rollers may be lowered into the trench and operated from top side. This procedure will continue to the grade surface. It is recommended that the trench be tracked or rolled in. During excavation, clean soil from the top 2 feet may have been separated to be used to cover the last segments. Where these materials are not clean, it is recommended that clean fill be used for the top cover.

If a low-permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

#### **6.9 Records**

The appropriate sample log sheet (see Attachment A of this SOP) must be completed by the site geologist/sampler for all samples collected. All soil sampling locations should be documented by tying in

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the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) or obtaining GPS coordinates; and shall be noted on the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see Attachment C of this SOP) shall contain a sketch of pit conditions. If the project-specific work plan requires photographs, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits, and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.

Other data to be recorded in the field logbook include the following:

- Name and location of job
- Date of boring and excavation
- Approximate surface elevation
- Total depth of boring and excavation
- Dimensions of pit
- Method of sample acquisition
- Type and size of samples
- Soil and rock descriptions
- Photographs if required
- Groundwater levels
- PID/FID/LEL/O<sub>2</sub> meter readings
- Other pertinent information, such as waste material encountered

In addition, site-specific documentation to be maintained by the SSO and/or Competent Person will be required including:

- Calibration logs
- Excavation inspection checklists
- Soil type classification

## 7.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

NUS Corporation, 1986. Hazardous Material Handling Training Manual.

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NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

OSHA, Confined Space Entry 29 CFR 1910.146.

USEPA, November 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.

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**ATTACHMENT A  
SOIL & SEDIMENT SAMPLE LOG SHEET**

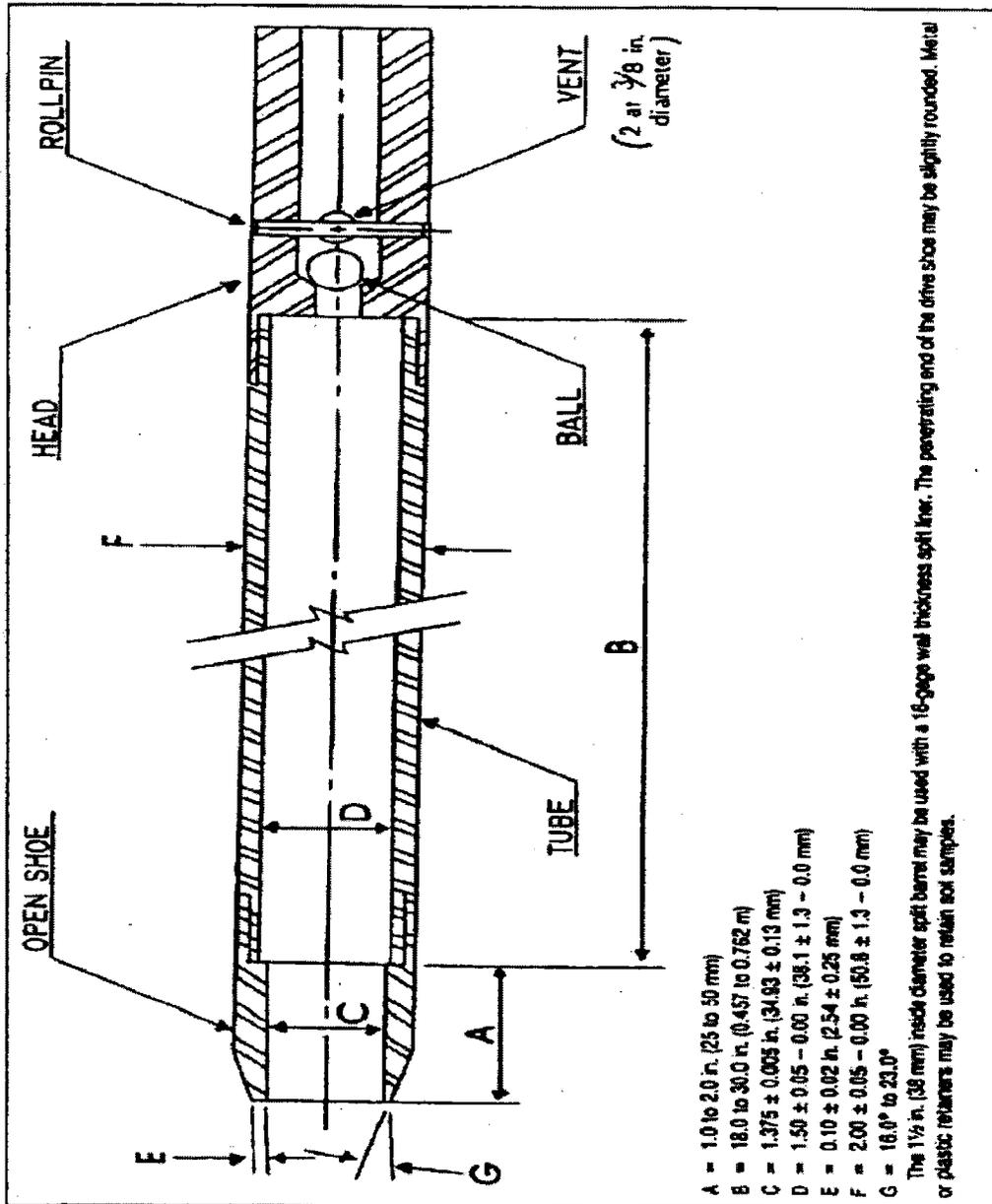


**SOIL & SEDIMENT SAMPLE LOG SHEET**

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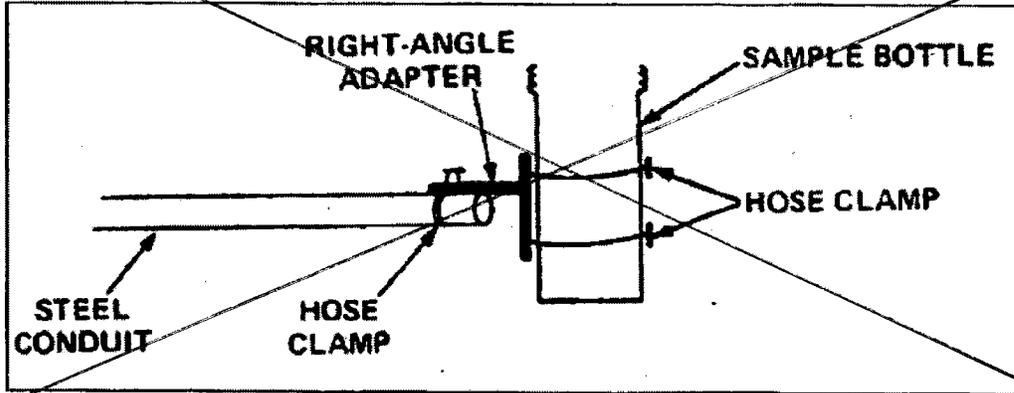
Project Site Name: _____		Sample ID No.: _____		
Project No.: _____		Sample Location: _____		
<input type="checkbox"/> Surface Soil <input type="checkbox"/> Subsurface Soil <input type="checkbox"/> Sediment <input type="checkbox"/> Other: _____ <input type="checkbox"/> QA Sample Type: _____		Sampled By: _____ C.O.C. No.: _____		
		Type of Sample: <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration		
<b>GRAB SAMPLE DATA:</b>				
Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)	
Time:				
Method:				
Monitor Reading (ppm):				
<b>COMPOSITE SAMPLE DATA:</b>				
Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				
<b>SAMPLE COLLECTION INFORMATION:</b>				
Analysis	Container Requirements	Collected	Other	
<b>OBSERVATIONS / NOTES:</b>		<b>MAP:</b>		
<b>Circle if Applicable:</b>		<b>Signature(s):</b>		
MS/MSD	Duplicate ID No.:			

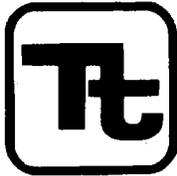
### ATTACHMENT B SPLIT-SPOON SAMPLER





**ATTACHMENT D  
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING**





TETRA TECH

# STANDARD OPERATING PROCEDURES

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Effective Date 01/2012	Revision 4
Applicability Tetra Tech, Inc.	
Prepared Earth Sciences Department	
Approved J. Zimmerly	

Subject DIRECT PUSH TECHNOLOGY (GEOPROBE®/HYDROPUNCH™)

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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.

Geoprobe7 - Geoprobe7 is a manufacturer of a hydraulically-powered, percussion/probing machines utilizing DPT to collect subsurface environmental samples. Geoprobe7 relies on a relatively small amount of static weight (vehicle) combined with percussion as the energy for advancement of a tool string. The Geoprobe7 equipment can be mounted in a multitude of vehicles for access to all types of environmental sites.

HydroPunch $\theta$  - HydroPunch $\theta$  is a manufacturer of stainless steel and Teflon<sup>7</sup> 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 $\theta$  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.

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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.

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- While wearing cut-resistant gloves (constructed of leather or other suitable material), cut 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 air/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

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### 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 to 10 minutes during the purging process. After two consistent readings of pH, specific conductance, temperature and turbidity ( $\nabla$ 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 air/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.

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**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 Tetra Tech

**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
  - Half face APR
  - SKA-PAC SAR
  - Skid Rig
- Escape Pack
- SCBA
- Bottle Trailer
- 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.....                 | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No | Hearing Protection (Plugs/Muffs) | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Safety Glasses .....          | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No | Safety belt/harness              | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No |
| Chemical/splash goggles ..... | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No | Radio                            | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No |
| Splash Shield.....            | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No | Barricades                       | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No |
| Splash suits/coveralls .....  | <input type="checkbox"/> Yes <input type="checkbox"/> No            | Gloves (Type - _____)            | <input type="checkbox"/> Yes <input type="checkbox"/> No            |
| Steel toe Work shoes or boots | <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No | Work/warming regimen             | <input type="checkbox"/> Yes <input type="checkbox"/> No            |

Modifications/Exceptions: Reflective vests for high traffic areas.

- VIII. Procedure review with permit acceptors 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

- |   |   |
|---|---|
| Equipment drained/depressurized .....                       | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA |
| Equipment purged/cleaned.....                               | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA |
| Isolation checklist completed.....                          | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA |
| Electrical lockout required/field switch tested .....       | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA |
| Blinds/misalignments/blocks & bleeds in place.....          | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA |
| Hazardous materials on walls/behind liners considered ..... | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA |

- 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: \_\_\_\_\_



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Effective Date	01/2012	Revision	4
Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
NON-RADIOLOGICAL SAMPLE HANDLING

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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.

## 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 (§261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (§261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

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<sub>2</sub>SO<sub>4</sub>
- Nitric Acid - HNO<sub>3</sub>
- Sodium Hydroxide - NaOH

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### Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>

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

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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 4EC. 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<sub>3</sub>, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4EC, 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.

The FOL is responsible for ensuring that an accurate Chemical Inventory is created and maintained for all hazardous chemicals brought to the work site (see Section 5 of the TiNUS Health and Safety Guidance Manual). Furthermore, the FOL must ensure that a corresponding Material Safety Data Sheet (MSDS) is collected for every substance entered on the site Chemical Inventory, and that all persons using/handling/ disposing of these substances review the appropriate MSDS for substances they will work with. The Chemical Inventory and the MSDSs must be maintained at each work site in a location and manner where they are readily-accessible to all personnel.

### 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 <sub>2</sub> SO <sub>4</sub> )	1 part concentrated H <sub>2</sub> SO <sub>4</sub> : 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO <sub>3</sub> )	Undiluted concentrated HNO <sub>3</sub>	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

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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

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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 and discard 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**

Only employees who have successfully completed the TtNUS "Shipping Hazardous Materials" training course are authorized to package and ship hazardous substances. These trained individuals are responsible for performing shipping duties in accordance with this training.

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 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 bag (e.g. "garbage" bag). Drain plugs on coolers must be taped shut.
- Pack with enough cushioning materials such as bubble wrap (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), place ice around sample container shoulders, and on top of 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) 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 cooler containing the vials for VOC analysis. The COC form should then state how many coolers are included with that shipment.

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- 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.

## 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.

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### ATTACHMENT A

#### GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration	Container <sup>(1)</sup>	Sample Size	Preservation <sup>(2)</sup>	Holding Time <sup>(2)</sup>
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#### WATER

Organics (GC&GC/MS)	VOC	Low	Borosilicate glass	2 x 40 mL	Cool to 4EC HCl to # 2	14 days <sup>(9)</sup>
	Extractables SVOCs and pesticide/PCBs)	(Low	Amber glass	2x2 L or 4x1 L	Cool to 4EC	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 <sub>3</sub> 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
		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		EnCore Sampler	(3) 5 g Samplers	Cool to 4EC	48 hours to lab preservation
	Extractables SVOCs and pesticides/PCBs)	(Low	Wide-mouth glass	8 oz.	Cool to 4EC	14 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticides/PCBs)	(Medium	Wide-mouth glass	8 oz.	Cool to 4EC	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium		Wide-mouth glass	8 oz.	Cool to 4EC	6 months (Hg - 28 days) Cyanide (14 days)
Organic/Inorga nic	High Hazard		Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All		Wide-mouth glass	4 oz.	None	35 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 4EC	5 days recommended
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- 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.

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## ATTACHMENT B

### ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container <sup>(1)</sup>	Preservation <sup>(2)(3)</sup>	Maximum Holding Time <sup>(4)</sup>
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#### INORGANIC TESTS:

Acidity	P, G	Cool, 4EC	14 days
Alkalinity	P, G	Cool, 4EC	14 days
Ammonia - Nitrogen	P, G	Cool, 4EC; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4EC	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4EC; H <sub>2</sub> SO <sub>4</sub> 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, 4EC	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4EC; NaOH to pH 12; 0.6 g ascorbic acid <sup>(5)</sup>	14 days <sup>(6)</sup>
Fluoride	P	None required	28 days
Hardness	P, G	HNO <sub>3</sub> to pH 2; H <sub>2</sub> SO <sub>4</sub> to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4EC; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4EC; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4EC	48 hours
Oil & Grease	G	Cool, 4EC; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4EC; HCl or H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4EC	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, 4EC; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4EC; H <sub>2</sub> SO <sub>4</sub> to pH 2	28 days
Residue, Total	P, G	Cool, 4EC	7 days
Residue, Filterable (TDS)	P, G	Cool, 4EC	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4EC	7 days
Residue, Settleable	P, G	Cool, 4EC	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4EC	7 days
Silica	P	Cool, 4EC	28 days
Specific Conductance	P, G	Cool, 4EC	28 days
Sulfate	P, G	Cool, 4EC	28 days

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**ATTACHMENT B  
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,  
AND HOLDING TIMES  
PAGE TWO**

Parameter Number/Name	Container <sup>(1)</sup>	Preservation <sup>(2)(3)</sup>	Maximum Holding Time <sup>(4)</sup>
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**INORGANIC TESTS (Cont'd):**

Sulfide	P, G	Cool, 4EC; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4EC	48 hours

**METALS:<sup>(7)</sup>**

Chromium VI (Hexachrome)	P, G	Cool, 4EC	24 hours
Mercury (Hg)	P, G	HNO <sub>3</sub> to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO <sub>3</sub> to pH 2	6 months

**ORGANIC TESTS:<sup>(8)</sup>**

Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> HCl to pH 2 <sup>(9)</sup>	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> adjust pH to 4-5 <sup>(10)</sup>	14 days
Phenols <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction
Benzidines <sup>(11), (12)</sup>	G, Teflon-lined cap	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction <sup>(13)</sup>
Phthalate esters <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4EC	7 days until extraction; 40 days after extraction
Nitrosamines <sup>(11), (14)</sup>	G, Teflon-lined cap	Cool, 4EC; store in dark; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction
PCBs <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4EC	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> ; store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs) <sup>(11), (14)</sup>	G, Teflon-lined cap	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup> ; store in dark	7 days until extraction; 40 days after extraction
Haloethers <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF) <sup>(11)</sup>	G, Teflon-lined cap	Cool, 4EC; 0.008% Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> <sup>(5)</sup>	7 days until extraction; 40 days after extraction

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**ATTACHMENT B  
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES,  
AND HOLDING TIMES  
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- (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 4EC 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 4EC, 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-diphenylhydrazine 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<sub>2</sub>S<sub>2</sub>O<sub>3</sub> 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<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
FIELD DOCUMENTATION

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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, Inc. (TtNUS) field activities.

## 2.0 SCOPE

Documents presented within this SOP (or equivalents) shall be used for all TtNUS 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 AND PERSONNEL QUALIFICATIONS

Project Manager (PM) - The PM 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 FOL is responsible for ensuring that the site logbook, notebooks, and all appropriate and current forms and field reports included in this SOP (and any additional forms required by the contract) are correctly used, accurately filled out, and completed in the required time frame.

General personnel qualifications for field documentation activities include the following:

- Occupational Safety and Health Administration (OSHA) 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate procedures for documentation, handling, packaging, and shipping.

## 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 on-site activities are documented. At a minimum, record or reference the following activities/events (daily) in the site logbook:

- All field personnel present
- Arrival/departure times and names of site visitors
- Times and dates of health and safety training
- Arrival/departure times of equipment
- Times and dates of equipment calibration

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- Start and/or completion of borehole, trench, monitoring well installation activities, etc.
- Daily on-site activities
- Sample pickup information
- Health and safety issues (level of protection, personal protective equipment [PPE], etc.)
- Weather conditions

Maintain a site logbook for each project and initiate it at the start of the first on-site activity (e.g., site visit or initial reconnaissance survey). Make entries every day that on-site activities take place involving TtNUS or subcontractor personnel. Upon completion of the fieldwork, provide the site logbook to the PM or designee for inclusion in the project's central file.

Record the following information on the cover of each site logbook:

- Project name
- TtNUS 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, either record the measurements and equipment used in the site logbook or reference the field notebook in which the measurements are recorded (see Attachment A).

Make all logbook, notebook, and log sheet entries in indelible ink (black pen is preferred). No erasures are permitted. If an incorrect entry is made, cross out the entry with a single strike mark, initial, and date it. At the completion of entries by any individual, the logbook pages used must be signed and dated by the person making the entries. The site logbook must also be signed by the FOL at the end of each day.

### **5.1.2 Photographs**

Sequentially number movies, slides, or photographs taken of a site or any monitoring location to correspond to logbook/notebook entries. Enter the name of the photographer, date, time, site location, site description, and weather conditions 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 because they can adversely affect the accuracy of photographs. Chain-of-custody procedures depend on the subject matter, type of camera (digital or film), and the processing it requires. Follow chain-of-custody procedures for film used for aerial photography, confidential information, or criminal investigation. After processed, consecutively number the slides of photographic prints and label them according to the logbook/notebook descriptions. Docket the site photographs and associated negatives and/or digitally saved images to compact disks 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

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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**            **FIELD FORMS**

All TtNUS field forms (see list in Section 6.0 of this SOP) can be found on the company's intranet site (<http://intranet.ttnus.com>) under Field Log Sheets. Forms may be altered or revised for project-specific needs, subject to 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 SOPs.

#### **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. The data recorded on these sheets are useful in describing the sample as well as pointing out any problems, difficulties, or irregularities encountered during sampling. Complete a sample log sheet 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. Complete the required information on the adhesive labels and apply them to every sample container. Obtain sample labels from the appropriate program/project source, request that they be electronically generated in house, or request them the laboratory subcontractor.

##### 5.3.1.3          Chain-of-Custody Record

The chain-of-custody 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 as follows for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site:

- Retain one carbonless copy of the completed chain-of custody form in the field.
- Send one copy is sent to the PM (or designee)
- Send the original to the laboratory with the associated samples. Place the original (top, signed copy) of the chain-of custody form inside a large Ziploc<sup>®</sup>-type bag taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one chain-of custody form, send the form with the cooler containing vials for volatile organic compound (VOC) analysis or the cooler with the air bill attached. Indicate on the air bill how many coolers are included with that shipment.

An example of a chain-of-custody form is provided as Attachment C. After the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed chain-of custody form (any discrepancies between the sample labels and chain-of custody form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the TtNUS PM). The chain-of custody form is signed and copied. The laboratory will retain the copy, and the original becomes part of the samples' corresponding analytical data package.

##### 5.3.1.4          Chain-of-Custody Seal

Attachment D is an example of a custody seal. The custody seal is an adhesive-backed label that 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. Sign and date custody seals

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and affix them across the lid and body of each cooler (front and back) containing environmental samples (see SOP SA-6.1). Obtain custody seals from the laboratory (if available) or purchase them from a supplier.

#### 5.3.1.5 Geochemical Parameters Log Sheets

Complete Field Analytical Log Sheets to record geochemical and/or natural attenuation field test results.

### 5.3.2 **Hydrogeological and Geotechnical Forms**

#### 5.3.2.1 Groundwater Level Measurement Sheet

Complete a Groundwater Level Measurement Sheet 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. Use a Pumping Test Data Sheet to facilitate this task by standardizing the data collection format for the pumping well and observation wells, and allowing the time interval for collection to be established in advance.

#### 5.3.2.3 Packer Test Report Form

Complete a Packer Test Report Form for each well at which a packer test is conducted.

#### 5.3.2.4 Boring Log

Complete a Summary Log of Boring, or Boring Log for each soil boring performed to document the materials encountered, operation and driving of casing, and locations/depths of samples collected. In addition, if volatile organics are monitored on cores, samples, cuttings from the borehole, or breathing zone, (using a photoionization detector [PID] or flame ionization detector [FID]), enter these readings on the boring log at the appropriate depth. When they become available, enter the laboratory sample number, concentrations of key contaminants, or other pertinent information in the "Remarks" column. This feature allows direct comparison of contaminant concentrations with soil characteristics.

#### 5.3.2.5 Monitoring Well Construction Details Form

Complete a Monitoring Well Construction Details Form 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, stick-up or flush mount), different forms are used.

#### 5.3.2.6 Test Pit Log

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log must be filled out by the responsible field geologist or sampling technician.

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### 5.3.2.7 Miscellaneous Monitoring Well Forms

Miscellaneous monitoring well forms that may be required on a project-specific basis include the Monitoring Well Materials Certificate of Conformance and Monitoring Well Development Record. Use a Monitoring Well Materials Certificate of Conformance to document all materials utilized during each monitoring well installation. Use a Monitoring Well Development Record to document all well development activities.

### 5.3.2.8 Miscellaneous Field Forms – Quality Assurance and Checklists

Miscellaneous field forms/checklists forms that may be required on a project-specific basis include the following:

- Container Sample and Inspection Sheet – use this form when a container (drum, tank, etc.) is sampled and/or inspected.
- QA Sample Log Sheet – use this form when a QA sample such as an equipment rinsate blank, source blank, etc. is collected.
- Field Task Modification Request (FTMR) – use this form to document deviations from the project planning documents. The FOL is responsible for initiating the FTMRs. Maintain copies of all FTMRs with the on-site planning documents, and place originals in the final evidence file.
- Field Project Daily Activities Checklist and Field Project Pre-Mobilization Checklist – used these during both the planning and field effort to ensure that all necessary tasks are planned for and completed. These two forms are not requirements but are useful tools for most field work.

### 5.3.3 **Equipment Calibration and Maintenance Form**

The calibration or standardization of monitoring, measuring, or test equipment is necessary to ensure the proper operation and response of the equipment, to document the accuracy, precision, or sensitivity of the measurements, 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, which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. Maintain an Equipment Calibration Log for each electronic measuring device used in the field; make entries for each day the equipment is used or in accordance with manufacturer recommendations.

## 5.4 **FIELD REPORTS**

The primary means of recording on-site 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 used for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain on site for extended periods of time and are thus not accessible for timely review by project management. Other reports useful for tracking and reporting the progress of field activities are described below.

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#### 5.4.1 Daily Activities Report

To provide timely oversight of on-site contractors, complete and submit Daily Activities Reports (DARs) as described below.

##### 5.4.1.1 Description

The DAR documents the activities and progress for each day's field work. Complete this report on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring that involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors. The DAR form can be found on the TtNUS intranet site.

##### 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 DAR to the FOL for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The DARs are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the PM.

#### 5.4.2 Weekly Status Reports

To facilitate timely review by project management, photocopies of logbook/notebook entries may be made for internal use.

In addition to those described herein, other summary reports may also be contractually required.

All TtNUS field forms can be found on the company's intranet site at <http://intranet.ttnus.com> under Field Log Sheets.

#### 6.0 LISTING OF FIELD FORMS ON THE TtNUS INTRANET SITE

- Boring Log
- Container Sample and Inspection Sheet
- Daily Activities Checklist
- Daily Activities Record
- Equipment Calibration Log
- Field Task Modification Request
- Field Analytical Log sheet - Geochemical Parameters
- Groundwater Level Measurement Sheet
- Groundwater Sample Log Sheet
- Hydraulic Conductivity Test Data Sheet
- Low Flow Purge Data Sheet
- Bedrock Monitoring Well Construction (Stick Up)
- Bedrock Monitoring Well Construction Flush Mount
- Bedrock Monitoring Well Construction Open Hole
- Confining Layer Monitoring Well Construction
- Monitoring Well Development Record

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- Monitoring Well Materials Certificate of Conformance
- Overburden Monitoring Well Construction Flush Mount
- Overburden Monitoring Well Construction Stick Up
- Packer Test Report Form
- Pumping Test Data Sheet
- QA Sample Log Sheet
- Soil/Sediment Sample Log Sheet
- Surface Water Sample Log Sheet
- Test Pit Log
- Field Project Pre-Mobilization Checklist

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

\_\_\_\_\_  
Field Operations Leader

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**ATTACHMENT B  
SAMPLE LABEL**

	Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		<b>Project:</b>
			<b>Site:</b>
		<b>Location:</b>	
<b>Sample No:</b>		<b>Matrix:</b>	
<b>Date:</b>	<b>Time:</b>	<b>Preserve:</b>	
<b>Analysis:</b>			
<b>Sampled by:</b>		<b>Laboratory:</b>	



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**ATTACHMENT D  
CHAIN-OF-CUSTODY SEAL**

<b>Signature</b> <hr/> <b>Date</b> <hr/> <b>CUSTODY SEAL</b>		<b>CUSTODY SEAL</b> <hr/> <b>Date</b> <hr/> <b>Signature</b>
--	--	--



TETRA TECH

# STANDARD OPERATING PROCEDURES

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Effective Date	01/2012	Revision	7
Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
DECONTAMINATION OF FIELD EQUIPMENT

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## 1.0 PURPOSE

Decontamination is the process of removing and/or neutralizing site contaminants that have contacted and/or accumulated on equipment. The purpose of this Standard Operating Procedure (SOP) is to protect site personnel, the general public, and the environment while preserving or maintaining sample integrity. It is further intended through this procedure to describe the steps necessary for proper decontamination of drilling equipment, earth-moving equipment, chemical sampling equipment and field operation and analytical equipment.

## 2.0 SCOPE AND APPLICABILITY

This procedure applies to all equipment used to provide access to/acquire environmental samples that may have become contaminated through direct contact with contaminated media including air, water, and soil. This equipment includes drilling and heavy equipment and chemical sampling and field analytical equipment. Where technologically and economically feasible, single-use sealed disposable equipment will be employed to minimize the potential for cross-contamination. This SOP also provides general reference information on the control of contaminated materials.

Decontamination methods and equipment requirements may differ from one project to another. General equipment items are specified in Section 6.0, but project-specific equipment must be obtained to address the project-specific decontamination procedures presented in Section 7.0 and applicable subsections.

## 3.0 GLOSSARY

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

Decontamination Solution - A solution selected/identified in the Health and Safety Plan or Project-Specific Quality Assurance Plan. The solution is selected and employed as directed by the project chemist/health and safety professional.

Deionized Water (DI) - Tap water that has been treated by passing through a standard deionizing resin column. This water may also pass through additional filtering media to attain various levels of analyte-free status. The DI water should meet College of American Pathologists (CAP) and National Committee for Clinical Laboratory Standards (NCCLS) specifications for reagent-grade Type I water.

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

Pressure Washing - Process employing a high-pressure pump and nozzle configuration to create a high-pressure spray of potable water. High-pressure spray is employed to remove solids from equipment.

Solvent - A liquid in which solid chemicals or other liquids are dissolved. The solvent of choice is pesticide-grade isopropanol. Use of other solvents (methanol, acetone, or hexane) may be required for particular projects or for a particular purpose (e.g., removal of concentrated waste) and must be justified in the project planning documents. For 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.

Steam Pressure Washing - A cleaning method employing a high-pressure spray of heated potable water to remove various organic/inorganic chemicals from equipment.

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#### 4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Decontamination Personnel - Individuals assigned the task of decontamination. It is the responsibility of these individuals to understand the use and application of the decontamination process and solutions as well as the monitoring of that process to ensure that it is working properly. This is accomplished through visual evaluation, monitoring instrument scanning of decontaminated items, and/or through the collection of rinsate blanks to verify contaminant removal.

Field Operations Leader (FOL) - Responsible for the implementation of project-specific planning documents. This includes on-site verification that all field activities are performed in compliance with approved SOPs or as otherwise dictated by the approved project plan(s). The FOL is also responsible for the completion and accuracy of all field documentation.

Site Safety Officer (SSO) - Exercises shared responsibility with the FOL concerning decontamination effectiveness. All equipment arriving on site (as part of the equipment inspection), leaving the site, and moving between locations is required to go through a decontamination evaluation. This is accomplished through visual examination and/or instrument screening to determine the effectiveness of the decontamination process. Improper or incomplete decontamination is sufficient to restrict equipment from entering the site, exiting the site, or moving to a new location on the site until the objectives are successfully completed.

General personnel qualifications for decontamination activities include the following:

- Occupational Safety and Health Administration (OSHA) 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate decontamination procedures.

#### 5.0 HEALTH AND SAFETY

In addition to the health and safety issues and reminders specified in subsections of this SOP, the following considerations and requirements must be observed as SOPs for field equipment decontamination activities:

- If any solvents or hazardous chemicals (e.g., isopropyl alcohol) are to be used in equipment decontamination activities, the FOL must first obtain the manufacturer's/supplier's Material Safety Data Sheet (MSDS) and assure that it is reviewed by all users (prior to its use), added to the site Hazardous Chemical Inventory, and maintained on site as part of the project Hazard Communication Program.
- Review and observe specific health and safety requirements (e.g., personal protective equipment [PPE]) specified in the project-specific health and safety plan for this activity.

#### 6.0 EQUIPMENT LIST

- Wood for decontamination pad construction, when applicable (see Section 7.1).

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- Tools for constructing decontamination pad frame, when applicable (see Section 7.1).
- Visqueen sheeting or comparable material to cover decontamination pad frame, when applicable (see Section 7.1).
- Wash/drying racks for auger flights and drill/drive rods, when applicable (see Section 7.2).
- PPE as specified in the project health and safety plan.
- Soap and water for washing and rinsing.
- Deionized water for final rinsing.
- Solvents (e.g., pesticide-grade isopropanol) for rinsing (see applicable portions of Section 7.2).
- Tubs, buckets, etc. for containerizing rinse water (see applicable portions of Section 7.2).
- Sample bottles for collecting rinsate blanks (see Section 7.2).
- Calibrated photoionization detector (PID) or flame ionization detector (FID) to monitor decontaminated equipment for organic vapors generated through the existence of residual contamination or the presence of decontamination solvent remaining after the piece was rinsed.
- Aluminum foil or clear clean plastic bag for covering cleaned equipment (see applicable portions of Section 7.2).
- Paper towels or cloths for wiping.
- Brushes, scrapers, or other hand tools useful for removing solid materials from equipment.
- Clear plastic wrap for covering or wrapping large decontaminated equipment items (see Section 7.2.2).
- Drum-moving equipment for moving filled waste drums (optional) (see Section 7.3).
- Drum labels for waste drums (see Attachment A).

## 7.0 PROCEDURES

The process of decontamination is accomplished through the removal of contaminants, neutralization of contaminants, or isolation of contaminants. To accomplish this activity, preparation is required including site preparation, equipment selection, and evaluation of the decontamination requirements and processes. Site contaminant types, concentrations, and media types are primary drivers in the selection of the types of decontamination and where it will be conducted. For purposes of this SOP, discussion is limited to decontamination procedures for general environmental investigations.

Decontamination processes will be performed at the location(s) specified in project-specific planning documents. Typical decontamination locations include the following:

- Temporary decontamination pads/facilities
- Sample locations
- Centralized decontamination pad/facilities

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- Combination of some or all of the above

The following discussion includes general considerations for the decontamination process. Specific construction and implementation procedures will be as specified in the project-specific planning documents and/or may be as dictated by site-specific conditions as long as the intent of the requirements in the planning documents is met. This intent is to contain any residual fluids and solids generated through the decontamination process.

## 7.1 Decontamination Pad Design/Construction Considerations

### 7.1.1 Temporary Decontamination Pads

Temporary decontamination pads may be constructed at satellite locations within the site area in support of temporary work areas. These structures are generally constructed to support the decontamination of heavy equipment such as drill rigs and earth-moving equipment but can be employed for smaller articles.

The purpose of the decontamination pad is to contain wash waters and potentially contaminated soil generated during decontamination procedures. Therefore, construction of these pads should take into account the following considerations:

- Site location – The decontamination site selected should be far enough from the work site to maximize decontamination effectiveness while minimizing travel distance. The location of the decontamination site shall be selected to provide, in the judgment of the FOL or FOL designee, compliance with as many of the following characteristics as practicable:
  - Well removed from pedestrian/vehicle thoroughfares.
  - Avoidance of areas where control/custody cannot be maintained.
  - Avoidance of areas where potential releases of contaminated media or decontamination fluids may be compounded through access to storm water transport systems, streams, or other potentially sensitive areas.
  - Avoidance of potentially contaminated areas.
  - Avoidance of areas too close to the ongoing operation, where cross-contamination may occur.

The selected decontamination site should include the following, where possible:

- Areas where potable water and electricity are provided.

#### **Safety Reminder**

When utilizing electrical power sources, either hard-wired or portable-generated sources, ensure that:

- All power is routed through a Ground Fault Circuit Interrupter (GFCI).
- All power cords are in good condition (no physical damage), rated for the intended energy load, and designated for outdoor use.

In situations where accomplishing these elements is not possible, it will be necessary to implement a site electrical grounding program.

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- Areas where support activities such as removing decontamination waters soil and sediment are possible without entering an active exclusion zone.
- Areas that offer sufficient size to carry out the specific decontamination sequence.
- Decontamination pad (decon pad) – The decon pad shall be constructed to meet the following characteristics:
  - Size – The size of the pad should be sufficient to accept the equipment to be decontaminated as well as permitting free movement around the equipment by the personnel conducting the decontamination. The size should permit these movements utilizing pressure/steam washer wands and hoses and minimizing splash due to work in close quarters.
  - Slope – An adequate slope will be constructed to permit the collection of water and potentially contaminated soil within a trough or sump constructed at one end. The collection point for wash waters should be of adequate distance that the decontamination workers do not have to walk through the wash waters while completing their tasks. Because the pad will be sloped, place a light coating of sand over the plastic to minimize potential slips and falls. See the text about liners below.
  - Sidewalls – The sidewalls shall be at least 6 inches in height (or as high as possible if 6 inches is not achievable) to provide adequate containment for wash waters and soil. If splash represents a potential problem, splash guards should be constructed to control overspray. Sidewalls may be constructed of wood, inflatables, sand bags, etc. to permit containment. Splash guards are typically wood frames with Visqueen coverings to control overspray.
  - Liner – Depending on the types of equipment and decontamination method to be used, the liner should be of sufficient thickness to provide a puncture-resistant barrier between the decontamination operation and the unprotected environment. Care should be taken to examine the surface area prior to placing the liner to remove sharp articles (sticks, stones, debris) that could puncture the liner. Liners are intended to form an impermeable barrier. The thickness may vary from a minimum recommended thickness of 10 mil to 30 mil. The desired thickness may be achieved through layering materials of lighter construction. It should be noted that various materials (rubber, polyethylene sheeting) become slippery when wet. To minimize this potential hazard associated with a sloped liner, a light coating of sand shall be applied to provide traction as necessary.
  - Wash/drying racks – Auger flights, drill/drive rods, and similar equipment require racks positioned off of the ground to permit these articles to be washed, drained, and dried while secured from falling during this process.

For decontamination of direct-push technology (DPT) equipment, the pad may be as simple as a mortar tub containing buckets of soapy water for washing and an empty bucket to capture rinse waters. Decontamination may be conducted at the rear of the rig to permit rapid tool exchange.

- Maintenance – Maintain the decontamination area by:
  - Periodically clearing the work area of standing water, soil, and debris, and coiling hoses to aid in eliminating slip, trip, and fall hazards. In addition, these articles will reduce potential backsplash and cross-contamination.

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- Regularly changing the decontamination fluids to ensure proper cleaning and prevent cross-contamination.
- PPE – Periodically evaluate the condition of, and maintain the decontamination equipment, including regular cleaning of face shields and safety glasses. This is critical to ensuring the safety of decontamination personnel and the integrity of the decontamination process, and it will ensure that equipment is functioning properly.

### **7.1.2 Decontamination Activities at Drill Rigs/DPT Units**

During subsurface sampling activities including drilling and DPT activities, decontamination of drive rods, Macro Core Samplers, split spoons, etc. is typically conducted at an area adjacent to the operation. Decontamination is generally accomplished using a soap/water wash and rinse utilizing buckets and brushes. This area requires sufficient preparation to accomplish the decontamination objectives.

Buckets shall be placed within mortar tubs or similar secondary containment tubs to prevent splash and spills from reaching unprotected environmental media. Drying racks shall be employed as directed for temporary pads to permit parts to dry and be evaluated prior to use/reuse. Methodology regarding this activity is provided in Section 7.2.

### **7.1.3 Decontamination Activities at Remote Sample Locations**

When sampling at remote locations, sampling equipment such as trowels and pumps/tubing should be evacuated of potentially contaminated media to the extent possible. This equipment should be wrapped in plastic for transport to the temporary/centralized decontamination location for final cleaning and disposition. Flushing and cleaning of single-use equipment such as disposable trowels, tubing, and surgeon's gloves may allow disposal of this equipment after visible soil and water remnants have been removed.

## **7.2 Equipment Decontamination Procedures**

The following represents procedures to be employed for the decontamination of equipment that may have contacted and/or accumulated contamination through site investigation activities.

### **7.2.1 Monitoring Well Sampling Equipment**

7.2.1.1 Groundwater sampling equipment – This includes pumps inserted into monitoring wells such as bladder pumps, Whale pumps, and Redi-Flo pumps and reusable bailers, etc.

1. Evacuate to the extent possible, any purge water within the pump/bailer.
2. Scrub using soap and water and/or steam clean the outside of the pump/bailer and, if applicable, the pump tubing.
3. Insert the pump and tubing/bailer into a clean container of soapy water. Pump/run a sufficient amount of soapy water through the pump/bailer to flush out any residual well water. After the pump is flushed, circulate soapy water through the pump to ensure that the internal components are thoroughly flushed.
4. Remove the pump and tubing/bailer from the container
5. Rinse external pump components using tap water.

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6. Insert the pump and tubing/bailer into a clean container of tap water. Pump/run a sufficient amount of tap water through the pump/bailer to evacuate all of the soapy water (until clear).

**CAUTION**

Do not rinse PE, PVC, and associated tubing with solvents –  
Use the procedures defined in the project-specific planning documents. If they are not defined, contact the FOL for guidance. The solvent rinse described in Step 7 may be omitted if groundwater does not contain oil, grease, PAHs, PCBs, or other hard to remove organic materials.

7. If groundwater contains or is suspected to contain oil, grease, PAHs, PCBs, or other hard to remove organic materials, rinse the equipment to be cleaned with pesticide-grade isopropanol.
8. Pass deionized water through the hose to flush out the tap water and solvent residue as applicable.
9. Drain residual deionized water to the extent possible.
10. Allow components of the equipment to air dry.
11. For bladder pumps, disassemble the pump and wash the internal components with soap and water, then rinse with tap water, isopropanol, and deionized water and allow to dry. After the parts are dry, conduct a visual inspection and a monitoring instrument scan to ensure that potential contaminants and all decontamination solvent have been removed. Collect a rinsate blank in accordance with the project-specific planning documents to ensure that the decontamination process is functioning as intended. The typical frequency of collection for rinsate blanks is 1 per 20 field samples. In addition, wipe samples or field tests such as UV light may be used.
12. Wrap pump/bailer in aluminum foil or a clear clean plastic bag for storage.

**SAFETY REMINDER**

Remember when handling powered equipment to disconnect the power source and render the equipment to a zero energy state (both potential and kinetic) before opening valves, disconnecting lines, etc.

7.2.1.2 Electronic Water Level Indicators/Sounders/Tapes

During water level measurements, rinsing the extracted tape and probe with deionized water and wiping the surface of the extracted tape between locations is acceptable. However, periodic full decontamination should be conducted as follows:

1. Wash with soap and water
2. Rinse with tap water
3. Rinse with deionized water

**NOTE**

In situations where oil, grease, free product, other hard to remove materials are encountered, probes and exposed tapes should be washed in hot soapy water. If probes or tapes cannot be satisfactorily decontaminated (they are still stained, discolored, etc.), they should be removed from service.

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### 7.2.1.3 Miscellaneous Equipment

Miscellaneous equipment including analytical equipment (water quality testing equipment) shall be cleaned per manufacturers' instructions. This generally includes wiping the sensor housing and rinsing with tap and deionized water.

Coolers/shipping containers employed to ship samples are received from the laboratory in a variety of conditions including marginal to extremely poor. Coolers shall be evaluated prior to use for the following:

- Structural integrity – Coolers missing handles or having breaks in the outer housing should be removed and not used. Notify the laboratory that the risk of shipping samples in the cooler(s) provided is too great and request a replacement unit.
- Cleanliness – As per protocol, only volatile organic samples are accompanied by a trip blank. If a cooler's cleanliness is in question (visibly dirty/stained) or if there are noticeable odors, the cooler should be decontaminated prior to use as follows:
  1. Wash with soap and water
  2. Rinse with tap water
  3. Dry

If these measures fail to clean the cooler to an acceptable level, remove the unit from use as a shipping container and ask the cooler provider (e.g., the analytical laboratory) to provide a replacement unit.

### 7.2.2 **Downhole Drilling Equipment**

This includes any portion of the drill rig that is over the borehole, including auger flights, drill stems, rods, and associated tooling that would extend over the borehole. The following procedure is to be employed prior to initiating the drilling/sampling activity, then between locations:

**CAUTION**

Exercise care when using scrapers to remove soil and debris from downhole drilling equipment. Inadvertent slips of scrapers have resulted in cuts, scrapes, and injured knuckles, so use scrapers carefully when removing soil from these items.

1. Remove loose soil using shovels, scrapers, etc.
2. Through a combination of scrubbing using soap and water and/or steam cleaning or pressure washing, remove visible dirt/soil from the equipment being decontaminated.

**CAUTION**

In Step 3, do not rinse PE, PVC, and associated tubing with solvents. The appropriate procedures should be defined within the project-specific planning documents. If they are not defined, contact the FOL for guidance. The solvent rinse described in Step 4 may be omitted if groundwater does not contain oil, grease, PAHs, PCBs, or other hard to remove organic materials.

3. Rinse the equipment with tap water, where applicable (steam cleaning and pressure washing incorporate rinsing as part of the process).

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4. If the equipment has directly or indirectly contacted contaminated sample media and is known or suspected of being contaminated with oil, grease, PAHs, PCBs, or other hard to remove organic materials, rinse equipment with pesticide-grade isopropanol
5. To the extent possible, allow components to air dry.
6. If the decontaminated equipment is to be used immediately after decontamination, screen it with a calibrated photoionization detector (PID)/flame ionization detector (FID) to ensure that all contaminants and possible decontamination solvents (if they were used) have been adequately removed.
7. Wrap or cover equipment in clear plastic until it is time to be used.

**SAFETY REMINDER**

Even when equipment is disconnected from power sources, dangers such as the following may persist:

Falls - An auger flight standing on its end may fall and injure someone. Secure all loose articles to prevent heavy articles from falling onto people or equipment.

Burns - Steam cleaner water is heated to more than 212 °F and exhibits thermal energy that can cause burns. Prevent contact of skin with hot water or surfaces.

High water pressure - Pressure washer discharge can have 2,000 to 4,000 psi of water pressure. Water under this amount of pressure can rupture skin and other human tissues. Water at 4,000 psi exiting a 0° tip can be dangerous because of its relatively high cutting power. The exit velocity and cutting power of the water are reduced when exiting a 40° fan tip, but damage to soft tissues is still possible.

In general, follow the rules below to avoid injury, equipment damage, or incomplete decontamination:

1. Read the operating manual and follow the manufacturers' recommended safety practices before operating pressure washers and steam cleaners.
2. Never point the pressure washer or steam cleaner at another person or use to clean your boots or other parts of your body. Water lacerations and burns may appear to be minor at first but can be life threatening. Do not attempt to hold small parts in your hand while washing them with high-temperature or high-pressure water.
3. Always wear PPE as specified in the HASP such as:
  - Hard hat, safety glasses, splash shield, impermeable apron or splash suit, and hearing protection. Remember that excessive noise is a hazard when operating gas-powered engines and electrically driven pressure washers. PPE will be identified in your project specific planning documents.
4. Inspect each device before use. An inspection checklist will be provided in the project-specific planning documents. If it is a rented device, safety measures are typically provided by the vendor. In all cases, if you are not familiar with the operation of a pressure washer/steam cleaner, do not operate it until you obtain and thoroughly review operating instructions and recommended safety practices.
5. Do not modify equipment unless the manufacturer has approved the modifications.

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### 7.2.3 Soil/Sediment Sampling Equipment

This section applies to soil sampling equipment including but not limited to hand augers, stainless steel trowels/spoons, bowls, dredges, scoops, split spoons, Macro Core samplers, etc.

1. Remove all loose soil from the equipment through manual means.
2. Through a combination of scrubbing using soap and water and/or steam cleaning or pressure washing, remove visible dirt/soil from the equipment.
3. Rinse the equipment with tap water.

**CAUTION**

Do not rinse PE, PVC, and associated tubing with solvents. The appropriate procedures should be defined within the project-specific planning documents. If they are not defined, contact the FOL for guidance. The solvent rinse described in Step 4 may be omitted if groundwater does not contain oil, grease, PAHs, PCBs, or other hard to remove organic materials.

4. If the equipment is contaminated or suspected to be contaminated with oil, grease, PAHs, PCBs, or other hard to remove organic materials, rinse the equipment with pesticide-grade isopropanol.
5. Rinse the equipment with deionized water.
6. To the extent possible, allow components to air dry.
7. If the equipment is to be used immediately after decontamination, screen it with a calibrated PID/FID to ensure that all solvents (if they were used) and trace contaminants have been adequately removed.
8. After the equipment has dried, wrap it in aluminum foil for storage until use.

Dredges employed in sediment sampling are typically decontaminated as follows:

- Remove the sediment sample from the sampling device
- If sufficient associated surface water is available at the sampling site, place the dredge in the water and flush to remove visible sediment.
- Extract the dredge and wash it in soap and water per the project-specific planning documents.

**CAUTION**

When handling dredges, the primary safety concern is trapping fingers or extremities in the larger dredge samplers within the jaws or pinch points of the mechanical jaws. Keep hands, fingers, and extremities away from these pinch and compression points. Either handle the device by the rope or preferably lock the jaws in place to control the potential for closing during maintenance and/or cleaning.

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### 7.3 Contact Waste/Materials

During the course of field investigations, disposable/single-use equipment becomes contaminated. These items include tubing, trowels, PPE (gloves, overboots, splash suits, etc.), and broken sample containers.

With the exception of the broken glass, single-use articles should be cleaned (washed and rinsed) of visible materials and disposed as normal refuse. The exception to this rule is that extremely soiled materials that cannot be cleaned shall be containerized for disposal in accordance with applicable federal, state, and local regulations.

#### 7.3.1 Investigation-Derived Wastes - Decontamination Wash Waters and Sediments

**NOTE**

Requirements for waste storage may differ from one facility to the next. Facility-specific directions for waste storage areas will be provided in project-specific documents, or separate direction will be provided by the Project Manager.

1. Assume that all investigation-derived waste (IDW) generated from decontamination activities contains the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. Waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.
2. Where possible, use filtering systems to extend the use of water within a closed system wash unit to recycle water and to reduce possible waste amounts.

**NOTE**

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.

3. Label waste storage containers appropriately labeled (see Attachment A).
4. Ensure that the IDW storage area is configured to meet the following specifications to permit access to the containers and to conduct spill/leak monitoring, sampling, and extraction when the disposal route is determined:
  - Enclose areas accessible by the general public using construction fencing and signs.
  - Stored materials in 55-gallon drums on pallets with four (or fewer) drums per pallet.
  - Maintain the retaining bolt and label on the outside of storage containers where readily visible.
  - Provide at least 4 feet of room between each row of pallets to allow access to containers for sampling, drum removal, and spill response.
  - As directed in project-specific planning documents, maintain an IDW Inventory List and provide the list to the site Point of Contact at the termination of each shift.
  - Maintain spill response equipment at the IDW storage area in case it is required for immediate access.

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- Where possible, use equipment for moving containers. Where not possible, obtain help to manipulate containers.

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**CAUTION**

Each container of water can weigh up to 490 pounds. Each 55-gallon drum of wet soil can weigh more than 750 pounds. Fill drums and temporary containers to 80 percent capacity to minimize spill and handling difficulties. Use drum carts to move filled drums.

See safe lifting techniques provided in Section 4.4 of the Tetra Tech NUS, Inc. Health and Safety Guidance Manual.

When placing drums, keep your fingers out of pinch and smash points such as between the drums. In some cases such as well development and/or purge water, you can place the drums to be filled on the pallet and transport materials in smaller easier to handle containers.

**7.4 Decontamination Evaluation**

Upon decontamination of equipment, determine the effectiveness of the decontamination process in the following manner:

- Visual evaluation – A visual evaluation will be conducted to ensure the removal of particulate matter. This shall be done to ensure that the washing/rinsing process is working as intended.
- Instrument Screening – A properly calibrated PID/FID should be used to evaluate the presence of site contaminants and solvents used in the cleaning process. The air intake of the instrument shall be passed over the article to be evaluated. Avoid placing the instrument probe into residual waters. A PID/FID reading greater than the daily established background level requires a repeat of the decontamination process, followed by rescreening with the PID/FID. This sequence must be repeated until no instrument readings greater than the daily established background level are observed. It should be noted that the instrument scan is only viable if the contaminants are detectable within the instrument's capabilities.

**NOTE**

When required by project-specific planning documents, collection of rinsate blanks (see next step) shall be completed without exception unless approval to not collect these samples is obtained from the Project Manager.

- Collection of Rinsate Blanks – It is recommended that rinsate samples be collected to:
  - Evaluate the decontamination procedure representing different equipment applications (pumps versus drilling equipment) and different decontamination applications.
  - Single-use disposable equipment – The number of samples should represent different types of equipment as well as different lot numbers of single-use articles.
  - The collection and the frequency of collection of rinsate samples are as follows unless specified differently in the project-specific planning documents:
    - Per decontamination method
    - Per disposable article/batch number of disposable articles

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**NOTE**

It is recommended that an initial rinsate sample be collected early in the project to ensure that the decontamination process is functioning properly and to avoid using a contaminated batch of single-use articles. It is recommended that a follow-up sample be collected later during the execution of the project to ensure that those conditions do not change.

Rinsate samples collection may be driven by types of and/or levels of contaminant. Difficult to remove contaminants, oils/greases, some PAHs/PCBs, etc. may also support the collection of additional rinsates due to the obvious challenges to the decontamination process. This is a field consideration to be determined by the FOL.



# STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech, Inc.		
Prepared	Earth Sciences Department		
Approved	J. Zimmerly		

Subject  
DECONTAMINATION OF FIELD EQUIPMENT

## Attachment A iDW Label

**INVESTIGATION DERIVED WASTE**

GENERATOR INFORMATION:

SITE \_\_\_\_\_ JOB NO. \_\_\_\_\_

LOCATION \_\_\_\_\_

DATE \_\_\_\_\_

DRUM# \_\_\_\_\_

CONTENTS \_\_\_\_\_

VOLUME \_\_\_\_\_

CONTACT \_\_\_\_\_

EMERGENCY PHONE NUMBER \_\_\_\_\_

**U.S. ENVIRONMENTAL PROTECTION AGENCY  
REGION I**

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

Quality Assurance Unit  
U.S. Environmental Protection Agency – Region 1  
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## USE OF TERMS

Equipment blank: The equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank needs only to include the pump in subsequent sampling rounds. If the pump and tubing are dedicated to the well, the equipment blank is collected prior to its placement in the well. If the pump and tubing will be used to sample multiple wells, the equipment blank is normally collected after sampling from contaminated wells and not after background wells.

Field duplicates: Field duplicates are collected to determine precision of the sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

Indicator field parameters: This SOP uses field measurements of turbidity, dissolved oxygen, specific conductance, temperature, pH, and oxidation/reduction potential (ORP) as indicators of when purging operations are sufficient and sample collection may begin.

Matrix Spike/Matrix Spike Duplicates: Used by the laboratory in its quality assurance program. Consult the laboratory for the sample volume to be collected.

Potentiometric Surface: The level to which water rises in a tightly cased well constructed in a confined aquifer. In an unconfined aquifer, the potentiometric surface is the water table.

QAPP: Quality Assurance Project Plan

SAP: Sampling and Analysis Plan

SOP: Standard operating procedure

Stabilization: A condition that is achieved when all indicator field parameter measurements are sufficiently stable (as described in the "Monitoring Indicator Field Parameters" section) to allow sample collection to begin.

Temperature blank: A temperature blank is added to each sample cooler. The blank is measured upon receipt at the laboratory to assess whether the samples were properly cooled during transit.

Trip blank (VOCs): Trip blank is a sample of analyte-free water taken to the sampling site and returned to the laboratory. The trip blanks (one pair) are added to each sample cooler that contains VOC samples.

## SCOPE & APPLICATION

The goal of this groundwater sampling procedure is to collect water samples that reflect the total mobile organic and inorganic loads (dissolved and colloidal sized fractions) transported through the subsurface under ambient flow conditions, with minimal physical and chemical alterations from sampling operations. This standard operating procedure (SOP) for collecting groundwater samples will help ensure that the project's data quality objectives (DQOs) are met under certain low-flow conditions.

The SOP emphasizes the need to minimize hydraulic stress at the well-aquifer interface by maintaining low water-level drawdowns, and by using low pumping rates during purging and sampling operations. Indicator field parameters (e.g., dissolved oxygen, pH, etc.) are monitored during purging in order to determine when sample collection may begin. Samples properly collected using this SOP are suitable for analysis of groundwater contaminants (volatile and semi-volatile organic analytes, dissolved gases, pesticides, PCBs, metals and other inorganics), or naturally occurring analytes. This SOP is based on Puls, and Barcelona (1996).

This procedure is designed for monitoring wells with an inside diameter (1.5-inches or greater) that can accommodate a positive lift pump with a screen length or open interval ten feet or less and with a water level above the top of the screen or open interval (Hereafter, the "screen or open interval" will be referred to only as "screen interval"). This SOP is not applicable to other well-sampling conditions.

While the use of dedicated sampling equipment is not mandatory, dedicated pumps and tubing can reduce sampling costs significantly by streamlining sampling activities and thereby reducing the overall field costs.

The goal of this procedure is to emphasize the need for consistency in deploying and operating equipment while purging and sampling monitoring wells during each sampling event. This will help to minimize sampling variability.

This procedure describes a general framework for groundwater sampling. Other site specific information (hydrogeological context, conceptual site model (CSM), DQOs, etc.) coupled with systematic planning must be added to the procedure in order to develop an appropriate site specific SAP/QAPP. In addition, the site specific SAP/QAPP must identify the specific equipment that will be used to collect the groundwater samples.

This procedure does not address the collection of water or free product samples from wells containing free phase LNAPLs and/or DNAPLs (light or dense non-aqueous phase

liquids). For this type of situation, the reader may wish to check: Cohen, and Mercer (1993) or other pertinent documents.

This SOP is to be used when collecting groundwater samples from monitoring wells at all Superfund, Federal Facility and RCRA sites in Region 1 under the conditions described herein. Request for modification of this SOP, in order to better address specific situations at individual wells, must include adequate technical justification for proposed changes. All changes and modifications must be approved and included in a revised SAP/QAPP before implementation in field.

## **BACKGROUND FOR IMPLEMENTATION**

It is expected that the monitoring well screen has been properly located (both laterally and vertically) to intercept existing contaminant plume(s) or along flow paths of potential contaminant migration. Problems with inappropriate monitoring well placement or faulty/improper well installation cannot be overcome by even the best water sampling procedures. This SOP presumes that the analytes of interest are moving (or will potentially move) primarily through the more permeable zones intercepted by the screen interval.

Proper well construction, development, and operation and maintenance cannot be overemphasized. The use of installation techniques that are appropriate to the hydrogeologic setting of the site often prevent "problem well" situations from occurring. During well development, or redevelopment, tests should be conducted to determine the hydraulic characteristics of the monitoring well. The data can then be used to set the purging/sampling rate, and provide a baseline for evaluating changes in well performance and the potential need for well rehabilitation. Note: if this installation data or well history (construction and sampling) is not available or discoverable, for all wells to be sampled, efforts to build a sampling history should commence with the next sampling event.

The pump intake should be located within the screen interval and at a depth that will remain under water at all times. It is recommended that the intake depth and pumping rate remain the same for all sampling events. The mid-point or the lowest historical midpoint of the saturated screen length is often used as the location of the pump intake. For new wells, or for wells without pump intake depth information, the site's SAP/QAPP must provide clear reasons and instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected. If the depths to top and bottom of the well screen are not known, the SAP/QAPP will need to describe how the sampling depth will be determined and how the data can be used.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU, and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection

may still take place provided the indicator field parameter criteria in this procedure are met. If after 2 hours of purging indicator field parameters have not stabilized, one of three optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization), c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may reflect a sampling bias and therefore, the data may not meet the data quality objectives of the sampling event).

It is recommended that low-flow sampling be conducted when the air temperature is above 32°F (0°C). If the procedure is used below 32°F, special precautions will need to be taken to prevent the groundwater from freezing in the equipment. Because sampling during freezing temperatures may adversely impact the data quality objectives, the need for water sample collection during months when these conditions are likely to occur should be evaluated during site planning and special sampling measures may need to be developed. Ice formation in the flow-through-cell will cause the monitoring probes to act erratically. A transparent flow-through-cell needs to be used to observe if ice is forming in the cell. If ice starts to form on the other pieces of the sampling equipment, additional problems may occur.

## **HEALTH & SAFETY**

When working on-site, comply with all applicable OSHA requirements and the site's health/safety procedures. All proper personal protection clothing and equipment are to be worn. Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc.

## **CAUTIONS**

The following cautions need to be considered when planning to collect groundwater samples when the below conditions occur.

If the groundwater degasses during purging of the monitoring well, dissolved gases and VOCs will be lost. When this happens, the groundwater data for dissolved gases (e.g., methane, ethene, ethane, dissolved oxygen, etc.) and VOCs will need to be qualified. Some conditions that can promote degassing are the use of a vacuum pump (e.g., peristaltic pumps), changes in aperture along the sampling tubing, and squeezing/pinching the pump's tubing which results in a pressure change.

When collecting the samples for dissolved gases and VOCs analyses, avoid aerating the groundwater in the pump's tubing. This can cause loss of the dissolved gases and VOCs in

the groundwater. Having the pump's tubing completely filled prior to sampling will avoid this problem when using a centrifugal pump or peristaltic pump.

Direct sun light and hot ambient air temperatures may cause the groundwater in the tubing and flow-through-cell to heat up. This may cause the groundwater to degas which will result in loss of VOCs and dissolved gases. When sampling under these conditions, the sampler will need to shade the equipment from the sunlight (e.g., umbrella, tent, etc.). If possible, sampling on hot days, or during the hottest time of the day, should be avoided. The tubing exiting the monitoring well should be kept as short as possible to avoid the sun light or ambient air from heating up the groundwater.

Thermal currents in the monitoring well may cause vertical mixing of water in the well bore. When the air temperature is colder than the groundwater temperature, it can cool the top of the water column. Colder water which is denser than warm water sinks to the bottom of the well and the warmer water at the bottom of the well rises, setting up a convection cell. "During low-flow sampling, the pumped water may be a mixture of convecting water from within the well casing and aquifer water moving inward through the screen. This mixing of water during low-flow sampling can substantially increase equilibration times, can cause false stabilization of indicator parameters, can give false indication of redox state, and can provide biological data that are not representative of the aquifer conditions" (Vrobesky 2007).

Failure to calibrate or perform proper maintenance on the sampling equipment and measurement instruments (e.g., dissolved oxygen meter, etc.) can result in faulty data being collected.

Interferences may result from using contaminated equipment, cleaning materials, sample containers, or uncontrolled ambient/surrounding air conditions (e.g., truck/vehicle exhaust nearby).

Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment and/or proper planning to avoid ambient air interferences. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

Clean and decontaminate all sampling equipment prior to use. All sampling equipment needs to be routinely checked to be free from contaminants and equipment blanks collected to ensure that the equipment is free of contaminants. Check the previous equipment blank data for the site (if they exist) to determine if the previous cleaning procedure removed the contaminants. If contaminants were detected and they are a concern, then a more vigorous cleaning procedure will be needed.

## **PERSONNEL QUALIFICATIONS**

All field samplers working at sites containing hazardous waste must meet the requirements of the OSHA regulations. OSHA regulations may require the sampler to take the 40 hour OSHA health and safety training course and a refresher course prior to engaging in any field activities, depending upon the site and field conditions.

The field samplers must be trained prior to the use of the sampling equipment, field instruments, and procedures. Training is to be conducted by an experienced sampler before initiating any sampling procedure.

The entire sampling team needs to read, and be familiar with, the site Health and Safety Plan, all relevant SOPs, and SAP/QAPP (and the most recent amendments) before going onsite for the sampling event. It is recommended that the field sampling leader attest to the understanding of these site documents and that it is recorded.

## **EQUIPMENT AND SUPPLIES**

### **A. Informational materials for sampling event**

A copy of the current Health and Safety Plan, SAP/QAPP, monitoring well construction data, location map(s), field data from last sampling event, manuals for sampling, and the monitoring instruments' operation, maintenance, and calibration manuals should be brought to the site.

### **B. Well keys.**

### **C. Extraction device**

Adjustable rate, submersible pumps (e.g., centrifugal, bladder, etc.) which are constructed of stainless steel or Teflon are preferred. Note: if extraction devices constructed of other materials are to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

If bladder pumps are selected for the collection of VOCs and dissolved gases, the pump setting should be set so that one pulse will deliver a water volume that is sufficient to fill a 40 mL VOC vial. This is not mandatory, but is considered a "best practice". For the proper operation, the bladder pump will need a minimum amount of water above the pump; consult the manufacturer for the recommended submergence. The pump's recommended submergence value should be determined during the planning stage, since it may influence well construction and placement of dedicated pumps where water-level fluctuations are significant.

Adjustable rate, peristaltic pumps (suction) are to be used with caution when collecting samples for VOCs and dissolved gases (e.g., methane, carbon dioxide, etc.) analyses. Additional information on the use of peristaltic pumps can be found in Appendix A. If peristaltic pumps are used, the inside diameter of the rotor head tubing needs to match the inside diameter of the tubing installed in the monitoring well.

Inertial pumping devices (motor driven or manual) are not recommended. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than submersible pumps (potentially increasing turbidity and sampling variability, etc.). This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

#### **D. Tubing**

Teflon or Teflon-lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics. Note: if tubing constructed of other materials is to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for metal and other inorganics analyses.

The use of 1/4 inch or 3/8 inch (inside diameter) tubing is recommended. This will help ensure that the tubing remains liquid filled when operating at very low pumping rates when using centrifugal and peristaltic pumps.

Silastic tubing should be used for the section around the rotor head of a peristaltic pump. It should be less than a foot in length. The inside diameter of the tubing used at the pump rotor head must be the same as the inside diameter of tubing placed in the well. A tubing connector is used to connect the pump rotor head tubing to the well tubing. Alternatively, the two pieces of tubing can be connected to each other by placing the one end of the tubing inside the end of the other tubing. The tubing must not be reused.

#### **E. The water level measuring device**

Electronic "tape", pressure transducer, water level sounder/level indicator, etc. should be capable of measuring to 0.01 foot accuracy. Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level "tape" at the start and end of each sampling event.

#### **F. Flow measurement supplies**

Graduated cylinder (size according to flow rate) and stopwatch usually will suffice.

Large graduated bucket used to record total water purged from the well.

#### **G. Interface probe**

To be used to check on the presence of free phase liquids (LNAPL, or DNAPL) before purging begins (as needed).

#### **H. Power source (generator, nitrogen tank, battery, etc.)**

When a gasoline generator is used, locate it downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate samples.

#### **I. Indicator field parameter monitoring instruments**

Use of a multi-parameter instrument capable of measuring pH, oxidation/reduction potential (ORP), dissolved oxygen (DO), specific conductance, temperature, and coupled with a flow-through-cell is required when measuring all indicator field parameters, except turbidity. Turbidity is collected using a separate instrument. Record equipment/instrument identification (manufacturer, and model number).

Transparent, small volume flow-through-cells (e.g., 250 mLs or less) are preferred. This allows observation of air bubbles and sediment buildup in the cell, which can interfere with the operation of the monitoring instrument probes, to be easily detected. A small volume cell facilitates rapid turnover of water in the cell between measurements of the indicator field parameters.

It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.

Turbidity samples are collected before the flow-through-cell. A "T" connector coupled with a valve is connected between the pump's tubing and flow-through-cell. When a turbidity measurement is required, the valve is opened to allow the groundwater to flow into a container. The valve is closed and the container sample is then placed in the turbidimeter.

Standards are necessary to perform field calibration of instruments. A minimum of two standards are needed to bracket the instrument measurement range for all parameters except ORP which use a Zobell solution as a standard. For dissolved oxygen, a wet sponge used for the 100% saturation and a zero dissolved oxygen solution are used for the calibration.

Barometer (used in the calibration of the Dissolved Oxygen probe) and the conversion formula to convert the barometric pressure into the units of measure used by the Dissolved Oxygen meter are needed.

**J. Decontamination supplies**

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

**K. Record keeping supplies**

Logbook(s), well purging forms, chain-of-custody forms, field instrument calibration forms, etc.

**L. Sample bottles**

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

**N. Sample tags or labels**

**O. PID or FID instrument**

If appropriate, to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

## **P. Miscellaneous Equipment**

Equipment to keep the sampling apparatus shaded in the summer (e.g., umbrella) and from freezing in the winter. If the pump's tubing is allowed to heat up in the warm weather, the cold groundwater may degas as it is warmed in the tubing.

## **EQUIPMENT/INSTRUMENT CALIBRATION**

Prior to the sampling event, perform maintenance checks on the equipment and instruments according to the manufacturer's manual and/or applicable SOP. This will ensure that the equipment/instruments are working properly before they are used in the field.

Prior to sampling, the monitoring instruments must be calibrated and the calibration documented. The instruments are calibrated using U.S Environmental Protection Agency Region 1 *Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductance, oxidation/reduction [ORP], and turbidity)*, January 19, 2010, or latest version or from one of the methods listed in 40CFR136, 40CFR141 and SW-846.

The instruments shall be calibrated at the beginning of each day. If the field measurement falls outside the calibration range, the instrument must be re-calibrated so that all measurements fall within the calibration range. At the end of each day, a calibration check is performed to verify that instruments remained in calibration throughout the day. This check is performed while the instrument is in measurement mode, not calibration mode. If the field instruments are being used to monitor the natural attenuation parameters, then a calibration check at mid-day is highly recommended to ensure that the instruments did not drift out of calibration. Note: during the day if the instrument reads zero or a negative number for dissolved oxygen, pH, specific conductance, or turbidity (negative value only), this indicates that the instrument drifted out of calibration or the instrument is malfunctioning. If this situation occurs the data from this instrument will need to be qualified or rejected.

## **PRELIMINARY SITE ACTIVITIES (as applicable)**

Check the well for security (damage, evidence of tampering, missing lock, etc.) and record pertinent observations (include photograph as warranted).

If needed lay out sheet of clean polyethylene for monitoring and sampling equipment, unless equipment is elevated above the ground (e.g., on a table, etc.).

Remove well cap and if appropriate measure VOCs at the rim of the well with a PID or FID instrument and record reading in field logbook or on the well purge form.

If the well casing does not have an established reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook (consider a photographic record as well). All water level measurements must be recorded relative to this reference point (and the altitude of this point should be determined using techniques that are appropriate to site's DQOs).

If water-table or potentiometric surface map(s) are to be constructed for the sampling event, perform synoptic water level measurement round (in the shortest possible time) before any purging and sampling activities begin. If possible, measure water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) the day before sampling begins, in order to allow for re-settlement of any particulates in the water column. This is especially important for those wells that have not been recently sampled because sediment buildup in the well may require the well to be redeveloped. If measurement of total well depth is not made the day before, it should be measured after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe may not be necessary unless analytical data or field analysis signal a worsening situation. This SOP cannot be used in the presence of LNAPLs or DNAPLs. If NAPLs are present, the project team must decide upon an alternate sampling method. All project modifications must be approved and documented prior to implementation.

If available check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). If changes are made in the intake depth or extraction rate(s) used during previous sampling event(s), for either portable or dedicated extraction devices, record new values, and explain reasons for the changes in the field logbook.

## **PURGING AND SAMPLING PROCEDURE**

Purging and sampling wells in order of increasing chemical concentrations (known or anticipated) are preferred.

The use of dedicated pumps is recommended to minimize artificial mobilization and entrainment of particulates each time the well is sampled. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each

sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

#### **A. Initial Water Level**

Measure the water level in the well before installing the pump if a non-dedicated pump is being used. The initial water level is recorded on the purge form or in the field logbook.

#### **B. Install Pump**

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the appropriate depth (may not be the mid-point of the screen/open interval). The Sampling and Analysis Plan/Quality Assurance Project Plan should specify the sampling depth (used previously), or provide criteria for selection of intake depth for each new well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well.

Pump tubing lengths, above the top of well casing should be kept as short as possible to minimize heating the groundwater in the tubing by exposure to sun light and ambient air temperatures. Heating may cause the groundwater to degas, which is unacceptable for the collection of samples for VOC and dissolved gases analyses.

#### **C. Measure Water Level**

Before starting pump, measure water level. Install recording pressure transducer, if used to track drawdowns, to initialize starting condition.

#### **D. Purge Well**

From the time the pump starts purging and until the time the samples are collected, the purged water is discharged into a graduated bucket to determine the total volume of groundwater purged. This information is recorded on the purge form or in the field logbook.

Start the pump at low speed and slowly increase the speed until discharge occurs. Check water level. Check equipment for water leaks and if present fix or replace the affected equipment. Try to match pumping rate used during previous sampling event(s). Otherwise, adjust pump speed until there is little or no water level drawdown. If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging.

Monitor and record the water level and pumping rate every five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" somewhat as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. If the initial water level is above the top of the screen do not allow the water level to fall into the well screen. The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

Avoid the use of constriction devices on the tubing to decrease the flow rate because the constrictor will cause a pressure difference in the water column. This will cause the groundwater to degas and result in a loss of VOCs and dissolved gasses in the groundwater samples.

Note: the flow rate used to achieve a stable pumping level should remain constant while monitoring the indicator parameters for stabilization and while collecting the samples.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (e.g., bladder, peristaltic), and/or the use of dedicated equipment. For new monitoring wells, or wells where the following situation has not occurred before, if the recovery rate to the well is less than 50 mL/min., or the well is being essentially dewatered during purging, the well should be sampled as soon as the water level has recovered sufficiently to collect the volume needed for all anticipated samples. The project manager or field team leader will need to make the decision when samples should be collected, how the sample is to be collected, and the reasons recorded on the purge form or in the field logbook. A water level measurement needs to be performed and recorded before samples are collected. If the project manager decides to collect the samples using the pump, it is best during this recovery period that the pump intake tubing not be removed, since this will aggravate any turbidity problems. Samples in this specific situation may be collected without stabilization of indicator field parameters. Note that field conditions and efforts to overcome problematic situations must be recorded in order to support field decisions to deviate from normal procedures described in this SOP. If this type of problematic situation persists in a well, then water sample collection should be changed to a passive or no-purge method, if consistent with the site's DQOs, or have a new well installed.

### E. Monitor Indicator Field Parameters

After the water level has stabilized, connect the "T" connector with a valve and the flow-through-cell to monitor the indicator field parameters. If excessive turbidity is anticipated or encountered with the pump startup, the well may be purged for a while without connecting up the flow-through-cell, in order to minimize particulate buildup in the cell (This is a judgment call made by the sampler). Water level drawdown measurements should be made as usual. If possible, the pump may be installed the day before purging to allow particulates that were disturbed during pump insertion to settle.

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, ORP, DO) at a frequency of five minute intervals or greater. The pump's flow rate must be able to "turn over" at least one flow-through-cell volume between measurements (for a 250 mL flow-through-cell with a flow rate of 50 mLs/min., the monitoring frequency would be every five minutes; for a 500 mL flow-through-cell it would be every ten minutes). If the cell volume cannot be replaced in the five minute interval, then the time between measurements must be increased accordingly. Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments followed by stabilization of indicator parameters. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings are within the following limits:

- Turbidity** (10% for values greater than 5 NTU; if three Turbidity values are less than 5 NTU, consider the values as stabilized),
- Dissolved Oxygen** (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
- Specific Conductance** (3%),
- Temperature** (3%),
- pH** ( $\pm 0.1$  unit),
- Oxidation/Reduction Potential** ( $\pm 10$  millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Samples for turbidity measurements are obtained before water enters the flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities. Record start and stop times and give a brief description of cleaning activities.

The flow-through-cell must be designed in a way that prevents gas bubble entrapment in the cell. Placing the flow-through-cell at a 45 degree angle with the port facing upward can help remove bubbles from the flow-through-cell (see Appendix B Low-Flow Setup Diagram). All during the measurement process, the flow-through-cell must remain free of any gas bubbles. Otherwise, the monitoring probes may act erratically. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must remain submerged in water at all times.

#### **F. Collect Water Samples**

When samples are collected for laboratory analyses, the pump's tubing is disconnected from the "T" connector with a valve and the flow-through-cell. The samples are collected directly from the pump's tubing. Samples must not be collected from the flow-through-cell or from the "T" connector with a valve.

VOC samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the pump's flow rate is too high to collect the VOC/dissolved gases samples, collect the other samples first. Lower the pump's flow rate to a reasonable rate and collect the VOC/dissolved gases samples and record the new flow rate.

During purging and sampling, the centrifugal/peristaltic pump tubing must remain filled with water to avoid aeration of the groundwater. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use the following procedure to collect samples: collect non-VOC/dissolved gases samples first, then increase flow rate slightly until the water completely fills the tubing, collect the VOC/dissolved gases samples, and record new drawdown depth and flow rate.

For bladder pumps that will be used to collect VOC or dissolved gas samples, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL VOC vial.

Use pre-preserved sample containers or add preservative, as required by analytical methods, to the samples immediately after they are collected. Check the analytical methods (e.g. EPA SW-846, 40 CFR 136, water supply, etc.) for additional information on preservation.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter (transparent housing preferred) is required, and the filter size (0.45  $\mu\text{m}$  is commonly used) should be based on the sampling objective. Pre-rinse the filter with groundwater prior to sample collection. Make sure the filter is free of air bubbles before samples are collected. Preserve the filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in groundwater for human health or ecological risk calculations.

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

#### **G. Post Sampling Activities**

If a recording pressure transducer is used to track drawdown, re-measure water level with tape.

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

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

Secure the well.

#### **DECONTAMINATION**

Decontaminate sampling equipment prior to use in the first well and then following sampling of each well. Pumps should not be removed between purging and sampling operations. The pump, tubing, support cable and electrical wires which were in contact with the well should be decontaminated by one of the procedures listed below.

The use of dedicated pumps and tubing will reduce the amount of time spent on decontamination of the equipment. If dedicated pumps and tubing are used, only the initial sampling event will require decontamination of the pump and tubing.

Note if the previous equipment blank data showed that contaminant(s) were present after using the below procedure or the one described in the SAP/QAPP, a more vigorous procedure may be needed.

#### Procedure 1

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

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

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

Optional - flush with isopropyl alcohol (pesticide grade; must be free of ketones {e.g., acetone}) or with methanol. This step may be required if the well is highly contaminated or if the equipment blank data from the previous sampling event show that the level of contaminants is significant.

Flush with distilled/deionized water. This step must remove all traces of alcohol (if used) from the equipment. The final water rinse must not be recycled.

#### Procedure 2

Steam clean the outside of the submersible pump.

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

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

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

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

### **FIELD QUALITY CONTROL**

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the groundwater samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. Quality control samples include field duplicates, equipment blanks, matrix spike/matrix spike duplicates, trip blanks (VOCs), and temperature blanks.

### **FIELD LOGBOOK**

A field log shall be kept to document all groundwater field monitoring activities (see Appendix C, example table), and record the following for each well:

Site name, municipality, state.

Well identifier, latitude-longitude or state grid coordinates.

Measuring point description (e.g., north side of PVC pipe).

Well depth, and measurement technique.

Well screen length.

Pump depth.

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

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

Pumping rate, drawdown, indicator parameters values, calculated or measured total volume pumped, and clock time of each set of measurements.

Type of tubing used and its length.

Type of pump used.

Clock time of start and end of purging and sampling activity.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analyses.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions, including approximate ambient air temperature.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

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

## **DATA REPORT**

Data reports are to include laboratory analytical results, QA/QC information, field indicator parameters measured during purging, field instrument calibration information, and whatever other field logbook information is needed to allow for a full evaluation of data usability.

Note: the use of trade, product, or firm names in this sampling procedure is for descriptive purposes only and does not constitute endorsement by the U.S. EPA.

## **REFERENCES**

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U.S. Environmental Protection Agency, EPA SW-846.

U.S. Environmental Protection Agency, 40 CFR 136.

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Vroblesky, Don A., Clifton C. Casey, and Mark A. Lowery, Summer 2007, Influence of Dissolved Oxygen Convection on Well Sampling, *Ground Water Monitoring & Remediation* 27, no. 3: 49-58.

## APPENDIX A PERISTALTIC PUMPS

Before selecting a peristaltic pump to collect groundwater samples for VOCs and/or dissolved gases (e.g., methane, carbon dioxide, etc.) consideration should be given to the following:

- The decision of whether or not to use a peristaltic pump is dependent on the intended use of the data.
- If the additional sampling error that may be introduced by this device is NOT of concern for the VOC/dissolved gases data's intended use, then this device may be acceptable.
- If minor differences in the groundwater concentrations could effect the decision, such as to continue or terminate groundwater cleanup or whether the cleanup goals have been reached, then this device should NOT be used for VOC/dissolved gases sampling. In these cases, centrifugal or bladder pumps are a better choice for more accurate results.

EPA and USGS have documented their concerns with the use of the peristaltic pumps to collect water sample in the below documents.

- "Suction Pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, December 1987.
- "The agency does not recommend the use of peristaltic pumps to sample ground water particularly for volatile organic analytes" *RCRA Ground-Water Monitoring Draft Technical Guidance*, EPA Office of Solid Waste, November 1992.
- "The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and volatiles loss", *Low-flow (Minimal drawdown) Ground-Water Sampling Procedures*, by Robert Puls & Michael Barcelona, April 1996, EPA/540/S-95/504.
- "Suction-lift pumps, such as peristaltic pumps, can operate at a very low pumping rate; however, using negative pressure to lift the sample can result in the loss of volatile analytes", USGS Book 9 Techniques of Water-Resources Investigation, Chapter A4. (Version 2.0, 9/2006).

## APPENDIX B

### SUMMARY OF SAMPLING INSTRUCTIONS

These instructions are for using an adjustable rate, submersible pump or a peristaltic pump with the pump's intake placed at the midpoint of a 10 foot or less well screen or an open interval. The water level in the monitoring well is above the top of the well screen or open interval, the ambient temperature is above 32°F, and the equipment is not dedicated. Field instruments are already calibrated. The equipment is setup according to the diagram at the end of these instructions.

1. Review well installation information. Record well depth, length of screen or open interval, and depth to top of the well screen. Determine the pump's intake depth (e.g., mid-point of screen/open interval).
2. On the day of sampling, check security of the well casing, perform any safety checks needed for the site, lay out a sheet of polyethylene around the well (if necessary), and setup the equipment. If necessary a canopy or an equivalent item can be setup to shade the pump's tubing and flow-through-cell from the sun light to prevent the sun light from heating the groundwater.
3. Check well casing for a reference mark. If missing, make a reference mark. Measure the water level (initial) to 0.01 ft. and record this information.
4. Install the pump's intake to the appropriate depth (e.g., midpoint) of the well screen or open interval. Do not turn-on the pump at this time.
5. Measure water level and record this information.
6. Turn-on the pump and discharge the groundwater into a graduated waste bucket. Slowly increase the flow rate until the water level starts to drop. Reduce the flow rate slightly so the water level stabilizes. Record the pump's settings. Calculate the flow rate using a graduated container and a stop watch. Record the flow rate. Do not let the water level drop below the top of the well screen.

If the groundwater is highly turbid or colored, continue to discharge the water into the bucket until the water clears (visual observation); this usually takes a few minutes. The turbid or colored water is usually from the well being disturbed during the pump installation. If the water does not clear, then you need to make a choice whether to continue purging the well (hoping that it will clear after a reasonable time) or continue to

the next step. Note, it is sometimes helpful to install the pump the day before the sampling event so that the disturbed materials in the well can settle out.

If the water level drops to the top of the well screen during the purging of the well, stop purging the well, and do the following:

Wait for the well to recharge to a sufficient volume so samples can be collected. This may take awhile (pump maybe removed from well, if turbidity is not a problem). The project manager will need to make the decision when samples should be collected and the reasons recorded in the site's log book. A water level measurement needs to be performed and recorded before samples are collected. When samples are being collected, the water level must not drop below the top of the screen or open interval. Collect the samples from the pump's tubing. Always collect the VOCs and dissolved gases samples first. Normally, the samples requiring a small volume are collected before the large volume samples are collected just in case there is not sufficient water in the well to fill all the sample containers. All samples must be collected, preserved, and stored according to the analytical method. Remove the pump from the well and decontaminate the sampling equipment.

If the water level has dropped 0.3 feet or less from the initial water level (water level measure before the pump was installed); proceed to Step 7. If the water level has dropped more than 0.3 feet, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are be collected.

7. Attach the pump's tubing to the "T" connector with a valve (or a three-way stop cock). The pump's tubing from the well casing to the "T" connector must be as short as possible to prevent the groundwater in the tubing from heating up from the sun light or from the ambient air. Attach a short piece of tubing to the other end of the end of the "T" connector to serve as a sampling port for the turbidity samples. Attach the remaining end of the "T" connector to a short piece of tubing and connect the tubing to the flow-through-cell bottom port. To the top port, attach a small piece of tubing to direct the water into a calibrated waste bucket. Fill the cell with the groundwater and remove all gas bubbles from the cell. Position the flow-through-cell in such a way that if gas bubbles enter the cell they can easily exit the cell. If the ports are on the same side of the cell and the cell is cylindrical shape, the cell can be placed at a 45-degree angle with the ports facing upwards; this position should keep any gas bubbles entering the cell away from the monitoring probes and allow the gas bubbles to exit the cell easily (see Low-Flow Setup Diagram). Note,

make sure there are no gas bubbles caught in the probes' protective guard; you may need to shake the cell to remove these bubbles.

8. Turn-on the monitoring probes and turbidity meter.

9. Record the temperature, pH, dissolved oxygen, specific conductance, and oxidation/reduction potential measurements. Open the valve on the "T" connector to collect a sample for the turbidity measurement, close the valve, do the measurement, and record this measurement. Calculate the pump's flow rate from the water exiting the flow-through-cell using a graduated container and a stop watch, and record the measurement. Measure and record the water level. Check flow-through-cell for gas bubbles and sediment; if present, remove them.

10. Repeat Step 9 every 5 minutes or as appropriate until monitoring parameters stabilized. Note at least one flow-through-cell volume must be exchanged between readings. If not, the time interval between readings will need to be increased. Stabilization is achieved when three consecutive measurements are within the following limits:

**Turbidity** (10% for values greater than 5 NTUs; if three Turbidity values are less than 5 NTUs, consider the values as stabilized),

**Dissolved Oxygen** (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),

**Specific Conductance** (3%),

**Temperature** (3%),

**pH** ( $\pm 0.1$  unit),

**Oxidation/Reduction Potential** ( $\pm 10$  millivolts).

If these stabilization requirements do not stabilize in a reasonable time, the probes may have been coated from the materials in the groundwater, from a buildup of sediment in the flow-through-cell, or a gas bubble is lodged in the probe. The cell and the probes will need to be cleaned. Turn-off the probes (not the pump), disconnect the cell from the "T" connector and continue to purge the well. Disassemble the cell, remove the sediment, and clean the probes according to the manufacturer's instructions. Reassemble the cell and connect the cell to the "T" connector. Remove all gas bubbles from the cell, turn-on the probes, and continue the measurements. Record that the time the cell was cleaned.

11. When it is time to collect the groundwater samples, turn-off the monitoring probes, and disconnect the pump's tubing from the "T" connector. If you are using a centrifugal or peristaltic pump check the pump's tubing to determine if the tubing is completely filled with water (no air space).

All samples must be collected and preserved according to the analytical method. VOCs and dissolved gases samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

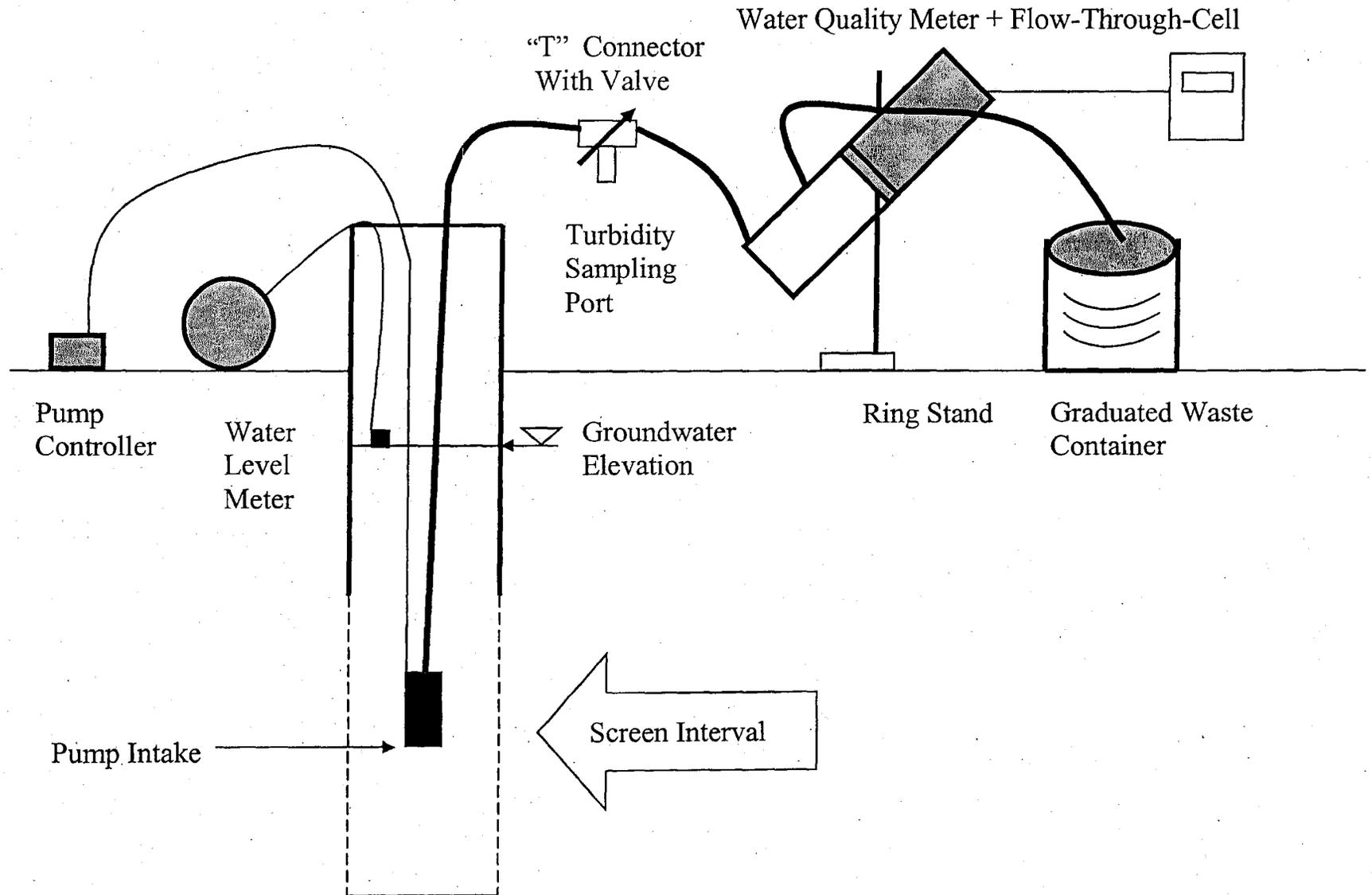
If the pump's tubing is not completely filled with water and the samples are being collected for VOCs and/or dissolved gases analyses using a centrifugal or peristaltic pump, do the following:

All samples must be collected and preserved according to the analytical method. The VOCs and the dissolved gases (e.g., methane, ethane, ethene, and carbon dioxide) samples are collected last. When it becomes time to collect these samples increase the pump's flow rate until the tubing is completely filled. Collect the samples and record the new flow rate.

12. Store the samples according to the analytical method.

13. Record the total purged volume (graduated waste bucket). Remove the pump from the well and decontaminate the sampling equipment.

# Low-Flow Setup Diagram





**METHOD FOR THE DETERMINATION  
OF EXTRACTABLE PETROLEUM HYDROCARBONS (EPH)**

**Massachusetts Department of Environmental Protection**

**Division of Environmental Analysis  
(Senator William X. Wall Experiment Station)**

**Office of Research and Standards**

**Bureau of Waste Site Cleanup**

**Commonwealth of Massachusetts**

**Executive Office of Environmental Affairs  
Ellen Roy Herzfelder  
Secretary**

**Department of Environmental Protection  
Robert W. Gollidge  
Commissioner**

**May 2004  
Revision 1.1**

**METHOD FOR THE DETERMINATION OF  
EXTRACTABLE PETROLEUM HYDROCARBONS (EPH)**

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**DISCLAIMER**

Mention of trade names or commercial products does not constitute endorsement by the Massachusetts Department of Environmental Protection (MADEP). Trade names and commercial products specified within this method are based upon their use in validation studies conducted by MADEP. Equipment and materials cited in this method may be replaced by similar products, as long as adequate data exist or have been produced documenting equivalent or superior performance.

# METHOD FOR THE DETERMINATION OF EXTRACTABLE PETROLEUM HYDROCARBONS

## MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

### 1.0 SCOPE & APPLICATION

- 1.1 This method is designed to measure the collective concentrations of extractable aliphatic and aromatic petroleum hydrocarbons in water and soil/sediment matrices. Extractable aliphatic hydrocarbons are collectively quantitated within two ranges: C<sub>9</sub> through C<sub>18</sub> and C<sub>19</sub> through C<sub>36</sub>. Extractable aromatic hydrocarbons are collectively quantitated within the C<sub>11</sub> through C<sub>22</sub> range. These aliphatic and aromatic hydrocarbon ranges correspond to a boiling point range between approximately 150 °C and 265 °C.
- 1.2 This method is based on a solvent extraction, silica gel solid-phase extraction (SPE)/fractionation process, and gas chromatography (GC) analysis using a flame ionization detector (FID). This procedure should be used by, or under the supervision of, analysts experienced in extractable organics analysis. Analysts should be skilled in the interpretation of gas chromatograms and their use as a quantitative tool.
- 1.3 This method is designed to complement and support the toxicological approach developed by the Massachusetts Department of Environmental Protection to evaluate human health hazards that may result from exposure to petroleum hydrocarbons (MADEP, 1994 and MADEP, 2003). It is intended to produce data in a format suitable for evaluation by that approach and that may be compared to reporting and cleanup standards promulgated in the Massachusetts Contingency Plan (310 CMR 40.0000).
- 1.4 This method is also able to measure the individual concentrations of Target Polynuclear Aromatic Hydrocarbons (PAH) Analytes, including Diesel PAH Analytes, in water and soil/sediment matrices. The use of this method to quantify these analytes is optional, and the Reporting Limits for some of these PAH compounds in water are greater than the notification and/or cleanup standards specified in the Massachusetts Contingency Plan for sites located in groundwater resource area categorized as RCGW-1 in 310 CMR 40.0362(1)(a). In cases where it is necessary to demonstrate compliance with these standards, the use of a gas chromatography/mass spectrometry (GC/MS) method in the selective ion monitoring (SIM) mode and/or high performance liquid chromatography (HPLC) methodology may be necessary.
- 1.5 The fractionation step described in this method can be eliminated to allow for a determination of a Total Petroleum Hydrocarbon (TPH), and/or to obtain qualitative "fingerprinting" information. While TPH provides little information on the chemical constituents, toxicity, or environmental fate of petroleum mixtures, it may be a cost-effective screening tool in cases where relatively low concentrations of contamination are suspected.
- 1.6 Petroleum products suitable for evaluation by this method include kerosene, fuel oil #2, fuel oil #4, fuel oil #6, diesel fuel, jet fuel, and certain lubricating oils. This method, in and of itself, is not suitable for the evaluation of gasoline, mineral spirits, petroleum naphthas, or other petroleum products which contain a significant percentage of hydrocarbons lighter than C<sub>9</sub>. This method, in and of itself, is also not suitable for the evaluation of petroleum products which contain a significant percentage of hydrocarbons heavier than C<sub>36</sub>.
- 1.7 The Reporting Limit (RL) of this method for each of the collective aliphatic and aromatic fractional ranges is approximately 20 mg/kg in soil/sediment, and approximately 100 µg/L in water. The RL of this method for TPH is approximately 10 mg/kg in soil and approximately 100 µg/L in water. The RL of this method for the Target PAH Analytes is compound-specific, and ranges from approximately 0.2 to 1.0 mg/kg in soil/sediment, and 2 to 5 µg/L in water.
- 1.8 This method includes a data adjustment step to subtract the concentration of Target PAH Analytes from the concentration of C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons. This data adjustment may be made by the laboratory or the data user .
- 1.9 Data reports produced using this method must contain all of the required EPH/TPH data information provided in Appendix 3. The format of these data reports is left to the discretion of individual laboratories.
- 1.10 Like all GC procedures, this method is subject to a "false positive" bias in the reporting of Target PAH Analytes, in that non-targeted hydrocarbon compounds eluting or co-eluting within a specified retention time window may be falsely identified and/or quantified as a Target or Diesel PAH Analyte. In addition, this

method is subject to a “false negative” bias in the reporting of Target PAH Analytes, in that the ability to identify Target PAH Analytes at low concentrations may be inhibited if a large unresolved complex mixture is present. While cleanup procedures specified in this method to segregate aliphatic and aromatic fractions will serve to mitigate these concerns, confirmatory analysis by dissimilar columns, GC/MS analysis, or other suitable technique is recommended in cases where a Target PAH Analyte reported by this method approaches or exceeds an applicable reporting or cleanup standard, and/or where coelution of a non-targeted hydrocarbon compound is suspected.

- 1.11 The first draft of this method was evaluated by two interlaboratory “Round Robin” testing programs. In the final evaluation effort, participating laboratories were provided (single-blind) sand samples spiked with a #2 fuel oil, and a “real world” groundwater sample contaminated by a highly weathered fuel oil. Laboratory proficiency was evaluated using a Z-score approach. Data received from 23 laboratories performing the method without significant modifications are summarized below:

Matrix	# Labs Proficient	% Labs Proficient	Data from Proficient Laboratories		
			Fraction	%RSD	% Labs within +/- 40% mean value
soil	19	83	C <sub>9</sub> -C <sub>18</sub> Aliphatics	23	95
			C <sub>19</sub> -C <sub>36</sub> Aliphatics	30	89
			C <sub>11</sub> -C <sub>22</sub> Aromatics	19	100
			Total All Fractions (TPH)	17	100
water	20	87	C <sub>9</sub> -C <sub>18</sub> Aliphatics	84	22
			C <sub>19</sub> -C <sub>36</sub> Aliphatics	192	94
			C <sub>11</sub> -C <sub>22</sub> Aromatics	47	72
			Total All Fractions (TPH)	35	83

Laboratory and method performance on the water sample were adversely impacted by the relatively low concentrations of the aliphatic fractions (due to the low solubilities of these hydrocarbons in “real world” samples), and by breakthrough of naphthalenes into the aliphatic extract during fractionation. Improvements incorporated into this final method are expected to mitigate problems of this nature and significantly improve overall method performance.

- 1.12 This method is one way to quantify collective concentrations of extractable aliphatic and aromatic petroleum hydrocarbons within specified carbon-number-ranges. It has been designed in a manner that attempts to strike a reasonable balance between analytical method performance and utility. In this manner, assumptions and biases have been incorporated into the method to help ensure protective, though not overly conservative data.

As an example, the Department recognizes that branched alkanes have lower boiling points than their n-alkane counterpart, while many of the cycloalkane constituents of diesel range volatile organics have higher boiling points than their n-alkane counterpart. As a consequence:

- (1) Depending upon the specific chromatographic column used, most branched C<sub>9</sub> alkanes are expected to elute before n-nonane, the beginning marker compound for the C<sub>9</sub> through C<sub>18</sub> aliphatic hydrocarbon range, and will not be counted in this range;
- (2) Depending upon the specific chromatographic column used, most branched C<sub>19</sub> alkanes are expected to elute before n-nonadecane, the beginning marker compound for the C<sub>19</sub> through C<sub>36</sub> aliphatic hydrocarbon range, and will be conservatively counted in the more toxic C<sub>9</sub> through C<sub>18</sub> aliphatic hydrocarbon range; and
- (3) Depending upon the specific chromatographic column used, most cycloalkanes within the C<sub>9</sub> through C<sub>18</sub> and C<sub>19</sub> through C<sub>36</sub> aliphatic hydrocarbon ranges will be counted within their proper range.

Based on the nature of petroleum releases encountered in the environment, the collective concentrations of the extractable aliphatic ranges as measured by the EPH Method are considered to be suitable for the evaluation of the risks posed by these releases, consistent with the toxicological approach developed by the Department to evaluate human health hazards that may result from exposure to petroleum hydrocarbons (MADEP, 1994 and MADEP, 2003).

- 1.13 There may be better, more accurate, and/or less conservative ways to produce this data. MADEP encourages methodological innovations that (a) better achieve method and/or data quality objectives, (b) increase analytical precision and accuracy, (c) reduce analytical uncertainties and expenses, and/or (d) reduce the use of toxic solvents and generation of hazardous wastes.

All significant modifications to this method, however, must be disclosed and described on the data report form, as detailed in Section 11.3 and on the MADEP MCP Analytical Method Report Certification Form (See Appendix 3, Question D). Laboratories who make such modifications, and or develop and utilize alternative approaches and methods, are further required to demonstrate:

- That such modifications or methodologies adequately quantify the petroleum hydrocarbon target ranges, as defined in Sections 3.4 through 3.6 of this document, ensuring that any methodological uncertainties or biases are addressed in a manner that ensures protective (i.e., conservative) results and data (e.g., over, not under-quantification of the more toxic ranges);
- That such modifications and/or methodologies employ and document initial and continuing Quality Assurance/Quality Control procedures consistent with similar approaches detailed in the MADEP Compendium of Analytical Methods; and
- That such methods and procedures are fully documented in a detailed Standard Operating Procedure.

- 1.14 Additional information and details on the MADEP VPH/EPH approach, and the results of interlaboratory "Round Robin" evaluations of this method, are available on the World Wide Web at <http://www.magnet.state.ma.us/dep/bwsc/pubs.htm>.

- 1.15 This method is intended to be used in conjunction with the current version of WSC-CAM-IV B, "Quality Assurance and Quality Control Requirements for the Method For The Determination of Extractable Petroleum Hydrocarbons (EPH)". WSC-CAM-IV B was developed by the Department to complement the MADEP EPH Method and to provide more detailed guidance regarding compliance with the quality control requirements and performance standards of the EPH Method.

## 2.0 SUMMARY OF METHOD

- 2.1 A sample submitted for EPH analysis is extracted with methylene chloride, dried over sodium sulfate, solvent exchanged into hexane, and concentrated in a Kuderna-Danish apparatus. Sample cleanup and separation into aliphatic and aromatic fractions is accomplished using commercially available silica gel cartridges or prepared silica gel columns. The two individual fraction extracts produced are re-concentrated to a final volume of 1 mL (i.e., an aliphatic extract and an aromatic extract). The concentrated extracts are then separately analyzed by a capillary column gas chromatograph equipped with a flame ionization detector. The resultant chromatogram of aliphatic compounds is collectively integrated within the C<sub>9</sub> through C<sub>18</sub> and C<sub>19</sub> through C<sub>36</sub> ranges. The resultant chromatogram of aromatic compounds is collectively integrated within the C<sub>11</sub> through C<sub>22</sub> range, and is (optionally) used to identify and quantitate individual concentrations of Target PAH Analytes.
- 2.2 Average calibration factors or response factors determined using an aliphatic hydrocarbon standard mixture are used to calculate the collective concentrations of C<sub>9</sub> through C<sub>18</sub> and C<sub>19</sub> through C<sub>36</sub> aliphatic hydrocarbons. An average calibration factor or response factor determined using a PAH standard mixture is used to calculate a collective C<sub>11</sub> through C<sub>22</sub> aromatic hydrocarbon concentration. Calibration factors or response factors determined for individual components of the PAH standard mixture are also used to calculate individual concentrations of Target PAH Analytes.
- 2.3 This method is suitable for the analysis of waters, soils, sediments, wastes, sludges, and non-aqueous phase liquids (NAPL). However, it should be noted that the method was validated only for soil and water matrices.
- 2.4 This method is based on (1) USEPA Methods 8000B, 8100, 3510C, 3520C, 3540C, 3541, 3545A, 3546, 3580 A and 3630C, SW-846, "Test Methods for Evaluating Solid Waste"; (2) Draft "Method for Determination of Diesel Range Organics", EPA UST Workgroup, November, 1990; and (3) "Method for Determining Diesel Range Organics", Wisconsin Department of Natural Resources, PUBL-SW-141, 1992.

## 3.0 DEFINITIONS

- 3.1 **Aliphatic Hydrocarbon Standard** is defined as a 14 component mixture of the normal alkanes listed in Table 1. The compounds comprising the Aliphatic Hydrocarbon Standard are used to (a) define and establish windows for the two aliphatic hydrocarbons ranges, and (b) determine average calibration or response factors that can in turn be used to calculate the collective concentration of aliphatic hydrocarbons in environmental samples within those hydrocarbon ranges.
- 3.2 **Analytical Batch** is defined as a group of field samples with similar matrices which are processed as a unit. For Quality Control purposes, if the number of samples in such a group is greater than 20, then each group of 20 samples or less is defined as a separate analytical batch.
- 3.3 **Aromatic Hydrocarbon Standard** is defined as a 17 component mixture of the polynuclear aromatic hydrocarbons (PAHs) listed in Table 2. The compounds comprising the Aromatic Hydrocarbon Standard are used to (a) define the individual retention times and calibration or response factors for each of the PAH analytes listed in Table 2, (b) define and establish the window for the C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbon range, and (c) determine an average calibration or response factor that can in turn be used to calculate the collective concentration of aromatic hydrocarbons in environmental samples within the C<sub>11</sub> through C<sub>22</sub> hydrocarbon range.
- 3.4 **C<sub>9</sub> through C<sub>18</sub> Aliphatic Hydrocarbons** are defined as all aliphatic hydrocarbon compounds which contain between nine and 18 carbon atoms and are associated with the release of a petroleum product to the environment. In the EPH method, C<sub>9</sub> through C<sub>18</sub> aliphatic hydrocarbons are defined and quantitated as compounds which elute from n-nonane (C<sub>9</sub>) to just before n-nonadecane (C<sub>19</sub>).

**Table 1. Aliphatic Hydrocarbon Standard**

Carbon Number	Compound	Retention Time (min.) <sup>1</sup>
9	n-Nonane	3.14
10	n-Decane	4.55
12	n-Dodecane	7.86
14	n-Tetradecane	11.10
16	n-Hexadecane	14.05
18	n-Octadecane	16.71
19	n-Nonadecane	17.95
20	n-Eicosane	19.14
1-Chloro-octadecane	Surrogate	20.13
5-alpha-androstane	Internal Standard	21.25 (estimated)
22	n-Docosane	21.35
24	n-Tetracosane	23.40
26	n-Hexacosane	25.29
28	n-Octacosane	27.04
30	n-Triacontane	28.69
36	n-Hexatriacontane	34.82

<sup>1</sup> Results obtained using the column and chromatographic conditions described in Sections 6.4 and 9.5, respectively.

**Table 2. Aromatic Hydrocarbon Standard/Target PAH Analytes**

Compound	Retention Time (min.) <sup>1</sup>	MDL <sup>2</sup>	
		Water (µg/L)	Soil (mg/kg)
Naphthalene	7.66	0.14	0.09
2-Methylnaphthalene	9.49	0.18	0.09
Acenaphthylene	11.93	0.14	0.09
Acenaphthene	12.46	0.16	0.09
Fluorene	13.89	0.25	0.09
Phenanthrene	16.54	0.31	0.16
Anthracene	16.66	0.30	0.16
Ortho-Terphenyl (surrogate)	17.95	0.31	0.13
Fluoranthene	19.92	0.47	0.16
Pyrene	20.51	0.47	0.16
Benzo(a)Anthracene	24.08	0.60	0.19
Chrysene	24.21	0.60	0.19
Benzo(b)Fluoranthene	26.94	0.60	0.19
Benzo(k)Fluoranthene	27.02	0.66	0.16
Benzo(a)Pyrene	27.66	0.50	0.16
Indeno(1,2,3-cd)Pyrene <sup>3</sup>	30.25	0.41	0.13
(a,h)Anthracene <sup>3</sup>	30.36	0.44	0.13
Benzo(g,h,i)Perylene	30.76	0.57	0.13

<sup>1</sup> Results obtained using the column and chromatographic conditions described in Sections 6.4 and 9.5, respectively.

<sup>2</sup> Single laboratory MDL study; see Appendix 1 for more details.

<sup>3</sup> Indeno(1,2,3-cd)Pyrene and Dibenzo(a,h)Anthracene may co-elute under the column and chromatographic conditions described in Sections 6.4 and 9.5, respectively.

- 3.5 **C<sub>19</sub> through C<sub>36</sub> Aliphatic Hydrocarbons** are defined as all aliphatic hydrocarbon compounds which contain between 19 and 36 carbon atoms and are associated with the release of a petroleum product to the environment. In the EPH method, C<sub>19</sub> through C<sub>36</sub> aliphatic hydrocarbons are defined and quantitated as compounds, which elute from n-nonadecane (C<sub>19</sub>) to just after hexatriacontane (C<sub>36</sub>).
- 3.6 **C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons** are defined as all aromatic hydrocarbon compounds which contain between 11 and 22 carbon atoms and are associated with the release of a petroleum product to the environment. In the EPH method, C<sub>11</sub> through C<sub>22</sub> aromatic hydrocarbons are defined and quantitated as compounds which elute from naphthalene to just after benzo(g,h,i)perylene, excluding Target PAH Analytes.
- 3.7 **Calibration Standards** are defined as a series of standard solutions prepared from dilutions of a stock standard solution, containing known concentrations of each analyte and surrogate compound of interest.

- 3.8 **Continuing Calibration Standard** is defined as a calibration standard used to periodically check the calibration state of an instrument. The continuing calibration standard is prepared from the same stock standard solution as calibration standards, and is generally one of the mid-level range calibration standard dilutions.
- 3.9 **Diesel PAH Analytes** are defined as naphthalene, 2-methylnaphthalene, phenanthrene, and acenaphthene, and are a subset of Target PAH Analytes. For most sites known to be contaminated by a release of diesel and/or #2 fuel oil only, Diesel PAH Analytes will be the only Target PAH Analytes of interest.
- 3.10 **Extractable Petroleum Hydrocarbons (EPH)** are defined as collective fractions of hydrocarbon compounds eluting from n-nonane to n-hexatriacontane, excluding Target PAH Analytes. EPH is comprised of C<sub>9</sub> through C<sub>18</sub> Aliphatic Hydrocarbons, C<sub>19</sub> through C<sub>36</sub> Aliphatic Hydrocarbons, and C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons.
- 3.11 **Field Duplicates** are defined as two separate samples collected at the same time and place under identical circumstances and managed the same throughout field and laboratory procedures. Analyses of field duplicates give a measure of the precision associated with sample collection, preservation and storage, as well as laboratory procedures.
- 3.12 **Fractionation Surrogate Standards** are compounds that are added to sample extracts immediately prior to fractionation at known concentrations to evaluate fractionation efficiency.
- 3.13 **Initial Calibration Verification (ICV) Standard** is defined as a mid-range standard prepared from a separate source than used for the initial and continuing calibration standards. The analysis of an ICV must be performed when a separate source standard is not used for the preparation of the laboratory control sample and matrix spike sample.
- 3.14 **Internal Standard (IS)** is a compound added to every calibration standard, blank, matrix spike, sample (for VOAs), sample extract (for semi-volatiles) at a known concentration, prior to analysis. ISs are used as the basis for quantitation of the method's target analytes.
- 3.15 **Laboratory Control Sample (LCS)** is defined as a reagent water blank (when associated with aqueous samples) or clean sand blank (when associated with soil/sediment samples) fortified with a matrix spiking solution. The LCS is prepared and analyzed in the same manner as the samples and its purpose is to determine the bias of the analytical method.
- 3.16 **Laboratory Control Sample Duplicate (LCSD)** is defined as a reagent water blank (when associated with aqueous samples) or clean sand blank (when associated with soil/sediment samples) fortified with a matrix spiking solution separately prepared, processed and analyzed in the same manner as the LCS. The analysis of LCS duplicates gives a measure of the precision associated with laboratory procedures, but not with sample collection, preservation, or storage procedures.
- 3.17 **Laboratory Method Blank** is defined as an aliquot of reagent water (when associated with aqueous samples) or clean sand (when associated with soil/sediment samples) spiked with a surrogate standard. The laboratory method blank is prepared and analyzed in the same manner as a sample, exposed to all glassware, solvents, reagents, and equipment. A laboratory method blank is prepared and analyzed with every batch of samples, to determine if method analytes or other interferences are present in the laboratory environment, reagents, or equipment.
- 3.18 **Matrix Duplicates** are defined as split samples prepared and analyzed separately with identical procedures. For soil/sediment samples, matrix duplicate samples are taken from the same sampling container. For aqueous samples, a separate container is used for the matrix duplicate sample. The analysis of matrix duplicates gives a measure of the precision associated with laboratory procedures, but not with sample collection, preservation, or storage procedures.
- 3.19 **Matrix Spike (MS) Sample** is defined as an environmental sample which has been spiked with a matrix spiking solution containing known concentrations of method analytes. The purpose of the MS sample is to determine whether the sample matrix contributes bias to the analytical results. The background concentrations of the analytes in the sample matrix must be determined through the separate analyses of an unspiked sample

aliquot. The measured values in the MS sample must be corrected for background concentrations when calculating recoveries of spiked analytes.

- 3.20 **Matrix Spiking Solution** is defined as a solution prepared from a separate source than used for the calibration standards, containing known concentrations of method analytes.
- 3.21 **System Solvent Blank** is defined as an aliquot of a method solvent (e.g., hexane or methylene chloride, pesticide-grade or better) that is directly injected into the GC system. The System Solvent Blank provides one way of determining the level of noise and baseline rise attributable solely to the analytical system, in the absence of any other analytes or non-analytical related contaminants.
- 3.22 **Surrogate Standards** are compounds spiked into all samples, blanks, LCSs, and matrix spikes to monitor the efficacy of sample extraction, chromatographic, and calibration systems.
- 3.23 **Target PAH Analytes** are defined as the 17 polynuclear aromatic hydrocarbon (PAH) compounds listed in Table 2.
- 3.24 **Total Petroleum Hydrocarbons (TPH)** are defined as the collective concentration of all hydrocarbon compounds eluting from n-nonane to n-hexatriacontane, **excluding Target PAH Analytes**. TPH is equivalent to the summation of C<sub>9</sub> through C<sub>18</sub> Aliphatic Hydrocarbons, C<sub>19</sub> through C<sub>36</sub> Aliphatic Hydrocarbons, and C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons.
- 3.25 **Unadjusted C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons** are defined as all aromatic hydrocarbon compounds eluting from naphthalene through benzo(g,h,i)perylene.
- 3.26 **Unadjusted TPH** is defined as the collective concentration of all hydrocarbon compounds eluting from n-nonane to n-hexatriacontane, **including the Target PAH Analytes**.
- 3.27 All other terms are as defined in the most current version of SW-846, "Test Method for Evaluating Solid Waste", USEPA.

#### 4.0 INTERFERENCES

- 4.1 Method interferences are reduced by washing all glassware with hot soapy water and then rinsing with warm tap water, acetone, and methylene chloride.
- 4.2 High purity reagents must be used to minimize interference problems.
- 4.3 Cross-contamination can occur whenever a low-concentration sample is analyzed immediately after a high-concentration sample. To reduce carryover, the sample syringe must be rinsed between samples with solvent. Whenever an unusually concentrated sample is encountered, it must be followed by the analysis of a system solvent blank to check for cross-contamination. However, due to the potential for samples to be analyzed using an autosampler, the ability to perform this blank analysis may not always be possible. If the sample analyzed immediately after the unusually concentrated sample is free from contamination, then the assumption can be made that carryover or cross-contamination is not an issue. However, if this sample did detect analytes which were present in the unusually concentrated sample, reanalysis is required for all samples analyzed after this highly concentrated sample which detected similar analytes.
- 4.4 Matrix interferences may be caused by contaminants that are coextracted from the sample. The extent of matrix interference will vary considerably from one source to another depending upon the nature and complexity of the site being sampled. A silica gel SPE cleanup procedure is used to overcome many of these interferences, but some samples may require additional and more rigorous cleanup procedures which are beyond the scope of this method.
- 4.5 Other organic contaminants commingled with petroleum product releases, including chlorinated hydrocarbons, phenols, and phthalate esters, will be quantitated as Total and Extractable Petroleum Hydrocarbons. If necessary and/or desirable, additional sample cleanup and/or analytical procedures may be employed to minimize or document the presence of such compounds.
- 4.6 The leaching of plasticizers and other compounds have been observed from commercially available silica gel cartridges used to fractionate EPH sample extracts. Concerns of this nature must be continuously monitored and

documented by analysis of Laboratory Method Blanks. Section 9.2 provides a procedure to eliminate or minimize this contamination.

- 4.7 Because of their weakly polar nature, naphthalene and substituted naphthalenes readily mobilize into the aliphatic extract if excessive amounts of hexane are used to elute the silica gel cartridge/column. Because these compounds constitute a significant percentage of the water-soluble fraction of fuel oils, this occurrence is especially problematic in the analysis of water samples. For this reason, the method requires the evaluation of the aliphatic fraction for the presence of naphthalene and 2-methylnaphthalene in the LCS/LCSD pair on a batch basis. The fractionation surrogate, 2-Bromonaphthalene, is used to monitor sample-specific fractionation efficiency.

## 5.0 HEALTH AND SAFETY ISSUES

The toxicity and carcinogenicity of each reagent used in this method has not been precisely defined. However, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current file of Occupational Safety and Health Administration (OSHA) regulations regarding the safe handling of the chemicals specified in this method. A reference file of material safety data sheets (MSDS) should also be made available to all personnel involved in the chemical analysis.

## 6.0 APPARATUS AND MATERIALS

- 6.1 The following is a partial list of glassware used for this method:

6.1.1 1-L amber glass bottles

6.1.2 4 oz. (120 mL) amber wide-mouth glass jars

6.1.3 Vials:

10.4.4.6 autosampler: 2-mL glass vials with Teflon-lined rubber crimp caps

10.4.4.6 10-mL vials with Teflon-lined caps

6.1.4 Glass funnels

6.1.5 2-L Separatory funnels with Teflon stopcock (aqueous liquid-liquid extraction only)

6.1.6 Kuderna-Danish apparatus including 10-mL graduated concentrator tube, 500-mL Evaporative flask, & 3-ball Snyder column

6.1.7 250-mL Erlenmeyer flasks

6.1.8 25-mL graduated cylinder

6.1.9 1-Liter graduated cylinder

6.1.10 100-mL beakers

6.1.11 Class "A" volumetric flasks: 10, 25, 50 and 100-mL

6.1.12 Class "A" volumetric pipets: 1, 5 or 10-mL

- 6.2 An analytical balance capable of accurately weighing 0.0001 g must be used for weighing standards. A top-loading balance capable of weighing to the nearest 0.1 g must be used for weighing soil/sediment samples.

- 6.3 An air or nitrogen blowdown apparatus, or equivalent sample concentration apparatus, is required to concentrate extracts.

### 6.4 Gas Chromatographic System

- 6.4.1 Gas Chromatograph: An analytical system incorporating a temperature-programmable oven with the ability to accommodate a capillary column. The following components are also required:

- 6.4.1.1 Detector: A Flame Ionization Detector (FID) is required.
- 6.4.1.2 Column: The analytical column must adequately resolve the n-C<sub>9</sub> to n-C<sub>36</sub> aliphatic hydrocarbon standard compounds and the Target PAH Analytes listed in Tables 1 and 2, respectively. The recommended analytical column is an RTX-5 capillary column (30-m x 0.32-mm i.d., 0.25-μm film thickness [Restek Corp. or equivalent]).
- 6.4.1.3 Data Station: The data station must be capable of storing and reintegrating chromatographic data and must be capable of determining peak areas using a forced baseline projection.
- 6.4.1.4 Autosampler: An autosampler capable of making 1 to 4 μL injections is recommended.
- 6.5 Water bath: heated with a concentric ring cover, capable of temperature control (± 2°C). The bath should be used in a hood.
- 6.6 Disposable pipets: Pasteur
- 6.7 Microsyringes: 10-μL, 100-μL, 250-μL, 500-μL, 1000-μL
- 6.8 Boiling Chips
- 6.9 Soxhlet, Soxtec or alternative extraction apparatus
- 6.10 Drying oven
- 6.11 Dessicator

## 7.0 REAGENTS AND STANDARDS

### 7.1 Reagents

- 7.1.1 Reagent Water: organic free water (ASTM Type I reagent grade water).
- 7.1.2 Solvents: hexane, methylene chloride, and acetone; pesticide-grade or better. Store away from other solvents.
- 7.1.3 Sodium sulfate: (ACS) granular, anhydrous. Purify by heating at 400°C for 4 hours in a shallow tray.
- 7.1.4 Ottawa and/or masonry sand: free of extractable petroleum hydrocarbons.
- 7.1.5 Silica Gel (5 - 10 grams), either prepared and packed by the laboratory, or purchased in 5 g/20-mL cartridges from a commercial vendor. Silica gel prepared and packed by the laboratory should be activated at 130°C for at least 16 hours, and heated to 150-160°C for several hours before use. Refer to Section 9.2.2 for guidance on the use of silica gel.

NOTE: Leaching of plasticizers and other compounds have been observed from commercially prepared silica gel cartridges, and must be monitored and documented by analyses of Laboratory Method Blanks. Refer to Section 9.2 for a procedure to eliminate or minimize this contamination.

**NOTE: Silica gel is hygroscopic.** Unused cartridges readily absorb moisture from ambient air if not properly sealed. To preclude moisture adsorption, which adversely effects cartridge performance, unused cartridges must be stored in a properly-maintained dessicator prior to use.

### 7.2 Stock Standard Solutions

Prepare stock standard solutions at approximately 1000 ng/μL, or purchase as certified solutions.

- 7.2.1 Aromatic Hydrocarbon Standard: The Aromatic Hydrocarbon Standard consists of the 17 PAH compounds listed in Table 2, a surrogate compound (i.e., ortho-terphenyl) and fractionation surrogate compounds. Prepare stock standard solutions by accurately weighing approximately 0.0100 g of pure material. Dissolve the material in methylene chloride and dilute to volume in a 10-mL volumetric flask.

- 7.2.2 Aliphatic Hydrocarbon Standard: The Aliphatic Hydrocarbon Standard consists of the 14 normal alkanes listed in Table 1, naphthalene, 2-methylnaphthalene, and a surrogate compound (i.e., 1-chloro-octadecane). Prepare stock standard solutions by accurately weighing approximately 0.0100 g of pure material. Dissolve the material in hexane and dilute to volume in a 10-mL volumetric flask.
- 7.2.3 Stock standard solutions must be replaced after 6 months, or sooner if comparison with check standards indicates a problem.
- 7.2.3 Calibration standards are prepared by serial dilution of the stock standard as described in Section 9.7.2.1

### 7.3 Petroleum Reference Spiking Solution

- 7.3.1 The Petroleum Reference Spiking Solution consists of an API or commercial diesel fuel standard. Prepare stock standard solutions by accurately weighing approximately 0.02500 g of neat product. Dissolve neat product in acetone and dilute to volume in a 10-mL volumetric flask. An appropriately diluted aliquot of the stock solution may be used to evaluate method performance.

### 7.4 Surrogate Standards

- 7.4.1 Surrogate standards are used to monitor the efficiency of sample extraction, chromatographic, and calibration systems.
- 7.4.2 The recommended surrogate standards are chloro-octadecane (COD, available from Restek Corporation, Bellefonte, PA) and ortho-terphenyl (OTP, available from EM Sciences, Gibbstown, NJ). Alternatively, 5-alpha-androstane may also be used as an aliphatic fraction surrogate without qualification.
- 7.4.3 The surrogate standard COD is prepared by accurately weighing approximately 0.0100 g of pure material in a 10-mL volumetric flask. Dissolve the material in hexane.
- 7.4.4 The surrogate standard OTP is prepared by accurately weighing approximately 0.0100 g of pure material in a 10-mL volumetric flask. Dissolve the material in methylene chloride.
- 7.4.5 Surrogate Spiking Solution: The recommended surrogate spiking solution is comprised of a mixture of the COD and OTP surrogate standards. Prepare a surrogate spiking solution which contains the surrogate standards at a concentration of 40 ng/ $\mu$ L in acetone or methanol. Each sample, blank, and matrix spike is fortified with 1.0 mL of the surrogate spiking solution. The use of higher concentrations are permissible and advisable when spiking highly contaminated samples.

### 7.5 Fractionation Surrogate Standards

- 7.5.1 The fractionation surrogate standards are added to the sample (hexane) extract just prior to fractionation. The purpose of the fractionation surrogate standards is to monitor the efficiency of the fractionation process, and ensure that unacceptable quantities of naphthalene and substituted naphthalenes are not being eluted into the aliphatic extract.
- 7.5.2 The recommended fractionation surrogate standard is 2-Bromonaphthalene. Other alternative fractionation surrogate compounds, including 2-Fluorobiphenyl are permissible, provided that a demonstration is made that such compounds exhibit polarities/fractionation properties similar to naphthalene.
- 7.5.3 The fractionation surrogate standards are prepared by accurately weighing approximately 0.0100 g of pure material in a 10-mL volumetric flask. Dissolve the material in Methylene Chloride.
- 7.5.4 Fractionation Surrogate Spiking Solution: is comprised of 2-Bromonaphthalene and 2-Fluorobiphenyl (optional) prepared in hexane at concentrations of 40 ng/ $\mu$ L. An aliquot of 1 mL of the fractionation surrogate spiking solution is added to the 1 mL EPH sample extract prepared in accordance with the provisions of Sections 9.1.1 and 9.1.2. Alternative concentrations/volumes of the fractionation surrogate spiking solution are permissible.

## 7.6 Internal Standards (ISs)

- 7.6.1 Internal standards are compounds with similar physical and chemical properties, and chromatographic compatibility with an analytical method's target analytes. ISs are added to all samples, both for analysis and quality control, at a known concentration and carried through the entire analytical process (extraction and analysis). Internal standards are used as the basis for quantification of target analyte compounds (and ranges) for the applied analytical method. For the EPH Method, ISs are only utilized when GC/MS is utilized for quantification.
- 7.6.2 The recommended internal standard for the EPH Method is 5-alpha-androstane (EM Sciences, Gibbstown, NJ) when a modified SW-846 8270C is used to quantify the Target PAH Analytes and the fractionated aliphatic and/or aromatic range concentrations using GC/MS. Alternatively, 1-Chloro-octadecane (COD) may also be used as an internal standard for GC/MS analysis.
- 7.6.3 The internal standard is prepared by accurately weighing approximately 0.0500 grams of pure material in a 10-mL volumetric flask. Dissolve the material in methylene chloride or hexane.
- 7.6.4 An aliquot of 10 µL of the internal standard stock standard is added to the 1 mL EPH sample extract prepared in accordance with Section 9.3. Alternative concentrations/volumes of the internal standard spiking solution are permissible.

## 7.7 Matrix Spiking Solution

- 7.7.1 Analytes from each hydrocarbon group (i.e., aromatic and aliphatic hydrocarbons) are used in a matrix spiking solution, which is prepared using a separate source from the calibration standards.
- 7.7.2 The spiking solution, consisting of all normal alkanes in Table 1 and all PAHs in Table 2, is prepared in methanol or acetone at concentrations between 50 - 150 ng/µL (The concentration should be between the mid and upper level of calibration).
- 7.7.3 The samples selected as the matrix spike are fortified with 1.0 mL of the matrix spiking solution.

Analytical Note: The Matrix Spiking Solution should always be brought to room temperature before use to avoid dissolution of the highest boiling (marginal solubility) hydrocarbon standards.

## 7.8 Fractionation Check Solution

- 7.8.1 The Fractionation Check Solution is used to monitor the fractionation efficiency of the silica gel cartridge/column, and establish the optimum hexane volume required to efficiently elute aliphatic hydrocarbons while not allowing significant aromatic hydrocarbon breakthrough.
- 7.8.2 Prepare a Fractionation Check Solution in hexane containing 200 ng/µL of the Aliphatic Hydrocarbon standard (C<sub>9</sub>-C<sub>36</sub> alkanes) and 200 ng/µL of the Aromatic Hydrocarbon standard (Target PAH Analytes). The final solution will contain 14 alkanes and 17 PAHs at concentrations of 200 ng/µL each. Alternative concentrations are permissible.

## 8.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

### 8.1 Aqueous Samples

- 8.1.1 It is good practice to instruct field personnel to collect aqueous samples in duplicate. Samples must be collected in 1 liter amber glass bottles with Teflon-lined screw caps.
- 8.1.2 Aqueous samples must be preserved at the time of sampling by the addition of a suitable acid to reduce the pH of the sample to less than 2.0. This may be accomplished by the addition of 5 mL of 1:1 HCl to a 1 liter sample. The uses of alternative acids are permissible. Following collection and addition of acid, the sample must be cooled to 4± 2° C.

- 8.1.3 A chain of custody form must accompany all sample bottles and must document the date and time of sample collection and preservation method used. The laboratory must determine the pH of all water samples as soon as possible after sample receipt and prior to sample extraction. Any sample found to contain a pH above 2 must be so noted on the laboratory/data report sheet and the pH must be adjusted as soon as possible.
- 8.1.4 Any sample received by the laboratory that is not packed in ice or cooled to  $4 \pm 2^\circ \text{C}$  must be so noted on the laboratory/data report sheet. The temperature of the cooler must be recorded by the laboratory upon receipt.
- 8.1.5 Aqueous samples must be extracted within 14 days of collection, and analyzed within 40 days of extraction.

## 8.2 Soil/Sediment Samples

- 8.2.1 Soil and sediment samples are collected in 4 oz. (120 mL) amber wide-mouth glass jars with Teflon-lined screw caps.
- 8.2.2 Soil and sediment samples must be cooled to  $4 \pm 2^\circ \text{C}$  immediately after collection.
- 8.2.3 A chain of custody form must accompany all sample bottles and must document the date and time of sample collection and preservation method used.
- 8.2.4 Any sample received by the laboratory that is not packed in ice or cooled to  $4 \pm 2^\circ \text{C}$  must be so noted on the laboratory/data report sheet. The temperature of the cooler must be recorded by the laboratory upon receipt.
- 8.2.5 Soil and sediment samples must be extracted within 14 days of collection, and analyzed within 40 days of extraction.
- 8.2.6 Alternatively, samples may be frozen ( $-10^\circ \text{C}$ ) in the field or in the laboratory. Samples frozen in the laboratory must be preserved at  $4 \pm 2^\circ \text{C}$  from the time of sampling and frozen within 48 hours.

8.3 A summary of sample collection, preservation, and holding times is provided in Table 3.

**Table 3. Holding Times and Preservatives for EPH Samples**

Matrix	Container	Preservation	Holding Time
Aqueous Samples	1-Liter amber glass bottle with Teflon-lined screw cap	Add 5 mL of 1:1 HCl; Cool to $4 \pm 2^\circ \text{C}$	Samples must be extracted within 14 days and extracts analyzed within 40 days
Soil/Sediment Samples	4-oz. (120 mL) wide-mouth amber glass jar with Teflon-lined screw cap	Cool to $4 \pm 2^\circ \text{C}$	Samples must be extracted within 14 days and extracts analyzed within 40 days of extraction
	4-oz. (120 mL) wide-mouth amber glass jar with Teflon-lined screw cap. Jar should be filled to only 2/3 capacity to avoid breakage if expansion occurs during freezing	Freeze at $-10^\circ \text{C}$ in the field or in the laboratory*.	Samples must be extracted within 14 days of the date thawed and extracts analyzed within 40 days of extraction.

\* Samples processed in the laboratory must be preserved at  $4 \pm 2^\circ \text{C}$  and frozen within 48 hours of the time of collection. Frozen samples may be held for up to one year prior to analysis and must be extracted within 24 hours of thawing.

## 9.0 SAMPLE ANALYSIS OF EXTRACTABLE PETROLEUM HYDROCARBONS (EPH)

### 9.1 Overview of Sample Extraction Procedures

Samples are extracted using methylene chloride and solvent-exchanged into hexane. EPH extraction may be accomplished manually or by automated methods. In this Section a detailed description of manual separatory funnel liquid-liquid extraction for aqueous samples (SW-846 Method 3510) and the Soxhlet extraction procedure (SW-846 Method 3540) for soils and/or sediments are presented to demonstrate general extraction concepts for petroleum products. The applicable SW-846 Method should be consulted for specific details for the other approved EPH extraction procedures

**NOTE: For optimum performance, the sample volumes/weights, solvent volumes, and final extract volumes cited in Sections 9.1.1 and 9.1.2 are recommended. Alternate volumes can be used as long as comparable reporting limits are achieved.**

The complete list of approved EPH extraction procedures for water and soil/sediment samples is presented in Table 4. Alternative extraction procedures other than those listed are acceptable, provided that the laboratory can document acceptable matrix- and petroleum product-specific performance. However, use of an alternative extraction procedure is considered a “significant modification” of the EPH method pursuant to Section 11.3.1.1 and as such would preclude obtaining “presumptive certainty” status for any analytical data produced using an alternative EPH extraction procedure

**Table 4 - Approved EPH Extraction Methods**

SW-846 Method	Matrix	Description
3510C	Aqueous	Separatory Funnel liquid-Liquid Extraction
3520C	Aqueous	Continuous Liquid-Liquid Extraction
3511	Aqueous	Organic Compounds in Water by Microextraction
3540C	Soil/Sediment	Soxhlet Extraction
3541	Soil/Sediment	Automated Soxhlet Extraction
3545A	Soil/Sediment	Pressurized Fluid Extraction (PFE)
3546	Soil/Sediment	Microwave Extraction
3570	Soil/Sediment	Microscale Solvent Extraction (MSE)
3550C	Contaminated Solids <sup>1</sup>	Ultrasonic Extraction
3580A	NAPL	Solvent Dilution

1. Sonication may only be used for the extraction of highly contaminated (free product) non-soil/sediments (debris). Any other use of ultrasonic extraction is considered a “**significant modification**” of the EPH Method.

#### 9.1.1 Water Extraction by Separatory Funnel Liquid-Liquid Extraction

9.1.1.1 Mark the meniscus on the 1 liter sample bottle (for later volume determination) and transfer the contents to a 2-liter separatory funnel. For blanks and quality control samples, pour 1 liter of reagent water into the separatory funnel. For all samples, blanks, LCSs, LCSDs and matrix spikes add 1.0 mL of the concentrated surrogate spiking solution (see Section 7.4) directly to the separatory funnel. For samples selected for spiking, also add 1.0 mL of the matrix spiking solution.

9.1.1.2 Check the pH of the sample with wide-range pH paper. Note the pH in the laboratory notebook. The pH of the sample must be adjusted to pH <2.

9.1.1.3 Add 60 mL methylene chloride to the sample bottle to rinse the inner walls of the container, then add this solvent to the separatory funnel.

9.1.1.4 Seal and shake the separatory funnel vigorously for at least three (3) minutes with periodic venting to release excess pressure.

**NOTE: Methylene chloride creates excessive pressure very rapidly; therefore, venting should be done immediately after the separatory funnel has been sealed and shaken once.**

- 9.1.1.5 Allow the organic layer to separate from the water phase for a minimum of 5 minutes. If the emulsion interface between layers is more than one-third the size of the solvent layer, the analyst must employ mechanical techniques to complete the phase separation. The optimum technique depends upon the sample and may include stirring, filtration of the emulsion through glass wool, centrifugation, or other physical methods. Collect the solvent extract in an Erlenmeyer flask.
- 9.1.1.6 Repeat the extraction two more times using additional 60 mL portions of solvent. Combine the three solvent extracts in a 250-mL Erlenmeyer flask. (Steps 9.1.1.3 to 9.1.1.5)
- 9.1.1.7 For sample volume determination add water to the sample bottle to the level of the meniscus previously marked and transfer this water to a graduated cylinder.
- 9.1.1.8 Assemble a Kuderna-Danish (K-D) concentrator by attaching a 10-mL concentrator tube to a 500-mL evaporation flask.
- 9.1.1.9 Dry the extract by passing it through a glass powder funnel containing anhydrous sodium sulfate or other suitable drying agent. Collect the dried extract in a K-D concentrator. Rinse the Erlenmeyer flask, which contained the solvent extract, with 20 to 30 mL of methylene chloride and add it to the funnel to complete the quantitative transfer.
- 9.1.1.10 Add one or two clean boiling chips to the K-D flask and attach a three ball Snyder column. Pre-wet the Snyder column by adding about 1 mL of methylene chloride to the top of the column. Place the K-D apparatus on a hot water bath (80-90°C) so that the concentrator tube is partially immersed in the hot water and the entire lower rounded surface of the flask is bathed with hot vapor. Adjust the vertical position of the apparatus and the water temperature as required to complete the concentration in 10 to 20 minutes. At the proper rate of distillation, the balls of the column will actively chatter, but the chambers will not flood. When the apparent volume of liquid reaches 1 mL, remove the K-D apparatus from the water bath and allow it to drain and cool for at least 10 minutes.
- 9.1.1.11 Exchange the methylene chloride with hexane by adding 50 mL of hexane to the top of the Snyder column. Concentrate the extract to less than 10 mL, as described in Section 9.1.1.10, raising the temperature of the water bath, if necessary, to maintain proper distillation.
- 9.1.1.12 Remove the Snyder column and evaporation flask from the 10-mL concentrator tube. Place the concentrator tube containing the hexane extract onto an air blowdown apparatus. Adjust the extract volume to 1 mL under a gentle stream of nitrogen or air. If the extract is highly colored, forms a precipitate, or stops evaporating, the final volume should be higher. If a TPH analysis is to be conducted, without fractionation, proceed to Section 9.3.3

Analytical Note: Due caution must be exercised during blowdown to avoid losses of the more volatile (C9 through C12) EPH components. The fractionation extract (or any extract) volume should never be reduced below 1 mL in this or any other step to minimize volatilization losses.

- 9.1.1.13 Add 1 mL of the concentrated fractionation surrogate (see Section 7.5) spiking solution to the 1 mL hexane extract. Alternatively, add 20-50 ng each of the fractionation surrogate standards using a microliter syringe (up to 10 uL volume). The concentrated matrix spiking solution ( see Section 7.7) should also be added at this time, as required.

Analytical Note: If the latter alternative is exercised, only a single extract will be available for fractionation unless the spiked extract is further diluted. Such dilution may not be advisable for samples with EPH target analytes or ranges at or near the method's reporting limit.

- 9.1.1.14 Record the sample preparation information for the extraction and concentration steps. At a minimum, record the date, sample laboratory number, sample volume, volume and

concentration of added surrogates and matrix spike solutions, final extract volume, and any deviations or problems associated with the extraction of the samples.

9.1.1.15 The 2 mL extract (1 mL extract + 1 mL fractionation surrogate) is now ready to be cleaned and fractionated using either commercially-available or self-packed silica gel SPE cartridges. If cleanup will not be performed immediately, transfer the extract to a Teflon-lined screw-cap vial, label, and refrigerate.

9.1.1.16 For cleanup and fractionation, refer to Section 9.2.

#### 9.1.2. Soil and/or Sediment Extraction using Soxhlet Extraction

9.1.2.1 Blend 10 g of the solid sample with 10 g anhydrous sodium sulfate and place in an extraction thimble. The extraction thimble must drain freely for the duration of the extraction period. Add 1.0 mL of the surrogate spiking solution (see Section 7.4) to all samples, blanks, LCSs, LCSDs and matrix spikes. Thoroughly mix the surrogate spiking solution into the sample. For samples selected for spiking, add 1.0 mL of the matrix spiking solution. Thoroughly mix the matrix spiking solution(s) into the sample.

9.1.2.2 Place 300 mL of methylene chloride into a 500-mL round-bottom flask containing one or two clean boiling chips. Attach the flask to the extractor and extract the sample for 16-24 hr. Volume of methylene chloride should be adjusted to accommodate the size of the round-bottom flask utilized.

9.1.2.3 Allow the extract to cool after the extraction is completed.

9.1.2.4 Assemble a Kuderna-Danish (K-D) concentrator by attaching a 10-mL concentrator tube to a 500-mL evaporation flask.

9.1.2.5 Dry the extract by passing it through a glass powder funnel containing anhydrous sodium sulfate or other suitable drying agent. Collect the dried extract in the K-D concentrator. Wash the extractor flask and sodium sulfate column with 100 to 125 mL of methylene chloride to complete the quantitative transfer.

9.1.2.6 Add one or two clean boiling chips to the flask and attach a three-ball Snyder column. Pre-wet the Snyder column by adding about 1 mL of methylene chloride to the top of the column. Place the K-D apparatus on a hot water bath (80-90°C) so that the concentrator tube is partially immersed in the hot water and the entire lower rounded surface of the flask is bathed with hot vapor. Adjust the vertical position of the apparatus and the water temperature, as required, to complete the concentration in 10 to 20 min. At the proper rate of distillation, the balls of the column will actively chatter, but the chambers will not flood. When the apparent volume of liquid reaches 1 mL, remove the K-D apparatus from the water bath and allow it to drain and cool for at least 10 minutes.

9.1.2.7 Exchange the methylene chloride with hexane by adding 50 mL of hexane to the top of the Snyder column. Concentrate the extract to less than 10 mL, as described in Section 9.1.2.6, raising the temperature of the water bath, if necessary, to maintain proper distillation.

9.1.2.11 Remove the Snyder column and evaporation flask from the 10-mL concentrator tube. Place the concentrator tube containing the hexane extract onto an air blowdown apparatus. Adjust the extract volume to 1 mL under a gentle stream of nitrogen or air. If the extract is highly colored, forms a precipitate, or stops evaporating, the final volume should be higher. If a TPH analysis is to be conducted, without fractionation, proceed to Section 9.3.3.

Analytical Note: Due caution must be exercised during blowdown to avoid losses of the more volatile (C9 through C12) EPH components. The fractionation extract (or any extract) volume should never be reduced below 1 mL in this or any other step to minimize volatilization losses.

9.1.2.9 Add 1 mL concentrated fractionation surrogate (see Section 7.5) spiking solution to the 1 mL hexane extract. Alternatively, add 20-50 ng each of the fractionation surrogate standards using a microliter syringe (up to 10 uL volume). The concentrated matrix spiking solution should also be added at this time, as required.

Analytical Note: If the latter alternative is exercised, only a single extract will be available for fractionation unless the spiked extract is further diluted. Such dilution may not be advisable for samples with EPH target analytes or ranges at or near the method's reporting limit.

- 9.1.2.10 Record the sample preparation information for the extraction and concentration steps. At a minimum, record the date, sample laboratory number, sample weight, volume and concentration of added surrogates and matrix spike solutions, extraction start and stop times, final extract volume and any deviations or problems associated with the extraction of the samples.
- 9.1.2.11 The 2 mL extract (1 mL extract + 1 mL fractionation surrogate) is now ready to be cleaned and fractionated using silica gel SPE. If cleanup will not be performed immediately, transfer the extract to a Teflon-lined screw-cap vial, label, and refrigerate.
- 9.1.2.12 For cleanup and fractionation, refer to Section 9.2.

## 9.2 Silica Gel Cleanups and Fractionation

**NOTE: The Silica Gel Cleanup and Fractionation step is a critical and highly sensitive procedure. Small changes in the volumes of eluting solvents, fractionation equipment, and/or fractionation techniques can significantly impact the proportion of hydrocarbons segregated in either the aliphatic or aromatic fractions. Considerable care and attention is required to ensure satisfactory results.**

- 9.2.1 Each sample fractionation requires 1 mL of sample extract. Because 2 mL of sample extract are available, two fractionations may be undertaken for each sample. Refractionation would be necessary if problems are experienced during the initial fractionation effort, if unacceptable breakthrough is noted for naphthalene and 2-methylnaphthalene in the LCS and/or LCSD, and/or if unacceptable recoveries are noted for the fractionation surrogate standard. The extra volume of sample extract is also provided to facilitate initial (unfractionated) TPH screening of a sample, to obtain a GC/FID "fingerprint", and/or to determine whether sufficient total hydrocarbons are present to warrant fractionation and comparison to risk-based cleanup standards.
- 9.2.2 Silica gel is a regenerative adsorbent of amorphous silica with weakly acidic properties. It is produced from sodium silicate and sulfuric acid. Silica gel can be used for column chromatography and is used for separating analytes from interfering compounds of a different chemical polarity. Silica gel is also used to separate petroleum distillates into aliphatic and aromatic fractions.

A 5 g/20 mL Solid Phase Extraction (SPE) silica gel cartridge is commercially available. Alternatively, the use of self-packed columns of activated silica gel may also be used. The use of activated silica gel for general column chromatographic applications is described in detail SW-846 Method 3630C

To ensure satisfactory fractionation, silica gel/cartridges must not be overloaded. It is recommended that loading be limited to no more than 5 mg total hydrocarbons/gram silica gel; for a 1 mL extract fractionated on a 5 gram silica gel cartridge, this would equate to a hydrocarbon extract loading of no greater than 25,000 µg/mL. It should be noted that overloading the column may result in a premature breakthrough of the C<sub>11</sub>-C<sub>22</sub> aromatic hydrocarbon range. If overloading is encountered, the sample must be re-fractionated at a dilution appropriate for the column's maximum loading capacity.

Unsealed silica gel/cartridges must be stored in a properly-maintained dessicator to avoid inadvertent adsorption of ambient moisture. Silica gel that has been exposed to moisture may perform erratically resulting in poor performance manifested by naphthalene/2-methylnaphthalene and fractionation surrogate breakthrough.

**Analytical Note: Air-drying of the cartridges may adversely affect silica gel performance and is not advised.**

9.2.3 If concerns exist over the presence of contaminants in the silica gel/cartridge, pre-rinse the column with 30 mL of methylene chloride.

9.2.3.1 Rinse the column with 30 mL of hexane, or 60 mL if pre-rinsed with methylene chloride per Section 9.2.3. Let the hexane flow through the column until the head of the liquid in the column is just above the column frit. Close the stopcock to stop solvent flow. Discard the collected hexane.

9.2.3.2 Load 1.0 mL of the combined sample extract and fractionation surrogate solution onto the column. Open the stopcock, and start collecting elutant immediately in a 25-mL volumetric flask labeled "aliphatics".

9.2.3.3 Just prior to exposure of the column frit to the air, elute the column with an additional 19 mL of hexane, so that a total of approximately 20 mL of hexane is passed through the column.

**It is essential that "plug flow" of the sample extract be achieved through the silica gel cartridge/column. Hexane should be added in 1-2 mL increments or dropwise using a pipet, with additions occurring when the level of solvent drops to the point just prior to exposing the column frit to air. The use of a stopcock is mandatory. Care must be taken to ensure that the silica gel is uniformly packed in the column. The analyst must be cognizant of any channeling, streaking, or changes in the silica gel matrix during fractionation; if any of these occur, the procedure must be repeated with another 1 mL volume of sample extract.**

**The amount of hexane used during fractionation is critical. Excessive hexane - as little as 0.5 mL - can cause significant elution of lighter aromatics into the aliphatic fraction. Insufficient hexane will cause low recoveries of the aliphatic fraction. The volume of the hexane fractionation elutriate should not exceed 20 mL.**

9.2.3.4 The Fractionation Check Solution described in Section 7.8 must be used to evaluate each new lot of silica gel/cartridges to re-establish the optimum volume of hexane elutriate. See Appendix 5, Section 5.0 for optimization specifications.

It is not uncommon to encounter inconsistent cartridge weights, mesh sizes and/or variable fractionation performance within the same lot of silica gel cartridges. It may be advisable to perform additional intra-lot fractionation performance checks particularly for larger lot sizes (500) of silica gel cartridges.

9.2.3.5 Following recovery of the aliphatic fraction, elute the column with 20 mL of methylene chloride and collect the eluant in a 25 mL volumetric flask. Label this fraction "aromatics".

### 9.3 Final Sample Extract Concentration

9.3.1 Transfer the contents of the 25.0 mL "aliphatics" (in hexane) and "aromatics" (in methylene chloride) volumetric flasks into separate labeled graduated concentrator tubes. Concentrate each of the extracts to a final volume of 1 mL under a gentle stream of air or nitrogen.

Analytical Note: Due caution must be exercised during blowdown to avoid losses of the more volatile (C9 through C12) EPH components. The fractionation extract (or any extract) volume should never be reduced below 1 mL in this or any other step to minimize volatilization losses.

9.3.2 Transfer the final 1 mL extracts from each concentrator tube to labeled two-mL glass autosampler vials with Teflon-lined rubber crimp caps. If appropriate, add an internal standard at the appropriate concentration.

9.3.3 Proceed with the analysis in accordance with Analyze all laboratory method blanks and QC samples under the same conditions as that used for samples.

### 9.4 Determination of Percent Moisture

9.4.1 Soil and sediment results must be reported on a dry-weight basis.

- 9.4.2 Transfer 5 to 10 g of sample into a tared ( $\pm 0.1$  g) crucible and determine “wet weight”. This sample must be obtained from a vial or container that does not contain methanol. Dry this 5 to 10 g sample overnight at 105°C. Allow crucible to cool in a desiccator and reweigh ( $\pm 0.1$  g). Re-desiccate and verify “dry weight”. Calculate the percent moisture of the sample using the equations provided in Section 9.9.4 (Equation 9). Refer to ASTM Method D2216, Determination of Moisture Content of Soils and Sediments, for more detailed analytical and equipment specifications.

## 9.5 Analytical Conditions

- 9.5.1 Recommended analytical conditions are presented below. A chromatographic column with equivalent chromatographic properties, as described in Section 6.4.2, or alternative chromatographic conditions may be substituted to improve resolution of extractable petroleum hydrocarbons.

<u>Chromatographic Column:</u>	30 m x 0.32 mm I.D., 0.25 $\mu$ m Restek RTX-5
<u>Oven Temperature Program</u>	Initial oven temperature 60°C, hold time 1 min; to 290 °C @ 8°C/min, hold time 6.75 min
<u>Total Run Time:</u>	36.5 min
<u>Sample/autosampler Injection</u>	1-4 $\mu$ L
<u>Gas Flow Rates:</u>	Carrier gas - Helium @ 2 to 3 mL/min Oxidizer - Air @ 400 mL/min Fuel – Hydrogen @ 35 mL/min Make up – Air @ 30.0 mL/min
<u>Injection Port Temperature:</u>	285°C
<u>Column Inlet Pressure:</u>	15 p.s.i.g.
<u>Detector Temperature:</u>	315°C (FID)
<u>Linear Velocity</u>	50 cm/sec

### 9.5.2 GC Maintenance

- 9.5.2.1 Capillary columns: Clean and deactivate the glass injection port insert or replace with a cleaned and deactivated insert.
- 9.5.2.2 Break off the first few inches, up to one foot, of the injection port side of the column.
- 9.5.2.3 Remove the column and solvent backflush according to the manufacturer's instructions.
- 9.5.2.4 Bake out the column at the maximum temperature of the temperature program. If these procedures fail to eliminate a column degradation problem, it may be necessary to replace the column.

## 9.6 Retention Time Windows

- 9.6.1 Before establishing retention time windows, optimize the GC system's operating conditions. Make three injections of the Aromatic Hydrocarbon and Aliphatic Hydrocarbon standard mixtures throughout the course of a 72-hr period. Serial injections over less than a 72-hr period may result in retention time windows that are too restrictive.
- 9.6.2 Calculate the standard deviation of the three absolute retention times for each individual component in the Aromatic Hydrocarbon standard, the Aliphatic Hydrocarbon standard, and all surrogates and internal standards.
- 9.6.3 The retention time window is defined as plus or minus three times the standard deviation of the absolute retention times for each compound in the Aliphatic and Aromatic Standards. However, the experience of the analyst should weigh heavily in the interpretation of chromatograms.
- 9.6.4 In those cases where the standard deviation for a particular standard is close to zero the default value of 0.1 minutes should be used. Alternatively, the laboratory may substitute the standard deviation of a closely eluting structurally similar compound to develop a representative statistically-derived retention time window.

- 9.6.5 The laboratory must calculate retention time windows for each compound in the Aliphatic and Aromatic Standards on each GC column and whenever a new GC column is installed. These data must be retained by the laboratory.
- 9.6.6 EPH retention time (Rt) windows are defined as beginning 0.1 minutes before the Rt of the beginning marker compound and ending 0.1 minutes after the Rt of the ending marker compound, except for n-C<sub>19</sub>, which is both a beginning and ending marker compound for two different ranges.

**The C<sub>9</sub> - C<sub>18</sub> Aliphatic Hydrocarbon range ends immediately (0.1 min) before the elution of the n-C<sub>19</sub> peak. The C<sub>19</sub> - C<sub>36</sub> Aliphatic Hydrocarbon range begins 0.1 min before the elution of the n-C<sub>19</sub> peak; therefore there is no overlap of the two ranges and the n-C<sub>19</sub> peak is only included in the C<sub>19</sub> - C<sub>36</sub> Aliphatic Hydrocarbon range.**

EPH marker compounds and windows are summarized in Table 5.

**Table 5. EPH Marker Compounds**

Hydrocarbon Range	Beginning Marker	Ending Marker
C <sub>9</sub> -C <sub>18</sub> Aliphatic Hydrocarbons	0.1 min before n-Nonane	0.1 min before n-Nonadecane
C <sub>19</sub> -C <sub>36</sub> Aliphatic Hydrocarbons	0.1 min before n-Nonadecane	0.1 min after n-Hexatriacontane
C <sub>11</sub> -C <sub>22</sub> Aromatic Hydrocarbons	0.1 min before Naphthalene	0.1 min after Benzo (g,h,i) Perylene

- 9.6.7 If a TPH analysis is done without fractionation, TPH retention time (Rt) windows are defined as beginning 0.1 minutes before the Rt of n-Nonane and ending 0.1 minutes after the Rt of n-Hexatriacontane.

## 9.7 Calibration

### 9.7.1 Internal Standard Calibration Procedure

An internal standard calibration procedure is not recommended for this method except when GC/MS is used to quantify target PAH Analytes and hydrocarbon ranges (see Section 9.10).

### 9.7.2 External Standard Calibration Procedure

The use of Calibration Factors (CF) is the preferred approach to determine the relationship between the detector response and the analyte and collective range concentrations. It is also permissible to utilize linear regression to calculate the slope and y-intercept that best describes the linear relationship between the analyte and collective range concentrations and the instrument response. The linear regression approach for analytes and collective ranges is described in Appendix 4.

- 9.7.2.1 Prepare Aromatic and Aliphatic Hydrocarbon calibration standards from the Stock Standard Solution (in methanol) at a minimum of five concentrations (i.e., 1x, 10x, 50x, 100x and 200x) by adding volumes of one or more stock standard solutions to volumetric flasks and diluting to volume with methylene chloride and hexane, respectively. The surrogate OTP and the fractionation surrogates are included in the Aromatic Hydrocarbon Standard; the surrogate COD is included in the Aliphatic Hydrocarbon Standard. The lowest concentration (1x) determines the minimum working range of the calibration curve and defines the Reporting Limit (RL) for individual Target Analytes. The highest concentration (200x) defines the maximum upper working range of the calibration curve. Target analytes may not be reported above this concentration without sample dilution. RLs for collective EPH aliphatic and aromatic hydrocarbon ranges are discussed in Section 12.0. The collective concentrations of individual EPH aliphatic and aromatic hydrocarbon ranges are provided in Table 6.

**Table 6. Recommended Calibration Standard Concentrations**

(1  $\mu\text{L}$  Injection)

Component	Conc. of standard analytes (ng/ $\mu\text{L}$ )				
	1	10	50	100	200
Total Concentration C <sub>9</sub> - C <sub>18</sub> Aliphatic Hydrocarbons (6 components)	6	60	300	600	1200
Total Concentration C <sub>19</sub> - C <sub>36</sub> Aliphatic Hydrocarbons (8 components)	8	80	400	800	1600
Total Concentration C <sub>11</sub> - C <sub>22</sub> Aromatic Hydrocarbons/ PAHs (17 components)	17	170	850	1700	3400

9.7.2.2 Introduce each calibration standard into the gas chromatograph using the injection volume (e.g., 1 to 4  $\mu\text{L}$ ) that will be used to introduce the “actual” samples and following the procedures outlined in Section 9.8.

9.7.2.3 Target PAH Analyte Calibration: Tabulate peak area responses against the concentration injected. The ratio of area response to the concentration injected, defined as the calibration factor (CF), may be calculated for Target PAH analytes using Equation 1. The percent relative standard deviation (%RSD) of the calibration factor must be equal to or less than 25% over the working range for the analyte of interest, as determined using Equation 2. When this condition is met, linearity through the origin may be assumed, and the average calibration factor may be used in lieu of a calibration curve.

**Equation 1: Calibration Factor: Target PAH Analytes**

$$\text{Calibration Factor (CF)} = \frac{\text{area of peak}}{\text{concentration injected (ng / } \mu\text{L)}}$$

**Equation 2: Percent Relative Standard Deviation**

$$\%RSD = \frac{\text{Stand Dev of 5 CFs}}{\text{Mean of 5 CFs}} \times 100$$

9.7.2.4 Hydrocarbon Range Calibration (External Standard): A calibration factor must also be established for each hydrocarbon range of interest. Calculate the CFs for C<sub>9</sub>-C<sub>18</sub> Aliphatic Hydrocarbons, C<sub>19</sub>-C<sub>36</sub> Aliphatic Hydrocarbons and C<sub>11</sub>-C<sub>22</sub> Aromatic Hydrocarbons from the appropriate FID chromatogram. Tabulate the summation of the peak areas of all components in that fraction (i.e. C<sub>9</sub>-C<sub>18</sub> Aliphatic Hydrocarbons, 6 components) against the total concentration injected. The results can be used to calculate the ratio of the peak area response summation to the concentration injected, defined as the CF, for the hydrocarbon ranges using Equation 3. The %RSD of the calibration factor must be equal to or less than 25% over the working range for the hydrocarbon range of interest, as determined using Equation 2.

A listing of the collective nominal concentrations of standards within each hydrocarbon range is provided in Table 6.

**Note: For the calculation of calibration factors (CFs):**

**The area for the surrogates must be subtracted from the area summation of the range in which they elute (e.g., COD is subtracted from the C<sub>19</sub> - C<sub>36</sub> Aliphatic Hydrocarbon range).**

**The areas associated with naphthalene and 2-methylnaphthalene in the aliphatic range standard must be subtracted from the uncorrected collective C<sub>9</sub>-C<sub>18</sub> Aliphatic Hydrocarbon range area prior to calculating the CF.**

**Equation 3: Range Calibration Factor: Hydrocarbon Ranges**

$$\text{Range CF} = \frac{\text{Area Summation of Range Components}}{\text{Total concentration injected (ng / } \mu\text{L)}}$$

9.7.2.5 At a minimum, the calibration factor must be verified on each working day, after every 20 samples or every 24 hours (whichever is more frequent), and at the end of the analytical sequence by the injection of a mid-level continuing calibration standard to verify instrument performance. If the percent difference (%D) for any analyte varies from the predicted response by more than  $\pm 25\%$ , as determined using Equation 4, a new five-point calibration must be performed for that analyte. Greater percent differences are permissible for n-nonane. If the %D or percent drift for n-nonane is greater than 30, note the nonconformance in the case narrative. It should be noted that the %Ds are calculated when CFs are used for the initial calibration and percent drifts (Equation 4-5, Appendix 4) are calculated when calibration curves using linear regression are used for the initial calibration (see Section 10.4.3.1).

**Equation 4: Percent Difference (%D)**

$$\%D = \frac{CF_{AVG} - CF_{CC}}{CF_{AVG}} \times 100$$

where:

CF<sub>AVG</sub> = Average Calibration Factor calculated from initial calibration.  
CF<sub>CC</sub> = Calibration Factor calculated from continuing calibration standard.

9.7.2.6 For TPH analysis, without fractionation, calibration factors are developed based upon the response of all 14 aliphatic components using Equation 3.

## 9.8 GC Analysis

9.8.1 Samples are analyzed in a group referred to as an analytical batch. For methods that require extraction prior to analysis, such as EPH, the number of samples that comprise an analytical batch is generally limited to 20 samples plus the requisite QC samples processed concurrently with the extraction batch. The analytical sequence begins with instrument calibration (initial or continuing) followed by up to 20 samples interspersed with blanks and other QC samples and closed with a mid-range continuing calibration standard. The analytical sequence ends when one or more analytical batches have been processed or when any required qualitative and/or quantitative QC criteria are exceeded.

9.8.2 Aliphatic and aromatic extracts are introduced into the gas chromatograph by direct injection.

9.8.3 Inject 1 to 4  $\mu\text{L}$  of the sample extract using the solvent flush technique. Smaller volumes may be injected if automatic devices are employed. Record the volume injected to the nearest 0.05  $\mu\text{L}$  and the resulting peak size in area units. It is required that the sample and calibration standard injection volume be consistent.

9.8.4 Establish daily retention time windows for each analyte of interest. Use the absolute retention time for each analyte as the midpoint of the window for that day. The daily retention time window equals the midpoint  $\pm$  three

times the standard deviation determined in Section 9.6. Alternatively, the default value of 0.1 minutes may be used for the daily retention time window.

- 9.8.4.1 Tentative identification of a Target PAH Analytes occurs when a peak from a sample chromatogram falls within the daily retention time window. Confirmation on a second GC column or by GC/MS analysis may be necessary, if warranted by project's data quality objectives.
- 9.8.4.2 Validation of GC system qualitative performance must be accomplished by the analysis of mid-level standards within the analysis sequence. If the retention times of the Target PAH Analytes fall outside their daily retention time window in the standards, the system is out of control. In such cases, the cause of the non-conformance must be identified and corrected.
- 9.8.5 Aliphatic and aromatic ranges of interest are determined by the collective integration of all peaks that elute between specified range "marker" compounds. Due to the variability in software approaches and applications to collective peak area integration, it is recommended that a manual verification be initially performed to document accurate integration.
- 9.8.6 **When quantifying on a peak area basis by external calibration, collective peak area integration for the fractional ranges, or TPH, must be from baseline (i.e. must include the unresolved complex mixture "hump" areas).** For the integration of individual Target PAH Analytes, surrogate compounds, and internal standards, a valley-to-valley approach should typically be used, though this approach may be modified on a case-by-case basis by an experienced analyst. In any case, the unresolved complex mixture "hump" areas must not be included in the integration of individual Target PAH Analytes, surrogate compounds, and internal standards.
- 9.8.7 Baseline correction using a system solvent blank is **only** permissible for the calculation of aliphatic and aromatic hydrocarbon range concentrations when conducted in accordance with the procedures and requirements specified in Section 11.2.5.
- 9.8.8 If the Target or Diesel PAH Analytes are to be quantitated using this method, and the response for an individual analyte exceeds the highest calibration concentration, dilute the extract and reanalyze. The samples must be diluted so that all peaks fall within the calibration range of the detector and are bracketed by upper and lower calibration standards.
- 9.8.9 For non-target analytes eluting in the aliphatic, aromatic or TPH fractions, the upper linear range of the system should be defined by peak height measurement, based upon the maximum peak height documented for an aliphatic or aromatic standard within the fraction that is shown to be within the linear range of the detector.
- 9.8.10 Analytical conditions that require sample dilution include;
1. The concentration of one or more of the target analytes exceed the concentration of their respective highest calibration standard,
  2. Any non-target peak eluting within any aliphatic or aromatic range exceeds twice the peak height documented for the highest range-specific calibration standard, or
  3. Anytime a saturated chromatographic peak (flat-topped peak) is encountered

When sample extracts are diluted, the Reporting Limit (RL) for each target analyte and/or range must be adjusted (increased) in direct proportion to the Dilution Factor (DF). Where:

$$DF = \frac{\text{Sample Extract Volume (mL)} + \text{Diluent Volume (mL)}}{\text{Sample Extract Volume (mL)}}$$

And the revised RL for the diluted sample, RL<sub>d</sub>:

$$RL_d = DF \times \text{Lowest Calibration Standard for Target PAH Analyte (or hydrocarbon range)}$$

**It should be understood that samples with elevated RLs as a result of a dilution may not be able to satisfy "MCP program" reporting limits in some cases if the RL<sub>d</sub> is greater than the applicable MCP standard or criterion to which the concentration is being compared. Such increases in RLs are the unavoidable but acceptable**

consequence of sample extract dilution that enable quantification of target analytes which exceed the calibration range. All dilutions must be fully documented in the analytical report.

Analytical Note: Over dilution is an unacceptable laboratory practice. The target post-dilution concentration for the highest concentration target analyte should be at least 60 - 80% (must be at least 50%) of its highest calibration standard. This will avoid unnecessarily high reporting limits for other target analytes, which did not require dilution.

## 9.9 Calculations

### 9.9.1 External Standard Calibration

The concentration of Target PAH Analytes and hydrocarbon ranges in a sample may be determined by calculating the concentration of the analyte or hydrocarbon range injected, from the peak area response, using the calibration factor determined in Section 9.7.2. If linear regression is used for calibration, refer to Appendix 4 for sample concentration calculations.

### 9.9.2 Aqueous Samples (External standard):

The concentration of a specific analyte or hydrocarbon range in an aqueous sample may be calculated using Equations 5 and 6, respectively.

#### **Equation 5: Aqueous Samples (Target PAH Analytes: External Standard)**

$$\text{Conc Analyte ( } \mu\text{g/L)} = \frac{(A_x)(D)(V_t)}{(CF)(V_s)}$$

#### **Equation 6: Aqueous Samples (Hydrocarbon Ranges and TPH: External Standard)**

$$\text{Conc HC Range or TPH ( } \mu\text{g/L)} = \frac{(A_x)(D)(V_t)}{(\text{Range CF})(V_s)}$$

where:

$A_x$  = Response for the analyte, hydrocarbon range, or TPH in the sample. Units must be in area counts for Target PAH Analytes and must be an area count summation for the hydrocarbon ranges and TPH.

$D$  = Dilution factor\*; dimensionless.

$CF$  = Average Calibration Factor for Target PAH Analyte, determined in Section 9.7.2.3

$\text{Range CF}$  = Average Calibration Factor for hydrocarbon range or TPH, determined in Section 9.7.2.4 or 9.7.2.5 respectively.

$V_t$  = Volume of total extract,  $\mu\text{L}$  (fractionation + surrogate volume)

$V_s$  = Volume of sample extracted, mL.

#### Non-aqueous samples (External Standard):

The concentration of a specific analyte or hydrocarbon range in a non-aqueous sample may be calculated using Equations 7 and 8, respectively.

**Equation 7: Non-Aqueous Samples (Target PAH Analytes: External Standard)**

$$\text{Conc Analyte (ug/kg)} = \frac{(A_x)(V_t)(D)}{(W_d)(CF)}$$

**Equation 8: Non-Aqueous Samples (Hydrocarbon Ranges and TPH: External Standard)**

$$\text{Conc HC Range or TPH (ug/kg)} = \frac{(A_x)(V_t)(D)}{(W_d)(\text{Range CF})}$$

where:

$W_d$  = Dry weight of sample, g (see Equations 9 through 11)

$A_x$ ,  $V_t$ ,  $D$ ,  $CF$ , and Range  $CF$  have the same definition as described above for Equations 5 and 6.

9.9.4 Calculation of Dry Weight of Sample

In order to calculate the dry weight of sample extracted ( $W_d$ ), it is necessary to determine the moisture content of the soil/sediment sample, using the procedure outlined in Section 9.4. Using the data obtained from Section 9.4,  $W_d$  is calculated using Equations 9 through 11.

**Equation 9: Percent Moisture**

$$\% \text{ Moisture} = \frac{\text{g wet sample} - \text{g dry sample}}{\text{g wet sample}} \times 100$$

**Equation 10: Percent Solids**

$$\% \text{ Dry Solids} = (100) - (\% \text{ Moisture})$$

**Equation 11: Dry Weight of Sample**

$$W_d \text{ (g)} = (\% \text{ Dry Solids} / 100)(\text{g of extracted sample})$$

9.10 **Determination of Target PAH Analytes and EPH Aliphatic and Aromatic Range Concentrations by Gas Chromatography/Mass Spectrometry (GC/MS)**

Target PAH analytes and aliphatic and aromatic ranges may be quantified **after fractionation** using GC/MS under the MADEP EPH Method and not considered a “Significant Modification”, as described in Section 11.3.1.1, by satisfying the following requirements:

9.10.1 Target PAH Analytes in the aromatic hydrocarbon fraction must be identified, quantified and satisfy the QC requirements and performance standards of SW-846 Method 8270C as described in WSC-CAM-II B with the modifications listed below. For quantification of the EPH aliphatic and aromatic ranges the MS detector must be operated in the Total Ion Current mode.

9.10.2 Modified SW-846 Method 8270C QC Requirements for EPH Analysis\*

\* All referenced Section numbers refer to SW-846 Method 8270C .

9.10.2.1 DFTPP must be used as a tuning standard (Section 5.5),

9.10.2.2 5-alpha-androstane (using  $m/z$  245 as primary quantitation ion) is the recommended internal standard, other internal standards may be used, as appropriate.

- 9.10.2.3 OTP is the recommended analytical surrogate to evaluate % Recovery of the Target PAH analytes contained in the aromatic fraction (Section 5.7), other surrogates (i.e., d<sub>8</sub>-Naphthalene) may be used, as appropriate.
- 9.10.2.4 Evaluation of DDT breakdown, and Pentachlorophenol and Benzidine tailing is not required (section 7.3.1.1)
- 9.10.2.5 All Target PAH Analytes described in Table 2 must meet the initial and continuing calibration requirements for the SW-846 Method 8270C described in WSC-CAM-II B unless specifically excepted in this section.
- 9.10.2.6 Range Calibration Factors must be based on all the individual aliphatic or aromatic calibration standards described in Tables 1 and 2, that are included within the specified range as defined by the EPH marker compounds described in Table 5. Range Calibration Factors are determined by dividing the summation of the peak areas (Total Ion Current ) for all individual calibration standard components that elute within a specified range (i.e., C9 – C18 Aliphatic Hydrocarbons, 6 components) by the total concentration injected.
- 9.10.2.7 Evaluation of the System Performance Check Compounds (SPCC) and Calibration Check Compounds (CCC) alone, as described in Sections 7.3.4 and 7.3.5, respectively, are insufficient to verify calibration. All target analytes must be evaluated in the ICAL and CCV and meet the performance standards described in Table 7 below.
- 9.10.2.8 Evaluation of Continuing Calibration Standard (equivalent to the CCV described in SW-846 Method 8270C ) standards is required at the beginning and end of each analytical sequence,
- 9.10.2.9 The analytical batch for EPH analyses may include the analysis of up to 20 samples completed within 12 hours of the batch's tune, and
- 9.10.2.10 The performance standards for the EPH Aliphatic and Aromatic Ranges and comparable performance standards for the Target PAH Analytes are presented below in Table 7. In addition to these performance standards, the performance standards for the Target PAH Analytes must also meet the requirements of SW-846 Method 8270C as described in WSC-CAM-II B, Table II B-1.

**Table 7. Modified SW-846 Method 8270C Analytical QC Requirements and Performance Standards for Target PAH Analyte and EPH Aliphatic and Aromatic Range Analyses**

QC ELEMENT	PERFORMANCE STANDARD	
	Target PAH Data	EPH Range Data
Initial Calibration (% RSD)	≤ 15	≤ 25
Opening CCV (%drift)	≤ 20	≤ 25
Closing CCV (%drift)	≤ 20	≤ 25
Method Blanks	< RL	< RL
Internal Standard (IS)	Area Count of IS must be within 50 and 200% of associated Opening Calibration	Area Count of IS must be within 50 and 200% of associated Opening Calibration
Surrogate Recovery	40 – 140%	40 – 140%
Fractionation Surrogate Recovery	Not Required	40 – 140%
Laboratory Control Sample (LCS)	40 –140%	40 –140%
LCS Duplicate (RPD)	<20 for water, <30% for soil/sediment	< 25
Matrix Spike (MS)/MS Duplicate <sup>1</sup>	40 –140%; RPD ≤ 50	40 –140%; RPD ≤ 50
LCS/LCSD Naphthalene or 2-Methylnaphthalene Breakthrough	≤ 5 % for either constituent in EPH aliphatic fraction <sup>2</sup>	≤ 5 % for either constituent in EPH aliphatic fraction
1. At discretion of data user		
2. Naphthalene and 2-Methylnaphthalene must be measured in EPH aliphatic fraction of each sample for GC/MS analysis. Sample must be re-fractionated if concentration of either compound >5% in aliphatic fraction		

9.10.3 If the Aliphatic range concentrations are quantified by GC/MS, Naphthalene and , 2-Methylnaphthalene must be identified and quantified in the aliphatic hydrocarbon fraction using SW-846 Method 8270C, using an internal standard. The QC requirements and performance standards for SW-846 Method 8270C described in WSC-CAM-II B must also be satisfied.

9.10.4 The sample must be extracted using the procedures described in Section 9.1 and the resultant concentrated extract fractionated as described in Section 9.2.

9.10.5 WSC-CAM-II B must be identified as the “Method for Target Analytes” and “Method for Ranges” on the Required EPH Data Report Information form described in Appendix 3.

9.10.6 Any other modifications to the WSC-CAM-II B Method must be described in detail in the Laboratory Case Narrative Report.

## 10.0 QUALITY CONTROL

### 10.1 General Requirements and Recommendations

10.1.1 Each laboratory that uses this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability (IDLC) and an ongoing analysis of spiked samples to evaluate and document the quality of data. The initial demonstration of laboratory capability should be repeated whenever new staff are trained or significant changes in instrumentation or the method (i.e., new extraction method, etc.) are made. The laboratory must maintain records to document data quality. Ongoing data quality checks are compared with established performance criteria to determine if the results of analyses meet the performance standards for the method. When results of sample spikes indicate atypical method performance, a quality control check standard must be analyzed to confirm that the analytical system was in-control when the measurements were performed.

10.1.2 A system solvent blank must be run after all highly contaminated samples to minimize the potential for sample carryover. For purposes of this analytical requirement, any sample with an on-column concentration greater than the highest calibration standard is considered "highly contaminated" (see Section 4.4).

#### 10.1.3 Batch Analytical Quality Control Samples

10.1.3.1 At a minimum, for each analytical batch (up to 20 samples) or every 24 hours, whichever come first, a beginning and ending Continuing Calibration Standard must be analyzed. For analytical batches with more than 10 samples, the analysis of an additional mid-range Continuing Calibration Standard should also be considered. However, it should be noted that the analysis of the Continuing Calibration Standard is required prior to sample analysis, after every 20 samples or every 24 hours, whichever come first, and at the end of an analytical sequence, at a minimum.

10.1.3.2 At a minimum, for each analytical batch (up to 20 samples of similar matrix), a Laboratory Method Blank, a Laboratory Control Sample (LCS), and a LCS Duplicate must also be analyzed and results analyzed as part of the laboratory's continuing quality control program. The blank and quality control samples fortified with known concentrations and volumes of analytical standards should be carried through the complete sample preparation and measurement processes.

10.1.3.3 It should be noted that field QC samples (field blanks, duplicates, matrix spikes and matrix spike duplicates) are run on pre-identified field samples at the request of the data user. Coordination with the laboratory is required to assure that adequate sample volume is available.

10.1.4 The recommended analytical sequence is as follows:

- (1) Analytical Batch Opening Initial Calibration or mid-range Continuing Calibration Standard **[REQUIRED]**
- (2) Initial Calibration Verification **[REQUIRED\*]**,  
\* only if separate-source standard not used for LCS]
- (3) Extraction Batch Laboratory Control Sample **[REQUIRED]**
- (4) Extraction Batch Laboratory Control Sample Duplicate **[REQUIRED]**
- (5) Extraction Batch Laboratory Method Blank **[REQUIRED]**
- (6) Up to 20 Samples
- (7) Matrix Duplicate sample [As requested by data user]
- (8) Matrix Spike/MS Duplicate [As requested by data user]
- (9) Optional mid-range Continuing Calibration Standard (consider after 10 samples)

(10) Closing mid-range Continuing Calibration Standard <sup>a</sup> after 20 samples and at end of analytical batch **[REQUIRED]**

- a. May be used as Analytical Batch Opening Continuing Calibration for the next analytical batch if batches are processed continuously.

10.1.5 It is recommended that surrogate standard recoveries be monitored and documented on a continuing basis. At a minimum, when surrogate recovery from a sample, blank, or QC sample is less than 40% or more than 140%, check calculations to locate possible errors, check the fortifying solution for degradation, and check for changes in instrument performance. If the cause cannot be determined, re-extract and re-analyze the sample if the recovery of one surrogate is <40% or the recoveries of both surrogates are outside the acceptance limits. The laboratory may first reanalyze the archived portion (prior to fractionation) to see if the surrogate recoveries were possibly affected by fractionation. If surrogate recoveries are acceptable in the archived portion, refractionation and reanalysis of the archived extract must be performed. Reextraction and reanalysis are not required if one of the following exceptions applies:

- (1) Obvious interference is present on the chromatogram (e.g., unresolved complex mixture); and
- (2) If the surrogate exhibits high recovery and associated target analytes or hydrocarbon ranges are not detected in sample.

Analysis of the sample on dilution may diminish matrix-related surrogate recovery problems. This approach can be used as long as the reporting limits to evaluate applicable MCP standards can still be achieved with the dilution. If not, reanalysis without dilution must be performed.

## 10.2 Minimum Instrument QC

10.2.1 The instrument must be able to achieve adequate separation and resolution of peaks and analytes of interest.

10.1..1 The n-nonane (n-C<sub>9</sub>) peak must be adequately resolved from the solvent front of the chromatographic run.

10.1..2 The surrogates COD and OTP must be adequately resolved from any individual components in the Aliphatic Hydrocarbon and Aromatic Hydrocarbon standards.

10.1..3 All peaks of interest in the Aliphatic Hydrocarbon standard must be adequately resolved to baseline. In the Aromatic Hydrocarbon standard, baseline separation is expected for Phenanthrene and Anthracene. Benzo(a)Anthracene, Chrysene, Benzo(b)Fluoranthene, Benzo(k)fluoranthene, Dibenzo(a,h)Anthracene, and Indeno(1,2,3-cd)Pyrene are not expected to be chromatographically separated to baseline and may be reported as an unresolved mixture, unless adequate resolution is obtained.

For the purposes of this method, adequate resolution is assumed to be achieved if the height of the valley between two peaks is less than 25% of the average height of the two peaks.

10.2.2 Retention time windows must be re-established for Target EPH Analytes each time a new GC column is installed, and must be verified and/or adjusted on a daily basis. (See Sections 9.6 and 9.8.4).

10.2.3 Calibration curves, calibration factors, or response factors must be developed based upon the analysis of calibration standards prepared at a minimum of 5 concentration levels. The linearity of calibration or response factors may be assumed if the %RSD over the working range of the curve is less than or equal to 25%. Alternatively, if linear regression analysis is used for quantitation (i.e., calibration curve), the correlation coefficient (r) must be at least 0.99. (See Section 9.7).

10.2.4 In order to demonstrate the absence of aliphatic mass discrimination, the response ratio of C<sub>28</sub> to C<sub>20</sub> must be at least 0.85. If <0.85, this nonconformance must be noted in the laboratory case narrative.

The chromatograms of Continuing Calibration Standards for aromatics must be reviewed to ensure that there are no obvious signs of mass discrimination.

- 10.2.5 Due care must be exercised to assure that the peaks for naphthalene and n-dodecane in the aliphatic hydrocarbon fraction are adequately resolved to allow for an accurate determination of the naphthalene concentration in the LCS/LCSD pair.

### 10.3 Initial and Periodic Method QC Demonstrations

The QC procedures described in Appendix 5 and described in SW-846 Method 8000B, Section 8.4 must be conducted, successfully completed and documented as an initial demonstration of laboratory capability, prior to the analysis of any samples by the EPH Method. Subsequent to this initial demonstration, additional evaluations of this nature should be conducted on a periodic basis, in response to changes in instrumentation or operations, training new analysts and/or in response to confirmed or suspected systems, method, or operational problems. Elements of the Initial Demonstration of Laboratory Capability include:

- 10.3.1 Demonstration of Acceptable System Background, see Appendix 5, Section 2.0 (Optional)
- 10.3.2 Initial Demonstration of Accuracy (IDA), see Appendix 5, Section 3.0
- 10.3.3 Initial Demonstration of Precision (IDP), see Appendix 5, Section 4.0,
- 10.3.4 Initial Demonstration of Fractionation Efficiency, see Appendix 5, Section 5.0, and
- 10.3.5 Method Detection Limit (MDL), see Appendix 5, Section 6.0 (Optional)

### 10.4 Ongoing Method QC Demonstrations

10.4.1 Each sample, blank, LCS, LCSD, MS, and Matrix Duplicate must be fortified with the surrogate spiking solution. Required surrogate recovery is 40% to 140%. At a minimum, when surrogate recovery from a sample, blank, or QC sample is less than 40% or more than 140%, check calculations to locate possible errors, check the fortifying solution for degradation, and check for changes in instrument performance. If the cause cannot be determined, reextract and reanalyze the sample if the recovery of one surrogate is <40% or the recoveries of both surrogates are outside the acceptance limits. The laboratory may first reanalyze the archived portion (prior to fractionation) to see if the surrogate recoveries were possibly affected by fractionation. If surrogate recoveries are acceptable in the archived portion, refractionation and reanalysis of the archived extract must be performed. Re-extraction and reanalysis are not required if one of the following exceptions applies:

- (1) Obvious interference is present on the chromatogram (e.g., unresolved complex mixture); and
- (2) If the surrogate exhibits high recovery and associated target analytes or hydrocarbon ranges are not detected in sample.

Analysis of the sample on dilution may diminish matrix-related surrogate recovery problems. This approach can be used as long as the reporting limits to evaluate applicable MCP standards can still be achieved with the dilution. If not, reanalysis without dilution must be performed.

10.4.2 Each sample (field and QC sample) must be evaluated for potential breakthrough on a sample-specific basis by evaluating the % recovery of the fractionation surrogate (2-bromonaphthalene) and on a batch basis by quantifying naphthalene and 2-methylnaphthalene in both the aliphatic and aromatic fractions of the LCS and LCSD. **If either the concentration of naphthalene or 2-methylnaphthalene in the aliphatic fraction exceeds 5% of the total concentration for naphthalene or 2-methylnaphthalene in the LCS or LCSD, fractionation must be repeated on all archived batch extracts.** If the fractionation surrogate recovery is outside the 40 – 140% limits, then fractionation must be repeated on the archived extract of the affected sample. **NOTE: The total concentration of naphthalene or 2-methylnaphthalene in the LCS/LCSD pair includes the summation of the concentration detected in the aliphatic fraction and the concentration detected in the aromatic fraction.**

Analytical Note: Due care must be exercised to assure that the peaks for naphthalene and n-dodecane in the aliphatic hydrocarbon fraction are adequately resolved to allow for an accurate determination of the naphthalene concentration in the LCS/LCSD pair.

<b>Example Naphthalene* % Breakthrough Calculation</b>	
Naphthalene in Aromatic Fraction ( $N_{ar}$ )::	48 $\mu\text{g/L}$
Naphthalene in Aliphatic Fraction ( $N_{al}$ )::	1.5 $\mu\text{g/L}$
Total Naphthalene Concentration ( $NT_r$ )::	49.5 $\mu\text{g/L}$
% Naphthalene Breakthrough =	$\frac{N_{al}}{NT_r} \times 100$
% Naphthalene Breakthrough =	$\frac{1.5}{49.5} \times 100$
<b>% Naphthalene Breakthrough = 3.0</b>	
* may be applied to 2-methylnaphthalene breakthrough calculation also	

10.4.3 At a minimum, with every batch of 20 samples or less the laboratory must extract and analyze the following quality control samples:

10.4.3.1 **Continuing Calibration Standard** - A mid-range continuing calibration standard, prepared from the same stock standard solution used to develop the calibration curve, must be analyzed prior to sample analysis to verify the calibration state of the instrument. For large analytical batches that contain more than 10 samples, the analysis of an additional mid-range continuing calibration standard is recommended after the analysis of the tenth sample. However, it should be noted that a mid-range continuing calibration standard is required after every 20 samples or every 24 hours (whichever comes first) and at the end of the analytical sequence. If the percent difference or percent drift of any analyte within the continuing calibration standard varies from the predicted response by more than 25%, a new five-point calibration must be performed for that analyte. Greater differences are permissible for n-nonane. If the percent difference or percent drift is greater than 30% for n-nonane, note the nonconformance in the narrative. For the closing continuing calibration standard (analyzed after every 20 samples, every 24 hours, or at end of analytical sequence), four compounds may exhibit percent differences or percent drifts greater than 25% but less than 40%.

10.4.3.2 **Laboratory Method Blank** - A water or soil Laboratory Method Blank is prepared by fortifying a reagent water or clean sand blank (optional) with 1.0 mL of the surrogate spiking solution. Peaks must not be detected above the Reporting Limit within the retention time window of any analyte of interest. The hydrocarbon ranges must not be detected at a concentration greater than 10% of the most stringent MCP cleanup standard. Peaks detected within the retention time window of any analyte or range of interest above a Reporting Limit must be noted on the data report form. Re-extraction of all associated samples may be warranted.

10.4.3.3 **Laboratory Control Sample** - A Laboratory Control Sample is prepared by fortifying a reagent water or clean sand blank with 1.0 mL of the matrix spiking solution. The spike recovery must be between 40% and 140%. Lower recoveries of n-nonane are permissible. If the recovery of n-nonane is <30%, note the nonconformance in the narrative. Reextraction of all associated samples is required if criteria are not met.

10.4.3.4 **LCS Duplicate** - A Laboratory Control Sample Duplicate is prepared by fortifying a reagent water or clean sand blank with 1.0 mL of the matrix spiking solution (see Section 7.7 and Tables 1 and 2). The LCS Duplicate is separately prepared, processed and analyzed in the same manner as the LCS and is used as the data quality indicator of precision. The Analytical Batch Precision is determined from the Relative Percent Difference (RPD) of the concentrations (not recoveries) of LCS/LCSD pair. The RPD for

individual Target PAH Analytes and aliphatic and aromatic hydrocarbon range concentrations (sum of the individual aliphatic or aromatic compounds within the specified range) must be  $\leq 25$ .

- 10.4.3.5 **Initial Calibration Verification** – An Initial Calibration Verification standard, prepared from a separate source standard than used for initial and continuing calibrations, must be analyzed prior to sample analysis if a separate source standard is not used for the LCS. The recoveries of all Target Analytes must be between 80-120%. A new five-point calibration must be performed if criteria are not met.
- 10.4.3.6 **System Solvent Blank** - If baseline correction will be employed, as specified in Section 11.2.5, a system solvent blank, air blank, and/or system run must be undertaken with every batch, and after the analysis of a sample that is suspected to be highly contaminated. In no case shall baseline correction be used if the instrument baseline drift is more than 25% greater than the average level established by these charts.
- 10.4.3.7 **Fractionation Check Standard** – A fractionation check solution is prepared containing 14 alkanes and 17 PAHs at a nominal concentration of 200 ng/  $\mu$  l of each constituent. The Fractionation Check Solution must be used to evaluate the fractionation efficiency of each new lot of silica gel / cartridges as described in Appendix 5, Section 5.0, and establish the optimum hexane volume required to efficiently elute aliphatic hydrocarbons while not allowing significant aromatic hydrocarbon breakthrough. For each analyte contained in the fractionation check solution, excluding n-nonane, the Percent Recovery (see Appendix 5, Equation 5-4) must be between 40 and 140%. A 30% Recovery is acceptable for n-nonane.
- 10.4.4 At the request of the data user, and in consideration of sample matrices and data quality objectives, matrix spikes and matrix duplicates may be analyzed with every batch of 20 samples or less per matrix.
- 10.4.4.1 **Matrix duplicate** - Matrix duplicates are prepared by analyzing one sample in duplicate. The purpose of the matrix duplicates is to determine the homogeneity of the sample matrix as well as analytical precision. The RPD of detected results in the matrix duplicate samples must not exceed 50 when the results are greater than 5x the reporting limit.
- 10.4.4.2 **Matrix Spike/Matrix Spike Duplicate** - The water or soil MS is prepared by fortifying an actual water or soil sample with 1.0 mL of the matrix spiking solution. The desired spiking level is 50% of the highest calibration standard. However, the total concentration in the MS (including the MS and native concentration in the unspiked sample) should not exceed 75% of the highest calibration standard in order for a proper evaluation to be performed. The purpose of the matrix spike is to determine whether the sample matrix contributes bias to the analytical results. The background concentrations of the analytes in the sample matrix must be determined in a separate unspiked aliquot and the measured values in the matrix spike corrected for background concentrations. The corrected concentrations of each analyte within the matrix spiking solution must be within 40 - 140% of the true value. Lower recoveries of n-nonane are permissible, but must be noted in the narrative if  $<30\%$ .
- 10.4.5 If any of the performance standards specified in Section 10.4 are not met, the cause of the non-conformance must be identified and corrected before any additional samples may be analyzed. Any samples run between the last QC samples that met the criteria and those that are fallen out must be re-extracted and/or re-analyzed. These QC samples include the opening continuing calibration standard, laboratory method blank, LCS, LCSD, and closing continuing calibration standard. If this is not possible, that data must be reported as suspect.
- 10.4.6 The analyte and hydrocarbon range Reporting Limits should be verified/re-established at least once per year, or upon a major change in system equipment or operations (see Section 10.1.1).

## 11.0 DATA PRODUCTION AND REPORTING

### 11.1 Calibration

Using the external standard calibration procedure (9.7.2) calibrate the GC as follows:

- 11.1.1 Calculate a CF or linear regression (LR) for each Target PAH Analyte that comprises the Aromatic Hydrocarbon standard. This step is not necessary if the Target or Diesel PAH Analytes will not be individually identified and quantitated by the EPH method (i.e., if unadjusted values only will be reported for the hydrocarbon ranges or TPH or if reporting concentrations of Target PAH Analytes via another method).
- 11.1.2 Calculate a CF for the surrogates OTP, COD and the Fractionation Surrogates.
- 11.1.3 Calculate a collective CF or LR for the total concentration of the C<sub>9</sub> -C<sub>18</sub> Aliphatic Hydrocarbons. Tabulate the summation of the peak areas of all component standards in that fraction (e.g., C<sub>9</sub>-C<sub>18</sub> Aliphatics, 6 components) against the total concentration injected. Do not include any areal contribution of the internal standard, naphthalene, and 2-methylnaphthalene.
- 11.1.4 Calculate a CF or LR for naphthalene and 2-methylnaphthalene from the Aliphatic Hydrocarbon standard. Not required if the same instrument is calibrated, separately, for all aliphatic and aromatic compounds using the same internal standard and resolution of naphthalene from n-C<sub>12</sub> is demonstrated..
- 11.1.5 Calculate a collective CF or LR for the total concentration of the C<sub>19</sub> -C<sub>36</sub> Aliphatic Hydrocarbons. Tabulate the summation of the peak areas of all component standards in that fraction (e.g., C<sub>19</sub>-C<sub>36</sub> Aliphatics, 8 components) against the total concentration injected. Do not include the surrogate COD.
- 11.1.6 Calculate a collective CF or LR for the total concentration of the C<sub>11</sub> -C<sub>22</sub> Aromatic Hydrocarbons. Tabulate the summation of the peak areas of all component standards in that fraction (e.g., C<sub>11</sub>-C<sub>22</sub> Aromatics, 17 components) against the total concentration injected. Do not include the surrogate OTP, 2-Bromonaphthalene, or 2-Fluorobiphenyl.
- 11.1.7 For TPH analyses, without fractionation, calculate a collective CF or LR. Tabulate the summation of the peak areas of all component standards in the aliphatic fraction (i.e., 14 components) against the total concentration injected. Do not include surrogates or naphthalene and 2-methylnaphthalene in the Aliphatic Hydrocarbon standard.

### 11.2 Sample Analysis

#### 11.2.1 Aliphatic Fraction

- 11.2.1.1 Determine the total area count for all peaks eluting 0.1 minutes before the retention time (Rt) for n-C<sub>9</sub> and 0.01 minutes before the Rt for n-C<sub>19</sub>. It is not necessary to identify or quantitate individual aliphatic compounds within this range.
- 11.2.1.4 Determine the total area count for all peaks eluting 0.01 minutes before the Rt for n-C<sub>19</sub> and 0.1 minutes after the Rt for n-C<sub>36</sub>. It is not necessary to identify or quantitate individual aliphatic compounds within this range.
- 11.2.1.4 Determine the peak area count for the surrogate standard (COD). Subtract this value from the collective area count value within the C<sub>19</sub> through C<sub>36</sub> aliphatic hydrocarbon range.
- 11.2.1.4 Using the equations contained in Section 9.9, calculate the collective concentrations of C<sub>9</sub> through C<sub>18</sub> Aliphatic Hydrocarbons, C<sub>19</sub> through C<sub>36</sub> Aliphatic Hydrocarbons, and the individual concentration of the surrogate COD.

### 11.2.2 Aromatic Fraction

- 11.2.2.1 Determine the total area count for all peaks eluting 0.1 minutes before the retention time (Rt) for naphthalene and 0.1 minutes after the Rt for benzo(g,h,i)perylene.
- 11.2.2.2 Determine the peak area count for the sample surrogate (OTP) and fractionation surrogate(s). Subtract these values from the collective area count value.
- 11.2.2.3 Optionally, determine the peak area count for the Target or Diesel PAH Analytes.
- 11.2.2.4 Using the equations contained in Section 9.9, calculate the concentrations of Unadjusted C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons, the surrogate standard (OTP), fractionation surrogate standard(s) and optionally, the Target or Diesel PAH Analytes.

### 11.2.3 Total Petroleum Hydrocarbons

- 11.2.3.1 Determine the total area count for all peaks eluting 0.1 minutes before the retention time (Rt) for n-C<sub>9</sub> and 0.1 minutes after the Rt for n-C<sub>36</sub>. It is not necessary to identify or quantitate individual aliphatic compounds within this range.
- 11.2.3.2 Determine the peak area count for any surrogate and internal standards used. Subtract these values from the collective area count value.
- 11.2.3.3 Using the equations contained in Section 9.9, calculate the concentration of Unadjusted TPH.
- 11.2.3.4 If the concentrations of the Target or Diesel PAH Analytes were determined using a GC/MS method, subtract the concentration of the Target or Diesel PAH Analytes from the concentration of unadjusted TPH and report concentration of resulting TPH. If the concentration of Target or Diesel PAH Analytes were not determined using a GC/MS method, report a value for Unadjusted TPH, and indicate "Not Determined" for TPH.

### 11.2.4 Data Adjustments

- 11.2.4.1 By definition, the collective concentration of the aromatic fraction (and/or TPH) **excludes** the individual concentrations of the Target PAH Analytes. Accordingly, a data adjustment step is necessary to adjust the collective range concentration calculated in Sections 11.2.2.4 and 11.2.3.4, to eliminate "double counting" of analytes.
- 11.2.4.2 The necessary data adjustment step may be taken by the laboratory reporting the range/TPH concentration data, or by the data user. The extent of data adjustments taken by the laboratory must be noted on the data report form.
- 11.2.4.3 Subtract the individual concentrations of the Target or Diesel PAH Analytes from the collective concentration of Unadjusted C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons only if the concentrations of the Target or Diesel PAH Analytes are above the reporting limit. If the individual concentrations of Target PAH Analytes have been quantified using another method (e.g., by using an MS detector), note this on the data report form. It should be noted that the reported Target PAH Analyte results must be the results used to adjust the C<sub>11</sub>-C<sub>22</sub> Aromatics results.
- 11.2.4.4 Subtract the individual concentrations of the Target or Diesel PAH Analytes from the collective concentration of Unadjusted TPH only if the concentrations of the Target or Diesel PAH Analytes were determined using a GC/MS method.
- 11.2.4.5 If the individual concentrations of Target PAH Analytes have not been quantitated, report a value for Unadjusted C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons and/or Unadjusted TPH, and indicate "Not Determined" for C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons and/or TPH
- 11.2.4.6 For purposes of compliance with the reporting and cleanup standards specified in the Massachusetts Contingency Plan, the concentration of Unadjusted C<sub>11</sub> through C<sub>22</sub>

Aromatic Hydrocarbons and/or Unadjusted TPH may be conservatively deemed to be equivalent to the concentration of C<sub>11</sub> through C<sub>22</sub> Aromatic Hydrocarbons and/or TPH.

#### 11.2.5 Baseline Correction for Instrument Noise Level

11.2.5.1 EPH aliphatic and aromatic hydrocarbon range area data determined by the collective integration of all eluting peaks between the specified EPH range marker compounds (see Table 5) may be corrected by the manual or automatic subtraction of the baseline established by the injection of a System Solvent Blank. Correction in this manner is not recommended or preferred, but is permissible in cases where all reasonable steps have been taken to eliminate or minimize excessive baseline bias associated with analytical system noise.

11.2.5.2 The instrument baseline must be established by the direct injection of a system solvent blank. The injection of an air blank or activation of a temperature programmed chromatographic run without the injection of any material should be used to verify that the system noise is not attributable to solvent contamination. All system operational elements and parameters must be identical to those of a typical sample run.

If baseline correction is used, the baseline must be re-established for every analytical batch by the analysis of a System Solvent Blank. Baseline correction for EPH aliphatic and aromatic hydrocarbon area data may not be used for any sample for which the area count associated with the baseline correction is greater than 10% of the uncorrected area count for the sample's corresponding collective range.

#### 11.2.6 Contamination of SPE Cartridges

11.2.6.1 Range integration areas may be affected by peaks identified during the injection of a Laboratory Method Blank, and determined to be attributable to the leaching of plasticizers or other contaminants from silica gel SPE cartridges. In general, this contamination affects the C<sub>11</sub>-C<sub>22</sub> Aromatics. Blank correction is not permissible.

11.2.6.2 The laboratory must report the presence of this contamination in the associated range. Optionally, the laboratory may perform GC/MS analysis of the laboratory method blank extract to demonstrate that the contaminant in question is not a C<sub>11</sub>-C<sub>22</sub> aromatic compound. Analysis of only the method blank is acceptable as long as the associated samples exhibit the same contaminant peak at the same retention time. If demonstrated not to be a C<sub>11</sub>-C<sub>22</sub> aromatic compound, the contaminant does not need to be included in the calculation of the hydrocarbon range concentration. The laboratory must provide a discussion in the case narrative if this approach is used.

### 11.3 **Data Reporting Content**

11.3.1 The required content for EPH Method data is presented in Appendix 3. This information provides data users with a succinct and complete summary of pertinent information and data, as well as a clear affirmation that the QC procedures and standards specified in this method were evaluated and achieved. Any significant modification to the MADEP EPH Method, as described in Section 11.3.1.1, and indicated by a negative response to Question D on the MADEP MCP ANALYTICAL METHOD REPORT CERTIFICATION FORM (also included in Appendix 3) precludes the affected data from achieving "Presumptive Certainty" status. If a significant modification to the EPH Method is utilized, an attachment to the analytical report must be included to demonstrate compliance with the method performance requirements of Section 1.12 on a matrix- and petroleum product-specific basis.

While it is permissible to modify the reporting format, all of the data and information specified in Appendix 3 for these reports must be provided in a clear, concise, and succinct manner.

11.3.1.1 "Significant Modifications" to this method shall include, without limitation, all of the following:

11.3.1.1.1 The use of other than a silica-gel fractionation technique;

11.3.1.1.2 The use of an extraction procedure other than those presented in Table 4;

- 11.3.1.1.3 The use of solvents other than those recommended in this method or approved extraction methods listed in Table 4.
- 11.3.1.1.4 The use of a detector other than a Flame Ionization Detector (FID) to quantitate range/TPH concentrations (See Notes 1 and 2 below);
- 11.3.1.1.5 The use of aliphatic or aromatic surrogate compounds with retention times not within  $\pm 2$  minutes of the retention times of the recommended compounds or the use of inappropriate surrogates to represent the aliphatic and aromatic ranges;
- 11.3.1.1.6 Failure to provide all of the data and information presented in Appendix 3 as well as the required method deliverables discussed in Section 11.3.2.

**NOTE 1: Use of a GC/MS detector operated in the Total Ion Current mode to quantify the EPH Method's aliphatic and aromatic hydrocarbon ranges is not considered a significant modification provided that (1) the sample extract has been fractionated; (2) the GC/MS system was also used to identify and quantify the Target PAH Analytes in the sample's aromatic fraction; and (3) the QC requirements and performance standards specified in Section 9.10 are satisfied.**

**NOTE 2: If alternate detectors are used with or without fractionation, other than noted above, the laboratory must demonstrate that the performance standards listed in Section 1.12 were achieved. Use of an alternate detector, other than noted above, is considered a "significant modification". Any EPH data produced using a "significant modification" can not achieve presumptive certainty status.**

11.3.1.2 Positive affirmation that all required QA/QC procedures and performance standards were followed and achieved means that all of the required steps and procedures detailed in Section 10.0 have been followed, and that all data obtained from these steps and procedures were within the acceptance limits specified for these steps and procedures.

11.3.2 In addition to sample results, the EPH data report must contain the following items:

- Laboratory Method Blank Results
- Laboratory Control Sample Results
- LCS Duplicate Sample Results
- Matrix Spike Results (only if requested by data user)
- Matrix Duplicate Results (only if requested by data user)
- Fractionation Check Standard Results
- Surrogate Spike Recoveries (for all field samples and QC samples), including fractionation and extraction surrogates
- Percentage of total naphthalene and 2-methylnaphthalene concentrations detected in the aliphatic fractions of the LCS and LCS Duplicate (see Section 10.4.2)
- Results of reanalyses or dilutions must be reported as required in WSC-CAM-IV B, "Quality Assurance and Quality Control Requirements for the Method for the Determination of Extractable Petroleum Hydrocarbons (EPH), MADEP-EPH-03-1 for the Massachusetts Contingency Plan (MCP)", Table IV B-2.
- Demonstration of compliance with analytical performance standards specified in Section 1.12 on a matrix- and petroleum product-specific basis (only if a "significant modification" is utilized)

11.3.3 General laboratory reporting requirements are outlined in WSC-CAM-VII A, "Quality Assurance and Quality Control Guidelines for the Acquisition and Reporting of Analytical Data", Section 2.4. A copy of the required laboratory certification form is also included in Appendix 3 of this method.

## 12.0 REPORTING LIMITS

The Reporting Limits (RLs) for Target PAH Analytes shall be based upon the concentration of the lowest calibration standard for the analyte of interest. The RL must be greater than or equal to the concentration of the lowest calibration standard. **Target PAH Analytes with calculated concentrations below the RL should be reported as < the specific Target Analyte's RL (i.e., < 2.0 ug/L).** For GC/MS analysis only, calculated concentrations of Target PAH Analytes below the RL (lowest calibration standard) may be reported as a "J Value", or equivalent.

The RLs for hydrocarbon ranges shall be based upon the concentration of the lowest calibration standard for an individual analyte within the range of interest. The range RL will be set at 100x the concentration of the lowest calibration standard for the associated analyte. Calculated collective concentrations for EPH aliphatic and aromatic hydrocarbon ranges below the RL should be reported as < Range RL (i.e., < 100 ug/L).

Based on the on-column concentration of 1 ng/μL for the lowest calibration standard for all analytes, the following reporting limits would be generated for the hydrocarbon ranges:

Aqueous Samples: EPH Hydrocarbon range reporting limits would be equivalent to 100 μg/L based on the extraction of 1 liter of sample, a final fractionation extract volume of 2 mL, and a sample injection volume of 1 μL.

Soil/Sediment Samples: EPH Hydrocarbon range reporting limits would be equivalent to 20 mg/kg (dry weight basis) based on the extraction of 10 grams of soil, a final fractionation extract volume of 2 mL, and a sample injection volume of 1 μL.

## 13.0 METHOD PERFORMANCE

Single laboratory accuracy, precision and MDL data for method analytes are provided in Tables 1-1 through 1-4 in Appendix 1. Chromatograms are provided in Appendix 2.

## 14.0 REFERENCES

1. MADEP and ABB Environmental Services, Inc., "Interim Final Petroleum Report: Development of Health-Based Alternative to the Total Petroleum Hydrocarbon (TPH) Parameter", August, 1994.
2. MADEP, "Final Updated Petroleum Hydrocarbon Fraction Toxicity Values For the VPH/EPH/APH Methodology", January 2003.
3. USEPA, "Measurement of Petroleum Hydrocarbons: Report on Activities to Develop a Manual" Prepared by Midwest Research Institute, Falls Church, VA, under EPA Contract #68-WO-0015, WA No. 4; submitted to USEPA Office of Underground Storage Tanks, Washington, DC; November 20, 1990.
4. USEPA "SW-846 Test Methods for Evaluating Solid Waste", 3rd Edition; Methods 3510C, 3520C, 3540C, 3541, 3545A, 3546, 3580A, 3630C, 8000B, 8100
5. USEPA Federal Register 40 CFR Part 136, Appendix B, "Guidelines Establishing Test Procedures for the Analysis of Pollutants", July 1992.
6. Wisconsin Department of Natural Resources, "Modified DRO - Method for Determining Diesel Range Organics", PUBL-SW-141, 1992
7. USEPA, "Guidance on Evaluation, Resolution, and Documentation of Analytical Problems Associated with Compliance Monitoring", EPA 821-B-93-001; U.S. Government Printing Office, Washington D.C., June, 1993
8. Massachusetts DEP, "Report on the Results of the Fall 1997 VPH/EPH Round Robin Testing Program", December, 1997
9. EPA UST Workgroup, Draft "Method for Determination of Diesel Range Organics", November, 1990
10. ASTM 1990. Standard Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock, *Annual Book of ASTM Standards*, D 2216-90 (revision of 2216-63, 2216-80).

## APPENDIX 1

### SINGLE LABORATORY ACCURACY, PRECISION, AND METHOD DETECTION LIMIT (MDL) DATA

- Table 1-1. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Alkanes Spiked Into Reagent Water and Analyzed by the EPH Method**
- Table 1-2. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Polynuclear Aromatic Hydrocarbons (PAHs) Spiked Into Reagent Water and Analyzed by the EPH Method**
- Table 1-3. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Alkanes Spiked Into EPH-Free Sand and Analyzed by the EPH Method**
- Table 1-4. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Polynuclear Aromatic Hydrocarbons (PAHs) Spiked Into EPH-Free Sand and Analyzed by the EPH Method**

**Table 1-1. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Alkanes Spiked Into Reagent Water and Analyzed by the EPH Method**

Compound <sup>a</sup>	Compound Conc. Measured (µg/L)		Mean Accuracy (Mean % Recovery <sup>b</sup> )	Method Precision (RSD <sup>c</sup> - %)	MDL (µg/L)
	Mean	Std. Dev.			
C <sub>9</sub>	1.79	0.13	72	7.3	0.41
C <sub>10</sub>	2.65	0.02	106	0.7	0.06
C <sub>12</sub>	2.46	0.03	98	1.2	0.09
C <sub>14</sub>	2.51	0.05	100	1.9	0.15
C <sub>16</sub>	2.54	0.05	102	1.8	0.14
C <sub>18</sub>	2.53	0.05	101	2.1	0.17
C <sub>19</sub>	2.52	0.05	101	2.0	0.16
C <sub>20</sub>	2.50	0.06	100	2.4	0.19
COD	2.39	0.06	96	2.3	0.18
C <sub>22</sub>	2.45	0.08	98	3.2	0.25
C <sub>24</sub>	2.41	0.10	96	4.0	0.30
C <sub>26</sub>	2.40	0.13	96	5.4	0.41
C <sub>28</sub>	2.43	0.16	97	6.6	0.50
C <sub>30</sub>	2.46	0.16	98	6.5	0.50
C <sub>36</sub>	2.63	0.46	105	17.5	1.44

<sup>a</sup> Compounds were spiked into 7 samples at a concentration of 2.5 µg/L.  
<sup>b</sup> Recovery (%) of spiked concentration.  
<sup>c</sup> RSD = relative standard deviation (%) of mean concentration measured.

**Table 1-2. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Polynuclear Aromatic Hydrocarbons (PAHs) Spiked Into Reagent Water and Analyzed by the EPH Method**

Compound <sup>a</sup>	Compound Conc. Measured (µg/L)		Mean Accuracy (Mean % Recovery <sup>b</sup> )	Method Precision (RSD <sup>c</sup> - %)	MDL (µg/L)
	Mean	Std. Dev.			
Naphthalene	2.36	0.04	94	1.9	0.14
2-Methylnaphthalene	2.36	0.06	94	2.4	0.18
Acenaphthylene	2.37	0.04	95	1.9	0.14
Acenaphthene	2.39	0.05	96	2.2	0.16
Fluorene	2.35	0.08	94	3.4	0.25
Phenanthrene	2.29	0.10	91	4.3	0.31
Anthracene	2.02	0.10	81	4.8	0.30
OTP	2.36	0.10	94	4.2	0.31
Fluoranthene	2.26	0.15	90	6.6	0.47
Pyrene	2.27	0.15	91	6.6	0.47
Benzo(a)Anthracene	2.27	0.19	91	8.3	0.60
Chrysene	2.30	0.19	92	8.3	0.60
Benzo(b)Fluoranthene	2.47	0.19	99	7.7	0.60
Benzo(k)Fluoranthene	2.49	0.21	99	8.4	0.66
Benzo(a)Pyrene	2.29	0.15	92	6.6	0.50
Indeno(123 cd)Pyrene	2.00	0.13	80	6.5	0.41
Dibenzo(ah)Anthracene	1.99	0.14	80	7.0	0.44
Benzo(ghi)Perylene	2.11	0.18	84	8.5	0.57

<sup>a</sup> Compounds were spiked into 7 samples at a concentration of 2.5 µg/L.  
<sup>b</sup> Recovery (%) of spiked concentration.  
<sup>c</sup> RSD = relative standard deviation (%) of mean concentration measured.

**Table 1-3. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Alkanes Spiked Into EPH-Free Sand and Analyzed by the EPH Method**

Compound <sup>a</sup>	Compound Conc. Measured (mg/Kg)		Mean Accuracy (Mean % Recovery <sup>b</sup> )	Method Precision (RSD <sup>c</sup> - %)	MDL (mg/Kg)
	Mean	Std. Dev.			
C <sub>9</sub>	0.49	0.02	98	3.7	0.06
C <sub>10</sub>	0.46	0.02	92	3.9	0.06
C <sub>12</sub>	0.44	0.02	88	4.5	0.06
C <sub>14</sub>	0.46	0.03	92	6.5	0.09
C <sub>16</sub>	0.48	0.03	96	6.2	0.09
C <sub>18</sub>	0.51	0.03	102	5.8	0.09
C <sub>19</sub>	0.52	0.03	104	5.8	0.09
C <sub>20</sub>	0.53	0.03	106	5.7	0.09
COD	0.53	0.03	106	5.7	0.09
C <sub>22</sub>	0.55	0.03	110	5.5	0.09
C <sub>24</sub>	0.56	0.04	112	7.1	0.13
C <sub>26</sub>	0.57	0.05	114	8.8	0.16
C <sub>28</sub>	0.57	0.06	114	10.5	0.19
C <sub>30</sub>	0.58	0.07	116	12.1	0.22
C <sub>36</sub>	0.62	0.02	124	3.2	0.06

<sup>a</sup> Compounds were spiked into 7 samples at a concentration of 0.5 mg/Kg.

<sup>b</sup> Recovery (%) of spiked concentration.

<sup>c</sup> RSD = relative standard deviation (%) of mean concentration measured.

**Table 1-4. Single Laboratory Accuracy, Precision, and Method Detection Limits (MDLs) for Polynuclear Aromatic Hydrocarbons (PAHs) Spiked Into EPH-Free Sand and Analyzed by the EPH Method**

Compound <sup>a</sup>	Compound Conc. Measured (mg/Kg)		Mean Accuracy (Mean % Recovery <sup>b</sup> )	Method Precision (RSD <sup>c</sup> - %)	MDL (mg/Kg)
	Mean	Std. Dev.			
Naphthalene	0.48	0.03	96	6.3	0.09
2-Methylnaphthalene	0.48	0.03	96	6.3	0.09
Acenaphthylene	0.50	0.03	100	6.0	0.09
Acenaphthene	0.51	0.03	102	5.9	0.09
Fluorene	0.51	0.03	102	5.9	0.09
Phenanthrene	0.53	0.05	106	9.4	0.16
Anthracene	0.52	0/05	104	9.6	0.16
OTP	0.54	0.04	108	7.4	0.13
Fluoranthene	0.55	0.05	110	9.1	0.16
Pyrene	0.55	0.05	110	9.1	0.16
Benzo(a)Anthracene	0.59	0.06	118	10.2	0.19
Chrysene	0.59	0.06	118	10.2	0.19
Benzo(b)Fluoranthene	0.64	0.06	128	9.3	0.19
Benzo(k)Fluoranthene	0.63	0.05	126	7.9	0.16
Benzo(a)Pyrene	0.62	0.05	124	8.0	0.16
Indeno(123 cd)Pyrene	0.59	0.04	118	6.7	0.13
Dibenzo(ah)Anthracene	0.55	0.04	110	7.3	0.13
Benzo(ghi)Perylene	0.58	0.04	116	6.9	0.13

<sup>a</sup> Compounds were spiked into 7 samples at a concentration of 0.5 mg/Kg.  
<sup>b</sup> Recovery (%) of spiked concentration.  
<sup>c</sup> RSD = relative standard deviation (%) of mean concentration measured.

## **APPENDIX 2**

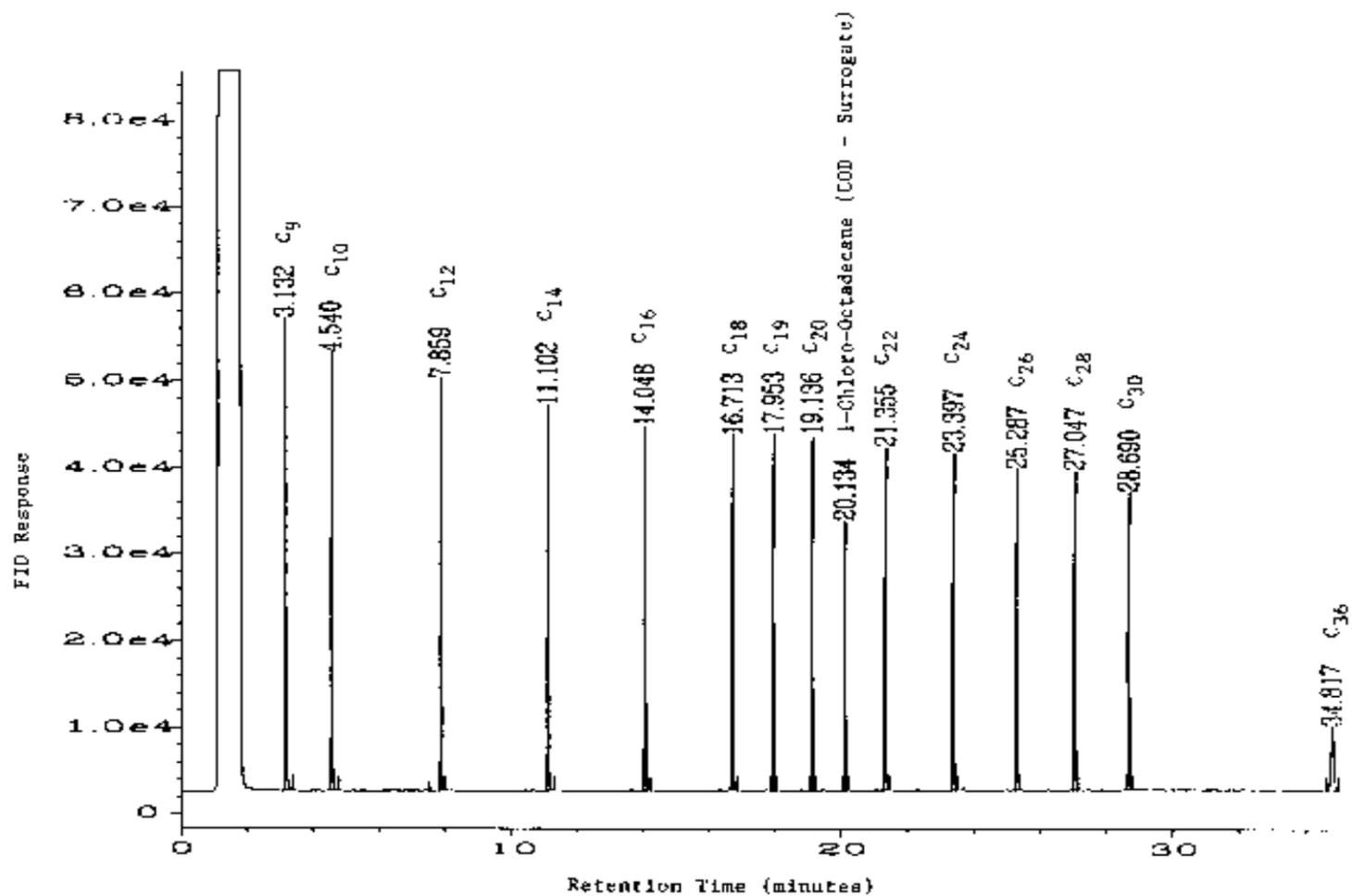
### **CHROMATOGRAMS**

**Figure 1 Gas Chromatogram (FID) of the EPH Alkane Component Standard (20 µg/L)**

**Figure 2 Gas Chromatogram (FID) of the EPH PAH Component Standard (20 µg/L)**

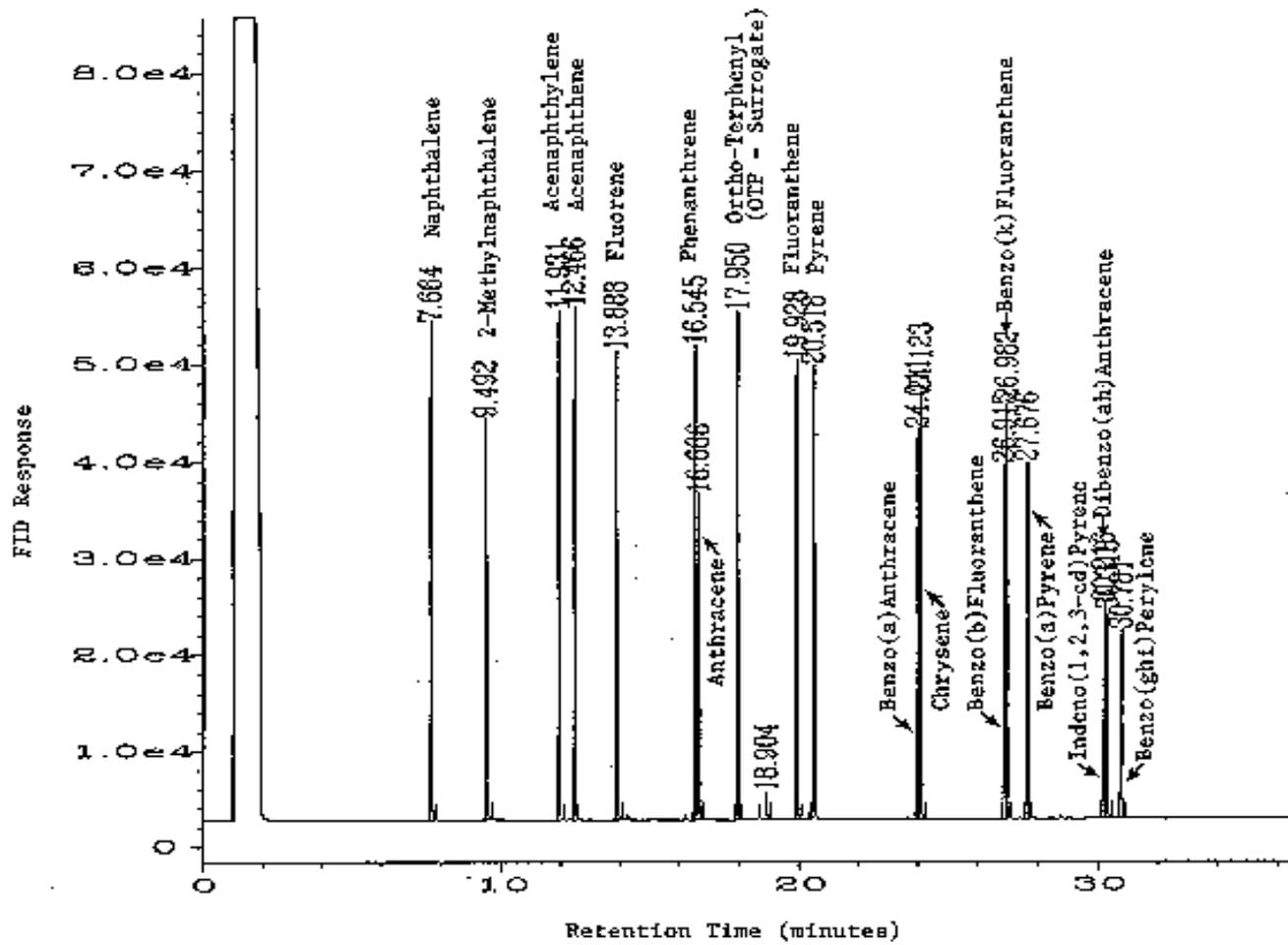
**Figure 3 Gas Chromatogram (FID) of a Diesel Standard (Aliphatic Fractions)**

**Figure 4 Gas Chromatogram (FID) of a Diesel Standard (Aromatic Fraction)**



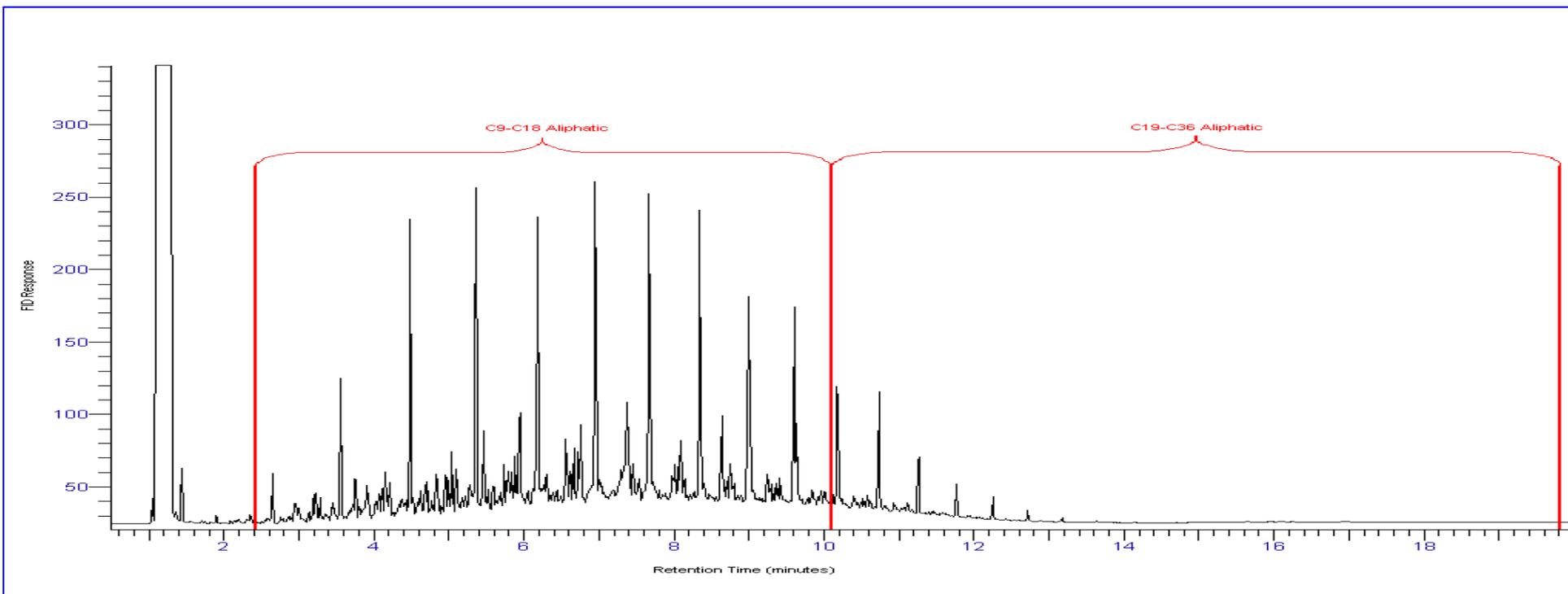
**Figure 1. Gas Chromatogram of the Alkane Diesel Component Standard (20 µg/mL).**

RTX-5 capillary column (30-m x 0.32-mm i.d., 0.25-µm film thickness); FID at 315°C; splitless injection of 2 µL at 285°C; oven programming, 60°C (hold 1 min) to 290°C at 8°C/min (hold 6.75 min); helium column flow, 2-3 mL/min; helium makeup flow, 30 mL/min; air flow 400 mL/min; hydrogen flow 35 mL/min; electronic pressure control of 15 psi at 60°C.



**Figure 2. Gas Chromatogram of the PAH Component Standard (20  $\mu\text{g}/\text{mL}$ ).**

All operating conditions same as specified for Figure 1.



**Figure 3 Gas Chromatogram (FID) of a Diesel Standard (Aliphatic Fractions)**

*Restek RTX-5 SIL-MS capillary column (30 meters .32mm .25 microns); FID detector on a HP 5890 Series II.*

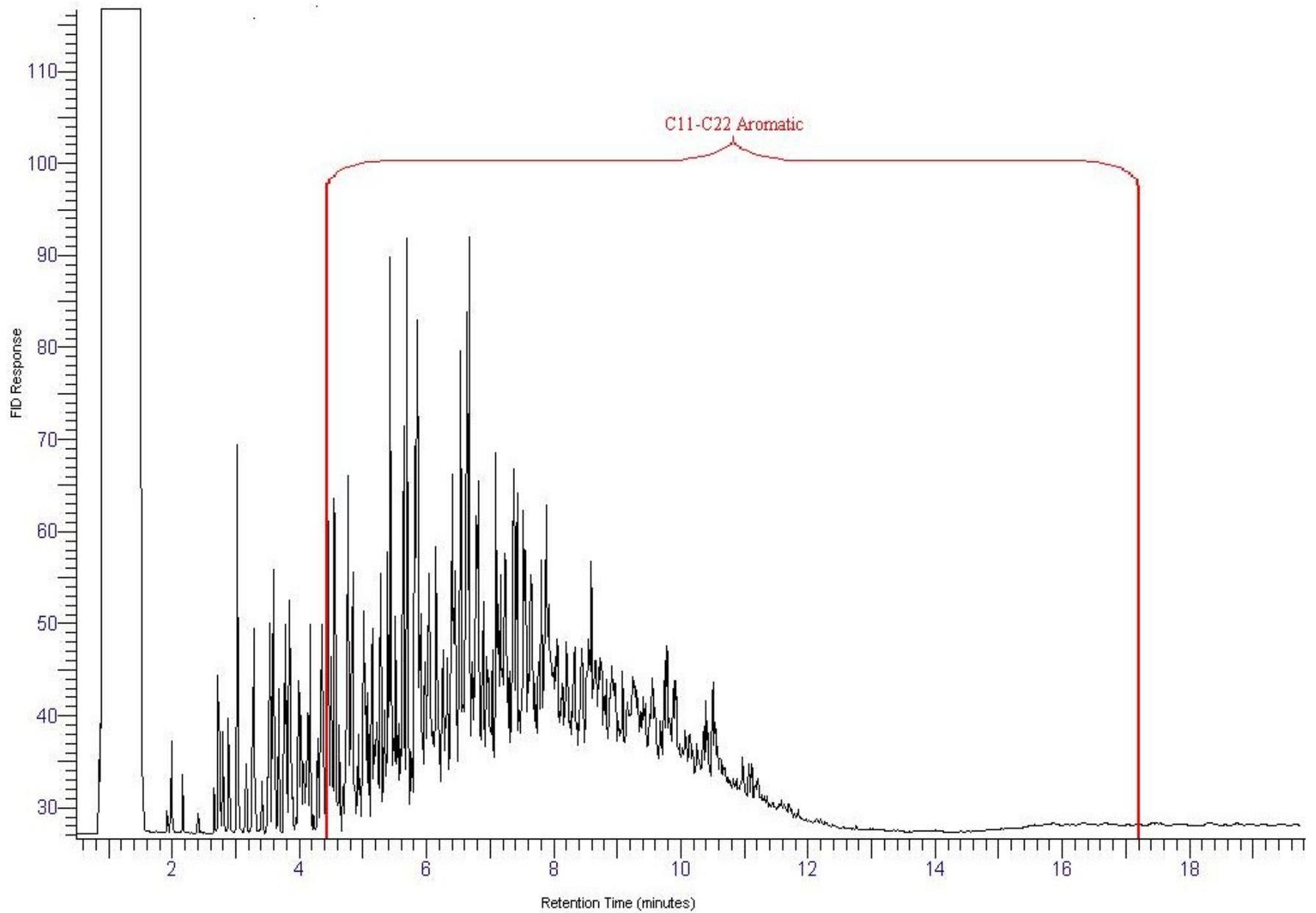


Figure 4 Gas Chromatogram (FID) of a Diesel Standard (Aromatic Fraction)

*All Operating Conditions Same as specified in Figure 3*

## **APPENDIX 3**

### **REQUIRED EPH and TPH DATA REPORT INFORMATION**

Exhibit 1. Required EPH and TPH Data Report Information (2 Pages)

Exhibit 2. MADEP MCP ANALYTICAL METHOD REPORT CERTIFICATION FORM

**APPENDIX 3: REQUIRED EPH DATA REPORT INFORMATION**

Exhibit 1 Page 1 of 2

**SAMPLE INFORMATION**

<b>Matrix</b>	<input type="checkbox"/> Aqueous	<input type="checkbox"/> Soil	<input type="checkbox"/> Sediment	<input type="checkbox"/> Other:
<b>Containers</b>	<input type="checkbox"/> Satisfactory <input type="checkbox"/> Broken <input type="checkbox"/> Leaking:			
<b>Aqueous Preservatives</b>	<input type="checkbox"/> N/A	<input type="checkbox"/> pH<2	<input type="checkbox"/> pH>2	Comment:
<b>Temperature</b>	<input type="checkbox"/> Received on Ice	<input type="checkbox"/> Received at 4 ± 2 °C	<input type="checkbox"/> Other:	°C
<b>Extraction Method</b>	Water:		Soil/Sediment	:

**EPH ANALYTICAL RESULTS**

Method for Ranges:		Client ID					
Method for Target Analytes:		Lab ID					
EPH Surrogate Standards:		Date Collected					
Aliphatic:		Date Received					
Aromatic:		Date Thawed					
		Date Extracted					
EPH Fractionation Surrogates:		Date Analyzed					
(1)		Time Analyzed					
(2)		Dilution Factor					
		% Moisture (soil/sediment)					
RANGE/TARGET ANALYTE		RL	Units				
Unadjusted C11-C22 Aromatics <sup>1</sup>							
Diesel PAH Analytes	Naphthalene						
	2-Methylnaphthalene						
	Phenanthrene						
	Acenaphthene						
Other Target PAH Analytes							
C9-C18 Aliphatic Hydrocarbons <sup>1</sup>							
C19-C36 Aliphatic Hydrocarbons <sup>1</sup>							
C11-C22 Aromatic Hydrocarbons <sup>1,2</sup>							
Aliphatic Surrogate % Recovery							
Aromatic Surrogate % Recovery							
Sample Surrogate Acceptance Range				40-140%	40-140%	40-140%	40-140%
Fractionation Surrogate (1) % Recovery							
Fractionation Surrogate (2) % Recovery							
Fractionation Surrogate Acceptance Range				40-140%	40-140%	40-140%	40-140%

<sup>1</sup>Hydrocarbon Range data exclude area counts of any surrogate(s) and/or internal standards eluting in that range

<sup>2</sup> C<sub>11</sub>-C<sub>22</sub> Aromatic Hydrocarbons exclude the concentration of Target PAH Analytes

**APPENDIX 3: REQUIRED TPH DATA REPORT INFORMATION**

Exhibit 1 Page 2 of 2

**SAMPLE INFORMATION**

Matrix	<input type="checkbox"/> Aqueous	<input type="checkbox"/> Soil	<input type="checkbox"/> Sediment	<input type="checkbox"/> Other:
Containers	<input type="checkbox"/> Satisfactory	<input type="checkbox"/> Broken	<input type="checkbox"/> Leaking:	
Aqueous Preservatives	<input type="checkbox"/> N/A	<input type="checkbox"/> pH $\leq$ 2	<input type="checkbox"/> pH $>$ 2	Comment:
Temperature	<input type="checkbox"/> Received on Ice	<input type="checkbox"/> Received at 4 $\pm$ 2 °C	<input type="checkbox"/> Other:	°C
Extraction Method	Water:		Soil/Sediment:	

**TPH ANALYTICAL RESULTS**

Method for Ranges: MADEP EPH 03-1		Client ID					
Method for Target Analytes:		Lab ID					
TPH Surrogate Standards:		Date Collected					
		Date Received					
		Date Thawed					
		Date Extracted					
		Date Analyzed					
		Time Analyzed					
		Dilution Factor					
		% Moisture (soil/sediment)					
Range/Target Analyte	RL	Units					
Unadjusted Total Petroleum Hydrocarbons <sup>1</sup>							
Diesel PAH Analytes	Naphthalene						
	2-Methylnaphthalene						
	Phenanthrene						
	Acenaphthene						
Other PAH Target Analytes							
Total Petroleum Hydrocarbons <sup>2</sup>							
Sample Surrogate % Recovery							
Sample Surrogate % Recovery							
Sample Surrogate Acceptance Range				40-140%	40-140%	40-140%	40-140%

<sup>1</sup>Hydrocarbon Range data exclude area counts of any surrogate(s) and/or internal standards eluting in that range

<sup>2</sup> Total Petroleum Hydrocarbons exclude the concentration of PAH Target Analytes only if determined by GC/MS

**APPENDIX 3: REQUIRED TPH DATA REPORT INFORMATION**  
**Exhibit 2 Page 1 of 1**

MADEP MCP ANALYTICAL METHOD REPORT CERTIFICATION FORM					
Laboratory Name:			Project #:		
Project Location:			MADEP RTN <sup>1</sup> :		
This Form provides certifications for the following data set: [list Laboratory Sample ID Number(s)]					
Sample Matrices: <input type="checkbox"/> Groundwater <input type="checkbox"/> Soil/Sediment <input type="checkbox"/> Drinking Water <input type="checkbox"/> Other: _____					
<b>MCP SW-846 Methods Used</b>	8260B ( )	8151A ( )	8330 ( )	6010B ( )	7470A/1A ( )
	8270C ( )	8081A ( )	VPH ( )	6020 ( )	9014M <sup>2</sup> ( )
As specified in MADEP Compendium of Analytical Methods. (check all that apply)	8082 ( )	8021B ( )	EPH ( )	7000 S <sup>3</sup> ( )	7196A ( )
	1 List Release Tracking Number (RTN), if known 2 M – SW-846 Method 9014 or MADEP Physiologically Available Cyanide (PAC) Method 3 S – SW-846 Methods 7000 Series List individual method and analyte.				
<b><i>An affirmative response to questions A, B, C and D is required for "Presumptive Certainty" status</i></b>					
<b>A</b>	Were all samples received by the laboratory in a condition consistent with that described on the Chain-of-Custody documentation for the data set?				<input type="checkbox"/> Yes <input type="checkbox"/> No <sup>1</sup>
<b>B</b>	Were all QA/QC procedures required for the specified analytical method(s) included in this report followed, including the requirement to note and discuss in a narrative QC data that did not meet appropriate performance standards or guidelines?				<input type="checkbox"/> Yes <input type="checkbox"/> No <sup>1</sup>
<b>C</b>	Does the data included in this report meet all the analytical requirements for "Presumptive Certainty", as described in Section 2.0 (a), (b), (c) and (d) of the MADEP document CAM VII A, "Quality Assurance and Quality Control Guidelines for the Acquisition and Reporting of Analytical Data"?				<input type="checkbox"/> Yes <input type="checkbox"/> No <sup>1</sup>
<b>D</b>	<b><u>VPH and EPH Methods only:</u></b> Was the VPH or EPH Method conducted without significant modifications (see Section 11.3 of respective Methods)				<input type="checkbox"/> Yes <input type="checkbox"/> No <sup>1</sup>
<b><i>A response to questions E and F below is required for "Presumptive Certainty" status</i></b>					
<b>E</b>	Were all analytical QC performance standards and recommendations for the specified methods achieved?				<input type="checkbox"/> Yes <input type="checkbox"/> No <sup>1</sup>
<b>F</b>	Were results for all analyte-list compounds/elements for the specified method(s) reported?				<input type="checkbox"/> Yes <input type="checkbox"/> No <sup>1</sup>
<sup>1</sup> All Negative responses must be addressed in an attached Environmental Laboratory case narrative.					
<b><i>I, the undersigned, attest under the pains and penalties of perjury that, based upon my personal inquiry of those responsible for obtaining the information, the material contained in this analytical report is, to the best of my knowledge and belief, accurate and complete.</i></b>					
Signature: _____			Position: _____		
Printed Name: _____			Date: _____		

## **APPENDIX 4**

### **EPH Calibration and Analysis Using Linear Regression**

**APPENDIX 4**  
**EPH Calibration and Analysis Using Linear Regression**  
**Page 1 of 3**

Use of linear regression is permissible to calculate the slope and y-intercept that best describes the linear relationship between EPH target analyte and range concentrations and instrument responses.

- 1.0 Prepare EPH Calibration Standards as described in Tables 1 and 2 of Section 3 at a minimum of five concentration levels in accordance with the procedures and specifications contained in Section 9.7.2. The EPH Marker Compounds for the C<sub>9</sub>-C<sub>18</sub> aliphatic, C<sub>19</sub>-C<sub>36</sub> aliphatic and C<sub>11</sub>-C<sub>22</sub> aromatic ranges are presented in Table 5 in Section 9.6.

Analyze each EPH Calibration Standard following the procedures outlined in Section 9.8. Tabulate area responses against the injected concentration. These data are used to calculate a calibration curve for each analyte (Equation 4-1). The correlation coefficient (r) of the resultant calibration curve must be greater than or equal to 0.99.

**Equation 4-1: Linear Regression: Target EPH Target Analytes**

$$\boxed{\text{Area of peak} = a \times \text{concentration injected} (\mu\text{g} / \text{L}) + b}$$

where:

a = the calculated slope of the line

b = the calculated y intercept of the "best fit" line

A collective calibration curve must also be established for each aliphatic and aromatic hydrocarbon range of interest. Calculate the collective calibration curve for C<sub>9</sub>-C<sub>18</sub> and C<sub>19</sub>-C<sub>36</sub> Aliphatic Hydrocarbons for the C<sub>11</sub>-C<sub>22</sub> Aromatic Hydrocarbons using the FID chromatogram of the appropriate fraction. Tabulate the summation of the peak areas of all components in that fraction (i.e. C<sub>9</sub>-C<sub>18</sub> Aliphatic Hydrocarbons, 6 components) against the total concentration injected. These data are used to calculate a calibration curve for each EPH hydrocarbon range (Equation 4-2). The correlation coefficient (r) of the resultant calibration curve must be greater than or equal to 0.99.

**Note: Do not include the area of any surrogate standard or internal standard in calculating a Range calibration curve or Range CF. Do not include the area of naphthalene or 2-methylnaphthalene in the LR analysis of the C<sub>9</sub> – C<sub>18</sub> Aliphatic Hydrocarbon range.**

**Equation 4-2: Linear Regression: EPH Aliphatic and Aromatic Hydrocarbon Ranges**

$$\boxed{\text{Area summation of range components} = a \times \text{total concentration injected} (\mu\text{g} / \text{L}) + b}$$

where:

a = the calculated slope of the line

b = the calculated y intercept of the "best fit" line

**APPENDIX 4**  
**EPH Calibration and Analysis Using Linear Regression**  
**Page 2 of 3**

- 2.0 The concentration of a specific target analyte or hydrocarbon range in aqueous samples may be calculated using linear regression analysis by applying Equation 4-3.

**Equation 4-3: Determination of Target EPH Analytes and Hydrocarbon Range Concentrations in Aqueous Samples using Linear Regression**

$$\text{Conc Analyte or HC Range ( } \mu\text{g/L)} = \left( \frac{A_x - b}{a} \right) \times D$$

where:

- $A_x$  = Response for the analyte or hydrocarbon range in the sample. Units are in area counts for Target EPH Analytes and the hydrocarbon ranges.
- $D$  = Dilution factor; if no dilution was made,  $D = 1$ , dimensionless.
- $a$  = Slope of the line for Target EPH Analyte or hydrocarbon range,
- $b$  = Intercept of the line for Target EPH Analyte or hydrocarbon range,

**Note: Do not include the area of any surrogate standard in  $A_x$  when calculating a Range concentration.**

- 3.0 The concentration of a specific target EPH analyte or hydrocarbon range in a soil or sediment sample may be calculated using linear regression analysis by applying Equation 4-4.

**Equation 4-4: Non-Aqueous Samples; Determination Target EPH Analytes and Hydrocarbon Range Concentrations in Soil and Sediment Samples by Linear Regression**

$$\text{Conc Analyte or HC Range ( } \mu\text{g/kg)} = \left( \frac{A_x - b}{a} \right) \times \frac{(V_t)(D)(V_w)}{(V_i)(W_d)}$$

where:  $A_x$ ,  $a$ ,  $b$ , and  $D$  have the same definition as for aqueous samples in Equation 4-3, and

$W_d$  = Dry weight of sample, g (see Section 9.9.4)

**Note: Do not include the area of any surrogate standard or internal standard in  $A_x$  when calculating a Range concentration.**

- 4.0 At a minimum, the working calibration factor must be verified on each working day, after every 20 samples, and at the end of the analytical sequence by the injection of a mid-level continuing calibration standard to verify instrument performance and linearity. If the percent drift for any analyte varies from the predicted response by more than  $\pm 25\%$ , as determined using Equation 4-5, a new five-point calibration must be performed for that analyte. A greater percent drift is permissible for n-nonane. If the percent drift for n-nonane is greater than 30, note the nonconformance in the case narrative. It should be noted that the %Ds (Equation 4, Section

9.7.2.5) are calculated when CFs are generated in the initial calibration and percent drifts are calculated when calibration curves are generated in the initial calibration.

**APPENDIX 4**  
**EPH Calibration and Analysis Using Linear Regression**  
**Page 3 of 3**

For the closing continuing calibration standard (analyzed after every 20 samples, every 24 hours, or at end of analytical sequence), four compounds may exhibit percent differences or percent drifts greater than 25% but less than 40%.

**Equation 4-5: Percent Drift**

$$\% \text{ Drift} = \frac{\text{Calculated concentration} - \text{Theoretical concentration}}{\text{Theoretical concentration}} \times 100$$

## **APPENDIX 5**

### **INITIAL DEMONSTRATION OF LABORATORY CAPABILITY (IDLC)**

**for**

### **MADEP EPH Method**

- 1.0 Overview of the Initial Demonstration of Laboratory Capability (IDLC) Approach
- 2.0 Demonstration of Acceptable System Background
- 3.0 Initial Demonstration of Accuracy (IDA)
- 4.0 Initial Demonstration of Precision (IDP)
- 5.0 Initial Demonstration of Fractionation Efficiency
- 6.0 Method Detection Limit (MDL)

**Table 5-1 LOQ Sample Calculation for Seven (7) System Solvent Blanks (SSBs)  
– EPH Ranges**

**Table 5-2 Initial Demonstration Of Laboratory Capability QC Requirements  
for EPH Analyses**

**INITIAL DEMONSTRATION OF LABORATORY CAPABILITY (IDLC) for MADEP EPH Method**  
**Page 2 of 7**

For purposes of the IDLC accuracy and precision determinations (*and only this application*) the calibration mixture presented in Tables 1 and 2 in Section 3.0 is considered to be representative of Extractable Petroleum Hydrocarbon (EPH) target analytes and ranges (cumulative sum of the concentrations of the individual aliphatic and aromatic range calibration standards). Other reference materials or combinations of reference materials (available from Environmental Resource Associates, Arvada, CO and other commercial vendors) with an individual assay for individual EPH target analytes and the C<sub>9</sub> through C<sub>18</sub> aliphatic, C<sub>18</sub> through C<sub>36</sub> aliphatic and C<sub>11</sub> through C<sub>22</sub> aromatic ranges are also suitable for this determination.

1.0 Overview of the Initial Demonstration of Laboratory Capability (IDLC) Approach

An IDLC must be conducted to characterize instrument and laboratory performance prior to performing analyses using the EPH Method. A laboratory may not report data to be used in support of MCP decisions unless the IDLC quality control requirements and performance standards described below and compiled in Table 5-2 are satisfied.

2.0 Demonstration of Acceptable System Background

Demonstration of Acceptable System Background is optional. To determine system background, a Laboratory Method Blank (LMB) must be prepared and treated exactly as a typical field sample submitted for analysis, including fractionation and exposure to all glassware, equipment, solvents and reagents. A LMB for water analyses is prepared by adding 1.0 mL of surrogate spiking solution to 1000 mL of organic-free water (ASTM Type I reagent grade). A LMB for solid analyses is prepared by adding 1.0 mL surrogate spiking solution to 10 g of certified organic contaminant-free soil [available from Environmental Resource Associates (ERA, Arvada, CO; Tel. 800-372-0122; [www.eraqc.com](http://www.eraqc.com))].

At least seven (7) replicate matrix-specific LMBs should be extracted, fractionated and analyzed, and the mean concentration of target EPH analytes and ranges determined, as appropriate. Data produced (mean EPH target analyte and range concentrations detected related to background noise) are used to assess instrument performance of a blank sample and evaluate potential contamination from the laboratory environment, in the absence of any other analytes or system contaminants. Calculate the measured concentration of C<sub>mean</sub> of the replicate values as follows.

**Equation 5-1. Calculation of C<sub>mean</sub> LMB**

$$C_{\text{mean}} = \frac{(C_1 + C_2 + C_3 + \dots C_n)}{n}$$

where,

C<sub>mean</sub> = Mean recovered concentration of the replicate LMB analysis.  
 C<sub>1</sub>, C<sub>2</sub>, ...C<sub>n</sub> = Recovered concentrations of the replicate 1,2...n.  
 n = at least 7

Any concentration of C<sub>mean</sub> that exceeds one half of the Reporting Limit (lowest target analyte calibration or collective range calibration standard) for either a target EPH analyte or range is considered unacceptable, and indicates that a laboratory and/or LMB contamination is present. The source of the non-conformance must be identified and corrected prior to conducting any sample analysis. For purposes of acceptable system background demonstration, concentrations are determined using Equations 5 through 8 in Section 9.9 for target EPH analytes and collective ranges.

Calculated concentrations below the lowest calibration standard, including zero (zero area), may be used in these calculations.

## Appendix 5

### INITIAL DEMONSTRATION OF LABORATORY CAPABILITY (IDLC) for MADEP EPH Method Page 3 of 7

#### 3.0 Initial Demonstration of Accuracy (IDA)

Prepare and analyze seven (7) replicate Laboratory Control Samples (LCSs) fortified at a concentration of 50% of the highest calibration curve standard (200 mg/L for waters and 20 mg/kg) for solids). An LCS must be prepared and treated exactly as a typical field sample submitted for analysis, including fractionation and exposure to all glassware, equipment, solvents and reagents. An LCS for water analyses is prepared by fortifying 1000 mL of organic-free water (ASTM Type I reagent grade) with 1.0 mL of a 100 mg/L matrix spiking solution (see Section 7.7) and 1.0 mL of a 40 mg/L surrogate spiking solution (see Section 7.4). An LCS for soil/sediment analyses is prepared by adding 1.0 mL matrix spiking solution and 1.0 mL of a surrogate spiking solution to 10 g (dry weight) of certified organic contaminant-free soil (available from Environmental Resource Associates [(ERA, Arvada, CO; Tel. 800-372-0122; [www.eraqc.com](http://www.eraqc.com))]. Alternatively, an appropriately “diluted” reference standard (specified above) may be used to obtain a soil/sediment LCS with a similar on-column concentration as with the matrix spiking solution. Calculate the mean measured concentration ( $C_{\text{mean}}$ ) of the replicate aliphatic and aromatic ranges and target PAH analytes as follows.

#### Equation 5-2. Calculation of $C_{\text{mean}}$

$$C_{\text{mean}} = \frac{(C_1 + C_2 + C_3 + \dots C_n)}{n}$$

where,

$C_{\text{mean}}$  = Mean recovered concentration of the replicate analysis.

$C_1, C_2, \dots C_n$  = Recovered concentrations of the replicate 1,2...n.

$n = 7$

The value derived for  $C_{\text{mean}}$  must be within  $\pm 40\%$  of the true value or between 60 ug/L and 140 ug/L for waters and 3.5 mg/kg and 6.5 mg/kg for solids.

#### 4.0 Initial Demonstration of Precision (IDP)

Using the results calculated from Sections 3.0 above, calculate the percent relative standard deviation (%RSD) of the seven (7) replicate analysis, as indicated below. The %RSD must be less than or equal to 25% for both waters and solids. Higher % RSDs are allowed for n-Nonane. Such allowable non-conformances must be documented.

#### Equation 5-3. Calculation of % RSD

$$\% \text{ RSD} = \frac{S_{n-1}}{C_{\text{mean}}} \times 100$$

where,

$S_{n-1}$  = sample standard deviation (n-1) of the replicate analyses.

$C_{\text{mean}}$  = mean recovered concentration of the replicate analysis.

**INITIAL DEMONSTRATION OF LABORATORY CAPABILITY (IDLC) for MADEP EPH Method**  
**Page 4 of 7**

### 5.0 Initial Demonstration of Fractionation Efficiency

A mixed aliphatic and aromatic hydrocarbon Fractionation Check Solution (FCS) is used to evaluate the separation efficiency of the silica gel cartridge/column and to establish the optimum hexane volume to efficiently elute aliphatic hydrocarbons while not allowing significant aromatic hydrocarbon breakthrough.

The Fractionation Check Solution (FCS) is prepared in hexane with a nominal concentration of 200 ng/μL of each Aliphatic Hydrocarbon standard (C<sub>9</sub>-C<sub>36</sub> alkanes) and 200 ng/μL of each Aromatic Hydrocarbon standard (Target PAH Analytes) as described in Tables 1 and 2 in Section 3.0. The final Fractionation Check Solution will contain 14 alkanes and 17 PAHs each at a nominal concentration of 200 ng/μL. Alternative concentrations are permissible.

- 5.1 To demonstrate the capability of properly fractionating aliphatic and aromatic hydrocarbons at least four (4) replicate FCSs (see Section 7.8) should be fractionated (using the fractionation procedures detailed in Section 9.2) and analyzed, and the mean measured concentration (C<sub>x mean</sub>) of the individual fractionation check compounds determined (see below).
- 5.2 For each analyte included in the FCS, excluding n-nonane, the % mean recovery for four (4) replicate samples, expressed as a percentage of the true value, must be between 40% and 140%. Lower recoveries are permissible for n-nonane. If recovery of n-nonane is <30%, the source of the problem should be found and the fractionation check repeated.

#### Equation 5-4. Calculation of % Mean Accuracy

$$\% \text{ Mean Recovery} = \frac{C_{x \text{ mean}}^* - \text{True Concentration}}{\text{True Concentration}} \times 100$$

$$* C_{x \text{ mean}} = \frac{C_1 + C_2 + C_3 \dots \dots C_n}{n}$$

- 5.3 Subsequent to the initial demonstration of laboratory capability, it is recommended that a Fractionation Check Solution be analyzed for each new lot of silica gel/cartridges, to re-establish the optimum volume of hexane elution. **NOTE: Within the same lot of cartridges, different mesh sizes and cartridge weights could exist. It is advisable to evaluate fractionation efficiency on a more frequent basis for large lots (> 500 units) to ensure consistent performance.**

### 6.0 Method Detection Limit (MDL)

The determination of MDL for the MADEP EPH Method is **optional**. The reporting limit (RL) for the Method is defined as the lowest calibration standard. Determination of the lowest detectable concentration of target EPH analytes and ranges is verified on a continuing basis by analysis of the lowest concentration calibration standard and recovery of method surrogates. The recommended RL concentrations for the EPH Method do not approach the sensitivity limits of the EPH Method for either target analytes or ranges and are more than adequate to meet the most stringent regulatory requirements of the MCP.

## Appendix 5

### INITIAL DEMONSTRATION OF LABORATORY CAPABILITY (IDLC) for MADEP EPH Method Page 5 of 7

An MDL may be established for target EPH analytes and ranges either analytically using the 40 CFR 136 approach or by the statistical evaluation of analytical system noise as a good laboratory practice component of an overall quality control program for the EPH Method.

#### 6.1 Determination of Method Detection Limit (MDL), 40 CFR 136, Appendix B Approach

To determine MDL values, take seven replicate aliquots of reagent water fortified at the "calculated" MDL concentration determined in Equation 5-7 below or the concentration of the lowest calibration standard, and process through the entire analytical method over a three day period. These seven MDL replicate analyses may be performed gradually over three days or may represent data that has been collected, at a consistent MDL "calculated" concentration, over a series of more than three days.

Perform all calculations defined in the method and report the concentration values in the appropriate units. Calculate the MDL as follows:

#### Equation 5-5. Calculation of MDL based on Laboratory Analysis

$$\text{MDL} = (t_{n-1}) \times (S_{n-1})$$

where,

$t_{n-1}$  = Student's t value for a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom [ $t_{n-1} = 3.14$  for seven replicates]

$S_{n-1}$  = Sample standard deviation (n-1) of 7 replicate analyses

#### 6.2 Determination of Method Detection Limit (MDL) and Limit of Quantitation (LOQ) by Statistical Evaluation of System Noise

A System Solvent Blank (SSB) is defined as an aliquot of method solvent that is directly injected into the GC system. The SSB for aliphatic hydrocarbon analyses is pesticide grade, or better, hexane. The SSB for aromatic hydrocarbon analyses is pesticide grade, or better, methylene chloride.

Seven (7) replicate aliquots of a System Solvent Blank (SSB) must analyzed exactly as a typical extract submitted for analysis by injecting 1-4  $\mu\text{L}$  of the appropriate solvent directly into the GC system either manually or using an autosampler.

Data produced are used to assess the level of noise and the baseline rise attributable solely to the GC system, in the absence of any other analytes or system contaminants. These data are used to calculate the Limit of Quantitation (LOQ) and Method Detection Limit (MDL) using the Keith statistical approach. **For these analyses, the data system's threshold for peak area integration must be adjusted to ensure that a positive value is recorded for the target analytes and ranges of interest, as practical. Tabulate the area response for each Target EPH analyte and Range. Calculate the LOQ and MDL using Equations 5-6 and 5-7, respectively. An example LOQ and MDL calculation for the EPH aliphatic and aromatic ranges for an aqueous sample is presented below in Table 5-1.**

## Appendix 5

### INITIAL DEMONSTRATION OF LABORATORY CAPABILITY (IDLC) for MADEP EPH Method Page 6 of 7

#### Equation 5-6. Calculation of Limit of Quantitation (LOQ)

$$LOQ_x = 10 * S_{x,n-1} CF_x$$

$S_{x,n-1}$  = Sample standard deviations for peak areas of EPH target analytes and ranges of interest for the seven (7) replicate System Solvent Blanks (SSBs) reported in appropriate units.

$CF_x$  = Representative Calibration Factor for appropriate EPH Target analyte or Range

#### Equation 5-7. Calculation of MDL

$$MDL = LOQ/3$$

**Table 5-1 LOQ Sample Calculation for Seven (7) System Solvent Blanks (SSBs) – EPH Ranges**

Replicate Number	EPH Range (Area Units)		
	C <sub>9</sub> – C <sub>18</sub> aliphatic	C <sub>19</sub> – C <sub>36</sub> aliphatic	C <sub>11</sub> - C <sub>22</sub> aromatic
1	175894	1003	0
2	1301396	1165	0
3	411286	312324	1210321
4	420174	1922	0
5	634725	326979	1935346
6	931209	152394	634862
7	760453	363432	1453265
Range Average	662162	165603	747685
<b>Calculations:</b>			
Range $S_{x, n-1}$ (Standard Deviation)	376248	167235	797103
Range CF (ng/μL * AU <sup>-1</sup> )	0.0000263	0.0000114	0.0000352
<i>Injected</i> <sup>1</sup> LOQ (ng/μL)	174	19	263
<i>Injected</i> <sup>1</sup> MDL (ng/μL)	40	9	82
<i>Aqueous Sample</i> <sup>2</sup> LOQ (mg/L)	133	30	272
<i>Aqueous Sample</i> <sup>2</sup> MDL (mg/L)	55	6	79
<i>Solid Sample</i> <sup>3</sup> LOQ (mg/kg)	27	6	54
<i>Solid Sample</i> <sup>3</sup> MDL (mg/kg)	9	2	27

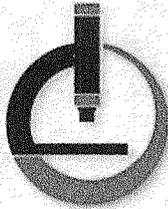
1. Assumes a 1.0 μL injection.
2. Assumes the extraction of 1,000 mL (1.0 L) of sample concentrated to 1.0 mL. Extract is then fractionated and the resultant elutriates re-concentrated to obtain 1.0 mL aliphatic and aromatic fractions ready for analyses. For purposes of these calculations the volume of any surrogates are assumed to be minimal.
3. Assumes the extraction of 10 grams of soil/sediment (dry weight basis). Sample extract is concentrated to 1.0 mL. Extract is then fractionated and the resultant elutriates re-concentrated to obtain 1.0 mL aliphatic and aromatic fractions ready for analyses. For purposes of these calculations the volume of the fractionation surrogate added to final extract is assumed to be 1.0 mL.

Table 5-2 Initial Demonstration Of Laboratory Capability QC Requirements for EPH Analyses

Reference Section	Requirement	Specification & Frequency	Acceptance Criteria
2.0	Initial Demonstration of Acceptable System Background (Optional)	Analyze at least four (4) replicate Laboratory Method Blanks (LMB) fortified with surrogate spiking solution. Calculate the mean recovered concentration for each Target EPH analyte and hydrocarbon range. See Equation 5-1, Section 2.0.	The LMB concentrations must be $< \frac{1}{2}$ of the RL (lowest point on calibration curve or lowest cumulative range calibration standard).
3.0	Initial Demonstration of Accuracy (IDA)	Analyze seven (7) replicate LMBs fortified with EPH calibration standards at a nominal concentration of 200 ug/L or 20 mg/kg for each standard analyte. Calculate the mean recovered concentration $C_{mean}$ for each target EPH analyte and hydrocarbon range. See Equation 5-2 in Section 3.0.	The $C_{mean}$ must be $\pm 40\%$ of the true value of the aliphatic and aromatic ranges and target PAH analytes for both waters and soils.
4.0	Initial Demonstration of Precision (IDP)	Calculate percent relative standard deviation (%RSD) of IDA replicates for each target EPH analyte and hydrocarbon range.. See Equation 5-3 in Section 4.0.	The %RSD must be $\pm 25\%$ for both waters and solids
5.0	Initial Demonstration of Fractionation Efficiency	Fractionate and analyze four (4) replicate FCSs at a concentration of 200 $\mu\text{g/L}$ . A mixed aliphatic and aromatic hydrocarbon Fractionation Check Solution (FCS) is used to evaluate the separation efficiency of the silica gel cartridge/column	The mean %Recovery for four (4) replicate samples, expressed as a percentage of the true value, must be between 40% and 140%. Lower recoveries (30%) are permissible for n-nonane.
6.0	Method Detection Limit (MDL) Determination (Optional)	Select a fortifying level at the "calculated" MDL or RL for the LCS. See Equation 5-7 in Section 6.2 Analyze these seven (7) replicate low-level LCSs over multiple days and calculate MDL using Equation 5-5 in Section 6.1. Do not subtract any blank contribution to this value.  MDL may also be determined by a statistical evaluation of system noise based on the analysis of seven (7) system solvent blanks (SSB). See Section 6.2	See 40 CFR 136, Appendix B  The MDL must be $< \frac{1}{2}$ RL for individual target EPH analytes and $< \frac{1}{2}$ RL for collective EPH hydrocarbon ranges. See Section 12.0
<b>Continuing QC for each Analytical Batch (up to 20 samples of a similar matrix analyzed contemporaneously)</b>			
Initial mid-range continuing calibration standard (I-CCS)			
Ending mid-range continuing calibration standard (E-CCS)			
Laboratory Method Blank (LMB)			
Full Analyte Laboratory Control Sample (LCS)			

**APPENDIX D**

**LABORATORY CERTIFICATION**



**LABORATORY  
ACCREDITATION  
BUREAU**



# Certificate of Accreditation

**ISO/IEC 17025:2005**

**Certificate Number L2223**

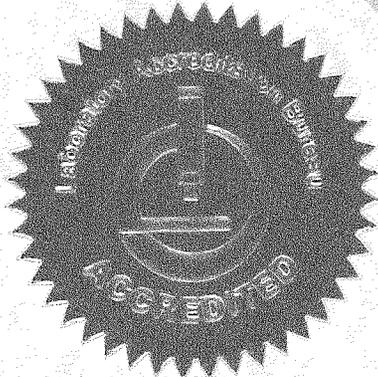
## **Katahdin Analytical Services, Inc.**

600 Technology Way  
Scarborough ME 04074

has met the requirements set forth in L-A-B's policies and procedures, all requirements of ISO/IEC 17025:2005 "General Requirements for the competence of Testing and Calibration Laboratories" and the U.S. Department of Defense Environmental Laboratory Accreditation Program (DoD ELAP).\*

The accredited lab has demonstrated technical competence to a defined "Scope of Accreditation" and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009).

Accreditation valid through: February 1, 2016



**R. Douglas Leonard, Jr., President, COO**  
**Laboratory Accreditation Bureau**  
**Presented the 1<sup>st</sup> of February 2013**

\*See the laboratory's Scope of Accreditation for details of accredited parameters

\*\*Laboratory Accreditation Bureau is found to be in compliance with ISO/IEC 17011:2004 and recognized by ILAC (International Laboratory Accreditation Cooperation) and NACLA (National Cooperation for Laboratory Accreditation).



**Scope of Accreditation  
For  
Katahdin Analytical Services, Inc.**

600 Technology Way  
Scarborough, ME 04074  
Leslie Dimond  
207-874-2400

In recognition of a successful assessment to ISO/IEC 17025:2005 and the requirements of the DoD Environmental Laboratory Accreditation Program (DoD ELAP) as detailed in the DoD Quality Systems Manual for Environmental Laboratories (DoD QSM v4.2) based on the National Environmental Laboratory Accreditation Conference Chapter 5 Quality Systems Standard (NELAC Voted Revision June 5, 2003), accreditation is granted to Katahdin Analytical Services to perform the following tests:

Accreditation granted through: February 1, 2016

**Testing - Environmental**

<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/ECD	EPA 8081B	2, 4'-DDD
GC/ECD	EPA 8081B	2, 4'-DDE
GC/ECD	EPA 8081B	2, 4'-DDT
GC/ECD	EPA 608; EPA 8081B	4, 4'-DDD
GC/ECD	EPA 608; EPA 8081B	4, 4'-DDE
GC/ECD	EPA 608; EPA 8081B	4, 4'-DDT
GC/ECD	EPA 608; EPA 8081B	Aldrin
GC/ECD	EPA 608; EPA 8081B	alpha-BHC (alpha-Hexachlorocyclohexane)
GC/ECD	EPA 8081B	Alpha-Chlordane
GC/ECD	EPA 608; EPA 8081B	beta-BHC (beta-Hexachlorocyclohexane)
GC/ECD	EPA 8081B	Cis-Nonaclor
GC/ECD	EPA 608; EPA 8081B	Chlordane (tech.)
GC/ECD	EPA 608; EPA 8081B	delta-BHC
GC/ECD	EPA 608; EPA 8081B	Dieldrin
GC/ECD	EPA 608; EPA 8081B	Endosulfan I
GC/ECD	EPA 608; EPA 8081B	Endosulfan II



Non-Potable Water		
Technology	Method	Analyte
GC/ECD	EPA 608; EPA 8081B	Endosulfan sulfate
GC/ECD	EPA 608; EPA 8081B	Endrin
GC/ECD	EPA 608; EPA 8081B	Endrin aldehyde
GC/ECD	EPA 8081B	Endrin Ketone
GC/ECD	EPA 8081B	gamma-BHC (Lindane gamma-Hexachlorocyclohexane)
GC/ECD	EPA 8081B	gamma-Chlordane
GC/ECD	EPA 608; EPA 8081B	Heptachlor
GC/ECD	EPA 608; EPA 8081B	Heptachlor epoxide
GC/ECD	EPA 8081B	Hexachlorobenzene
GC/ECD	EPA 8081B	Methoxychlor
GC/ECD	EPA 8081B	Mirex
GC/ECD	EPA 8081B	Oxychlordane
GC/ECD	EPA 608; EPA 8081B	Toxaphene (Chlorinated camphene)
GC/ECD	EPA 8081B	trans-Nonachlor
GC/ECD	EPA 608; EPA 8082A	Aroclor-1016 (PCB-1016)
GC/ECD	EPA 608; EPA 8082A	Aroclor-1221 (PCB-1221)
GC/ECD	EPA 608; EPA 8082A	Aroclor-1232 (PCB-1232)
GC/ECD	EPA 608; EPA 8082A	Aroclor-1242 (PCB-1242)
GC/ECD	EPA 608; EPA 8082A	Aroclor-1248 (PCB-1248)
GC/ECD	EPA 608; EPA 8082A	Aroclor-1254 (PCB-1254)
GC/ECD	EPA 608; EPA 8082A	Aroclor-1260 (PCB-1260)
GC/ECD	EPA 8082A MOD	Aroclor-1262 (PCB-1262)
GC/ECD	EPA 8082A MOD	Aroclor-1268 (PCB-1268)
GC/ECD	EPA 8082A	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (BZ 206)
GC/ECD	EPA 8082A	2,2',3,3',4,4',5,6-Octachlorobiphenyl (BZ 195)
GC/ECD	EPA 8082A	2,2',3,3',4,4',5-Heptachlorobiphenyl (BZ 170)
GC/ECD	EPA 8082A	2,2',3,3',4,4'-Hexachlorobiphenyl (BZ 128)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 5, 5'-Heptachlorobiphenyl (BZ 180)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 5', 6-Heptachlorobiphenyl (BZ 183)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 5-Hexachlorobiphenyl (BZ 138)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 6, 6'-Heptachlorobiphenyl (BZ 184)



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/ECD	EPA 8082A	2, 2', 3, 4', 5, 5', 6-Heptachlorobiphenyl (BZ 187)
GC/ECD	EPA 8082A	2, 2', 3, 4, 5'-Pentachlorobiphenyl (BZ 87)
GC/ECD	EPA 8082A	2, 2', 3, 5'-Tetrachlorobiphenyl (BZ 44)
GC/ECD	EPA 8082A	2, 2', 4, 4', 5, 5'-Hexachlorobiphenyl (BZ 153)
GC/ECD	EPA 8082A	2, 2', 4, 5, 5'-Pentachlorobiphenyl (BZ 101)
GC/ECD	EPA 8082A	2, 2', 4, 5-Tetrachlorobiphenyl (BZ 48)
GC/ECD	EPA 8082A	2, 2', 4, 5'-Tetrachlorobiphenyl (BZ 49)
GC/ECD	EPA 8082A	2, 2', 5, 5'-Tetrachlorobiphenyl (BZ 52)
GC/ECD	EPA 8082A	2, 2', 5-Trichlorobiphenyl (BZ 18)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4', 5-Hexachlorobiphenyl (BZ 156)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4', 5'-Hexachlorobiphenyl (BZ 157)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4'-Pentachlorobiphenyl (BZ 105)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4', 5, 5'-Heptachlorobiphenyl (BZ 189)
GC/ECD	EPA 8082A	2, 3', 4, 4', 5, 5'-Hexachlorobiphenyl (BZ 167)
GC/ECD	EPA 8082A	2, 3', 4, 4', 5-Pentachlorobiphenyl (BZ 118)
GC/ECD	EPA 8082A	2, 3', 4, 4', 5'-Pentachlorobiphenyl (BZ 123)
GC/ECD	EPA 8082A	2, 3', 4, 4'-Tetrachlorobiphenyl (BZ 66)
GC/ECD	EPA 8082A	2, 3, 4, 4', 5-Pentachlorobiphenyl (BZ 114)
GC/ECD	EPA 8082A	2, 4, 4'-Trichlorobiphenyl (BZ 28)
GC/ECD	EPA 8082A	2, 4'-Dichlorobiphenyl (BZ 8)
GC/ECD	EPA 8082A	3, 3', 4, 4', 5, 5'-Hexachlorobiphenyl (BZ 169)
GC/ECD	EPA 8082A	3, 3', 4, 4', 5-Pentachlorobiphenyl (BZ 126)
GC/ECD	EPA 8082A	3, 3', 4, 4'-Tetrachlorobiphenyl (BZ 77)
GC/ECD	EPA 8082A	3, 4, 4', 5-Tetrachlorobiphenyl (BZ 81)
GC/ECD	EPA 8082A	Decachlorobiphenyl (BZ 209)
GC/ECD	EPA 8151A	2, 4, 5-T
GC/ECD	EPA 8151A	2, 4-D
GC/ECD	EPA 8151A	2, 4-DB
GC/ECD	EPA 8151A	Dalapon
GC/ECD	EPA 8151A	Dicamba
GC/ECD	EPA 8151A	Dichloroprop



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/ECD	EPA 8151A	Dinoseb
GC/ECD	EPA 8151A	MCPA
GC/ECD	EPA 8151A	MCPP
GC/ECD	EPA 8151A	Pentachlorophenol
GC/ECD	EPA 8151A	Silvex (2, 4, 5-TP)
GC/FID	EPA 8015C/D MOD	Diesel range organics (DRO)
GC/FID	EPA 8015C/D MOD	Total Petroleum Hydrocarbon (TPH)
GC/FID	EPA 8015C/D MOD	Gasoline range organics (GRO)
GC/FID/PID	MA DEP VPH	Volatile Organic Hydrocarbons
GC/FID	MA DEP EPH	Extractable Petroleum Hydrocarbons
GC/FID	CT ETPH	Total Petroleum Hydrocarbons
GC/FID	TNRCC Method 1005	Total Petroleum Hydrocarbons
GC/FID	FL-PRO	Petroleum Range Organics
GC/ECD	EPA 8011; EPA 504	1, 2-Dibromoethane (EDB)
GC/ECD	EPA 8011; EPA 504	1, 2-Dibromo-3-chloropropane
GC/FID	RSK-175	Methane Ethane Ethene
GC/MS	EPA 8260B/C; EPA 524.2	1, 1, 1, 2-Tetrachloroethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 1, 1-Trichloroethane
GC/MS	EPA 624; 8260B/C; EPA 524.2	1, 1, 2, 2-Tetrachloroethane
GC/MS	EPA 8260B/C	1,1,2-Trichloro-1,2,2-trifluoroethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 1, 2-Trichloroethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 1-Dichloroethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 1-Dichloroethene
GC/MS	EPA 8260B/C; EPA 524.2	1, 1-Dichloropropene
GC/MS	EPA 8260B/C; EPA 524.2	1, 2, 3-Trichlorobenzene
GC/MS	EPA 8260B/C; EPA 524.2	1, 2, 3-Trichloropropane
GC/MS	EPA 8260B/C	1,2,3-Trimethylbenzene
GC/MS	EPA 8260B/C; EPA 524.2	1, 2, 4-Trichlorobenzene
GC/MS	EPA 8260B/C; EPA 524.2	1, 2, 4-Trimethylbenzene



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8260B/C; EPA 524.2	1, 2-Dibromo-3-chloropropane
GC/MS	EPA 8260B/C; EPA 524.2	1, 2-Dibromoethane (EDB)
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 2-Dichlorobenzene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 2-Dichloroethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 2-Dichloropropane
GC/MS	EPA 8260B/C	1,3,5-Trichlorobenzene
GC/MS	EPA 8260B/C; EPA 524.2	1, 3, 5-Trimethylbenzene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 3-Dichlorobenzene
GC/MS	EPA 8260B/C; EPA 524.2	1, 3-Dichloropropane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	1, 4-Dichlorobenzene
GC/MS	EPA 8260B/C	1, 4-Dioxane
GC/MS	EPA 8260B/C	1-Chlorohexane
GC/MS	EPA 8260B/C; EPA 524.2	2, 2-Dichloropropane
GC/MS	EPA 8260B/C; EPA 524.2	2-Butanone
GC/MS	EPA 624; EPA 8260B/C	2-Chloroethyl vinyl ether
GC/MS	EPA 8260B/C; EPA 524.2	2-Chlorotoluene
GC/MS	EPA 8260B/C; EPA 524.2	2-Hexanone
GC/MS	EPA 8260B/C; EPA 524.2	4-Chlorotoluene
GC/MS	EPA 8260B/C; EPA 524.2	4-Methyl-2-pentanone
GC/MS	EPA 8260B/C; EPA 524.2	Acetone
GC/MS	EPA 8260B/C	Acetonitrile
GC/MS	EPA 624; EPA 8260B/C	Acrolein
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Acrylonitrile
GC/MS	EPA 8260B/C; EPA 524.2	Allyl chloride
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Benzene
GC/MS	EPA 8260B/C	Benzyl chloride
GC/MS	EPA 8260B/C; EPA 524.2	Bromobenzene
GC/MS	EPA 8260B/C; EPA 524.2	Bromochloromethane



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Bromodichloromethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Bromoform
GC/MS	EPA 8260B/C; EPA 524.2	Carbon disulfide
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Carbon tetrachloride
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Chlorobenzene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Chloroethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Chloroform
GC/MS	EPA 8260B/C	Chloroprene
GC/MS	EPA 8260B/C; EPA 524.2	cis-1, 2-Dichloroethene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	cis-1, 3-Dichloropropene
GC/MS	EPA 8260B/C	Cis-1,4-Dichloro-2-butene
GC/MS	EPA 8260B/C	Cyclohexane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Dibromochloromethane
GC/MS	EPA 8260B/C; EPA 524.2	Dibromomethane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Dichlorodifluoromethane
GC/MS	EPA 8260B/C; EPA 524.2	Diethyl ether
GC/MS	EPA 8260B/C	Di-isopropylether
GC/MS	EPA 8260B/C; EPA 524.2	Ethyl methacrylate
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Ethylbenzene
GC/MS	EPA 8260B/C	Ethyl-t-butylether
GC/MS	EPA 8260B/C; EPA 524.2	Hexachlorobutadiene
GC/MS	EPA 8260B/C	Iodomethane
GC/MS	EPA 8260B/C	Isobutyl alcohol
GC/MS	EPA 8260B/C	Isopropyl alcohol
GC/MS	EPA 8260B/C; EPA 524.2	Isopropyl benzene
GC/MS	EPA 8260B/C; EPA 524.2	m p-xylenes
GC/MS	EPA 8260B/C	Methyl acetate



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8260B/C; EPA 524.2	Methacrylonitrile
GC/MS	EPA 624 / 8260B,C	Methyl bromide (Bromomethane)
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Methyl chloride (Chloromethane)
GC/MS	EPA 8260B/C; EPA 524.2	Methyl methacrylate
GC/MS	EPA 8260B/C; EPA 524.2	Methyl tert-butyl ether
GC/MS	EPA 8260B/C	Methylcyclohexane
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Methylene chloride
GC/MS	EPA 8260B/C; EPA 524.2	Naphthalene
GC/MS	EPA 8260B/C; EPA 524.2	n-Butylbenzene
GC/MS	EPA 8260B/C; EPA 524.2	n-Propylbenzene
GC/MS	EPA 8260B/C; EPA 524.2	o-Xylene
GC/MS	EPA 8260B/C	Pentachloroethane
GC/MS	EPA 8260B/C; EPA 524.2	p-Isopropyltoluene
GC/MS	EPA 8260B/C; EPA 524.2	Propionitrile
GC/MS	EPA 8260B/C; EPA 524.2	sec-butylbenzene
GC/MS	EPA 8260B/C; EPA 524.2	Styrene
GC/MS	EPA 8260B/C	t-Amylmethylether
GC/MS	EPA 8260B/C; EPA 524.2	tert-Butyl alcohol
GC/MS	EPA 8260B/C	tert-Butylbenzene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Tetrachloroethene (Perchloroethylene)
GC/MS	EPA 8260B/C; EPA 524.2	Tetrahydrofuran
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Toluene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	trans-1, 2-Dichloroethylene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	trans-1, 3-Dichloropropylene
GC/MS	EPA 8260B/C; EPA 524.2	trans-1, 4-Dichloro-2-butene
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Trichloroethene (Trichloroethylene)
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Trichlorofluoromethane
GC/MS	EPA 8260B/C	Vinyl acetate



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 624; EPA 8260B/C; EPA 524.2	Vinyl chloride
GC/MS	EPA 624 / 8260B,C	Xylene
GC/MS	EPA 8260B/C SIM	1,1,1,2-Tetrachloroethane
GC/MS	8260B, C SIM	1,1,1-Trichloroethane
GC/MS	EPA 8260B/C SIM	1,1,2,2-Tetrachloroethane
GC/MS	EPA 8260B/C SIM	1, 1, 2-Trichloroethane
GC/MS	EPA 8260B/C SIM	1,2,3-Trichloropropane
GC/MS	EPA 8260B/C SIM	1,1-Dichloroethane
GC/MS	EPA 8260B/C SIM	1,1-Dichloroethene
GC/MS	EPA 8260B/C SIM	1,2,4-Trichlorobenzene
GC/MS	EPA 8260B/C SIM	1,2,4-Trimethylbenzene
GC/MS	EPA 8260B/C SIM	1,2-Dibromo-3-chloropropane
GC/MS	EPA 8260B/C SIM	1,2-Dibromoethane
GC/MS	EPA 8260B/C SIM	1,2-Dichlorobenzene
GC/MS	EPA 8260B/C SIM	1,2-Dichloroethane
GC/MS	EPA 8260B/C SIM	1,2-Dichloropropane
GC/MS	EPA 8260B/C SIM	1,3-Dichlorobenzene
GC/MS	EPA 8260B/C SIM	1,3-Dichloropropane
GC/MS	EPA 8260B/C SIM	1,4-Dichlorobenzene
GC/MS	EPA 8260B/C SIM	2-Hexanone
GC/MS	EPA 8260B/C SIM	4-Methyl-2-pentanone
GC/MS	EPA 8260B/C SIM	Benzene
GC/MS	EPA 8260B/C SIM	Bromodichloromethane
GC/MS	EPA 8260B/C SIM	Carbon Tetrachloride
GC/MS	EPA 8260B/C SIM	Chloroform
GC/MS	EPA 8260B/C SIM	Chloromethane
GC/MS	EPA 8260B/C SIM	cis-1,2-Dichloroethene
GC/MS	EPA 8260B/C SIM	cis-1,3-Dichloropropene
GC/MS	EPA 8260B/C SIM	Dibromochloromethane
GC/MS	EPA 8260B/C SIM	Ethylbenzene
GC/MS	EPA 8260B/C SIM	Isopropylbenzene



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8260B/C SIM	Hexachlorobutadiene
GC/MS	EPA 8260B/C SIM	Methylcyclohexane
GC/MS	EPA 8260B/C SIM	m,p-Xylene
GC/MS	EPA 8260B/C SIM	o-Xylene
GC/MS	EPA 8260B/C SIM	Tetrachloroethene
GC/MS	EPA 8260B/C SIM	trans-1,2-Dichloroethene
GC/MS	EPA 8260B/C SIM	Trans-1,3-Dichloropropene
GC/MS	EPA 8260B/C SIM	Trichloroethene
GC/MS	EPA 8260B/C SIM	Trichlorofluoromethane
GC/MS	EPA 8260B/C SIM	Vinyl Chloride
GC/MS	EPA 8260B/C SIM	Xylenes (total)
GC/MS	EPA 8270C/D	1, 2, 4, 5-Tetrachlorobenzene
GC/MS	EPA 625; EPA 8270C/D	1, 2, 4-Trichlorobenzene
GC/MS	EPA 625; EPA 8270C/D	1, 2-Dichlorobenzene
GC/MS	EPA 8270C/D	1, 2-Diphenylhydrazine
GC/MS	EPA 8270C/D	1, 3, 5-Trinitrobenzene
GC/MS	EPA 625; EPA 8270C/D	1, 3-Dichlorobenzene
GC/MS	EPA 8270C/D	1, 3-Dinitrobenzene
GC/MS	EPA 625; EPA 8270C/D	1, 4-Dichlorobenzene
GC/MS	EPA 8270C/D	1, 4-Dioxane
GC/MS	EPA 8270C/D	1, 4-Naphthoquinone
GC/MS	EPA 8270C/D	1, 4-Phenylenediamine
GC/MS	EPA 8270C/D	1-Chloronaphthalene
GC/MS	EPA 8270C/D	1-Methylnaphthalene
GC/MS	EPA 8270C/D	1-Naphthylamine
GC/MS	EPA 8270C/D	2, 3, 4, 6-Tetrachlorophenol
GC/MS	EPA 8270C/D	2, 4, 5-Trochlorophenol
GC/MS	EPA 625; EPA 8270C/D	2, 4, 6-Trichlorophenol
GC/MS	EPA 625; EPA 8270C/D	2, 4-Dichlorophenol
GC/MS	EPA 625; EPA 8270C/D	2, 4-Dimethylphenol
GC/MS	EPA 625; EPA 8270C/D	2, 4-Dinitrophenol



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 625; EPA 8270C/D	2, 4-Dinitrotoluene (2, 4-DNT)
GC/MS	EPA 8270C/D	2, 6-Dichlorophenol
GC/MS	EPA 625; EPA 8270C/D	2, 6-Dinitrotoluene (2, 6-DNT)
GC/MS	EPA 8270C/D	2-Acetylaminofluorene
GC/MS	EPA 625; EPA 8270C/D	2-Chloronaphthalene
GC/MS	EPA 625; EPA 8270C/D	2-Chlorophenol
GC/MS	EPA 625; EPA 8270C/D	2-Methyl-4 6-dinitrophenol
GC/MS	EPA 8270C/D	2-Methylnaphthalene
GC/MS	EPA 8270C/D	2-Methylphenol
GC/MS	EPA 8270C/D	2-Naphthylamine
GC/MS	EPA 8270C/D	2-Nitroaniline
GC/MS	EPA 625; EPA 8270C/D	2-Nitrophenol
GC/MS	EPA 8270C/D	2-Picoline
GC/MS	EPA 8270C/D	3-Methylcholanthrene
GC/MS	EPA 8270C/D	3-Nitroaniline
GC/MS	EPA 8270C/D	4-Aminobiphenyl
GC/MS	EPA 625; EPA 8270C/D	4-Bromophenyl phenyl ether
GC/MS	EPA 625; EPA 8270C/D	4-Chloro-3-methylphenol
GC/MS	EPA 8270C/D	4-Chloroaniline
GC/MS	EPA 625; EPA 8270C/D	4-Chlorophenyl phenylether
GC/MS	EPA 8270C/D	4-Dimethyl aminoazobenzene
GC/MS	EPA 8270C/D	3, 4-Methylphenol
GC/MS	EPA 8270C/D	4-Nitroaniline
GC/MS	EPA 625; EPA 8270C/D	4-Nitrophenol
GC/MS	EPA 8270C/D	4-Nitroquinoline-1-oxide
GC/MS	EPA 8270C/D	5-Nitro-o-toluidine
GC/MS	EPA 8270C/D	7, 12-Dimethylbenz(a)anthracene
GC/MS	EPA 8270C/D	a a-Dimethylphenethylamine
GC/MS	EPA 625; EPA 8270C/D	Acenaphthene
GC/MS	EPA 625; EPA 8270C/D	Acenaphthylene
GC/MS	EPA 8270C/D	Acetophenone



Non-Potable Water		
Technology	Method	Analyte
GC/MS	EPA 8270C/D	Aniline
GC/MS	EPA 625; EPA 8270C/D	Anthracene
GC/MS	EPA 8270C/D	Aramite
GC/MS	EPA 8270C/D	Atrazine
GC/MS	EPA 8270C/D	Azobenzene
GC/MS	EPA 8270C/D	Benzaldehyde
GC/MS	EPA 625; EPA 8270C/D	Benzidine
GC/MS	EPA 625; EPA 8270C/D	Benzo(a)anthracene
GC/MS	EPA 625; EPA 8270C/D	Benzo(a)pyrene
GC/MS	EPA 625; EPA 8270C/D	Benzo(b)fluoranthene
GC/MS	EPA 625; EPA 8270C/D	Benzo(g h i)perylene
GC/MS	EPA 625; EPA 8270C/D	Benzo(k)fluoranthene
GC/MS	EPA 8270C/D	Benzoic Acid
GC/MS	EPA 8270C/D	Benzyl alcohol
GC/MS	EPA 8270C/D	1,1-Biphenyl
GC/MS	EPA 625; EPA 8270C/D	bis(2-Chloroethoxy)methane
GC/MS	EPA 625; EPA 8270C/D	bis(2-Chloroethyl) ether
GC/MS	EPA 625; EPA 8270C/D	bis(2-Chloroisopropyl) ether (2, 2'-Oxybis(1-chloropropane)
GC/MS	EPA 625; EPA 8270C/D	bis(2-Ethylhexyl)adipate
GC/MS	EPA 625; EPA 8270C/D	bis(2-Ethylhexyl) phthalate (DEHP)
GC/MS	EPA 625; EPA 8270C/D	Butyl benzyl phthalate
GC/MS	EPA 8270C/D	Caprolactam
GC/MS	EPA 8270C/D	Carbazole
GC/MS	EPA 8270C/D	Chlorobenzilate
GC/MS	EPA 625; EPA 8270C/D	Chrysene
GC/MS	EPA 8270C/D	Diallate
GC/MS	EPA 8270C/D	Dibenzo(a,j)acridine
GC/MS	EPA 625; EPA 8270C/D	Dibenz(a h)anthracene
GC/MS	EPA 8270C/D	Dibenzofuran
GC/MS	EPA 8270C/D	Diethyladipate
GC/MS	EPA 625; EPA 8270C/D	Diethyl phthalate



Non-Potable Water		
Technology	Method	Analyte
GC/MS	EPA 8270C/D	Dimethoate
GC/MS	EPA 625; EPA 8270C/D	Dimethyl phthalate
GC/MS	EPA 625; EPA 8270C/D	Di-n-butyl phthalate
GC/MS	EPA 625; EPA 8270C/D	Di-n-octyl phthalate
GC/MS	EPA 8270C/D	Dinoseb
GC/MS	EPA 8270C/D	Disulfoton
GC/MS	EPA 8270C/D	Ethyl methanesulfonate
GC/MS	EPA 8270C/D	Ethyl parathion
GC/MS	EPA 8270C/D	Ethyl methacrylate
GC/MS	EPA 8270C/D	Famfur
GC/MS	EPA 625; EPA 8270C/D	Fluoranthene
GC/MS	EPA 625; EPA 8270C/D	Fluorene
GC/MS	EPA 625; EPA 8270C/D	Hexachlorobenzene
GC/MS	EPA 625; EPA 8270C/D	Hexachlorobutadiene
GC/MS	EPA 625; EPA 8270C/D	Hexachlorocyclopentadiene
GC/MS	EPA 625; EPA 8270C/D	Hexachloroethane
GC/MS	EPA 8270C/D	Hexachlorophene
GC/MS	EPA 8270C/D	Hexachloropropene
GC/MS	EPA 625; EPA 8270C/D	Indeno(1, 2, 3-cd)pyrene
GC/MS	EPA 8270C/D	Isodrin
GC/MS	EPA 625; EPA 8270C/D	Isophorone
GC/MS	EPA 8270C/D	Isosafrole
GC/MS	EPA 8270C/D	Kepone
GC/MS	EPA 8270C/D	Methapyriline
GC/MS	EPA 8270C/D	Methy methanesulfonate
GC/MS	EPA 8270C/D	Methyl parathion
GC/MS	EPA 625; EPA 8270C/D	Naphthalene
GC/MS	EPA 625; EPA 8270C/D	Nitrobenzene
GC/MS	EPA 8270C/D	Nitroquinoline-1-oxide
GC/MS	EPA 8270C/D	n-Nitrosodiethylamine
GC/MS	EPA 625; EPA 8270C/D	n-Nitrosodimethylamine



Non-Potable Water		
Technology	Method	Analyte
GC/MS	EPA 8270C/D	n-Nitroso-di-n-butylamine
GC/MS	EPA 625; EPA 8270C/D	n-Nitrosodi-n-propylamine
GC/MS	EPA 625; EPA 8270C/D	n-Nitrosodiphenylamine
GC/MS	EPA 8270C/D	n-Nitrosomethylethylamine
GC/MS	EPA 8270C/D	n-Nitrosomorpholine
GC/MS	EPA 8270C/D	n-Nitrosopiperidine
GC/MS	EPA 8270C/D	n-Nitrosopyrrolidine
GC/MS	EPA 8270C/D	O,O,O-Triethyl phosphorothioate
GC/MS	EPA 8270C/D	o,o-Diethyl o-2pyrazinyl phosphorothioate
GC/MS	EPA 8270C/D	o-Toluidine
GC/MS	EPA 8270C/D	Pentachlorobenzene
GC/MS	EPA 8270C/D	Pentachloronitrobenzene
GC/MS	EPA 625; EPA 8270C/D	Pentachlorophenol
GC/MS	EPA 8270C/D	Phenacetin
GC/MS	EPA 625; EPA 8270C/D	Phenanthrene
GC/MS	EPA 625; EPA 8270C/D	Phenol
GC/MS	EPA 8270C/D	Phorate
GC/MS	EPA 8270C/D	Pronamide
GC/MS	EPA 625; EPA 8270C/D	Pyrene
GC/MS	EPA 8270C/D	Pyridine
GC/MS	EPA 8270C/D	Safrole
GC/MS	EPA 8270C/D	Sulfotepp
GC/MS	EPA 8270C/D	Thionazin
GC/MS	EPA 625; EPA 8270C/D	3, 3'-Dichlorobenzidine
GC/MS	EPA 8270C/D	3, 3'-Dimethylbenzidine
GC/MS	EPA 8270C/D SIM	1,1'-Biphenyl
GC/MS	EPA 8270C/D SIM	1,2,4,5-Tetrachlorobenzene
GC/MS	EPA 8270C/D SIM	1,4-Dioxane
GC/MS	EPA 8270C/D SIM	1-Methylnaphthalene
GC/MS	EPA 8270C/D SIM	2,2'-Oxybis(1-chloropropane
GC/MS	EPA 8270C/D SIM	2,3,4,6-Tetrachlorophenol



Non-Potable Water		
Technology	Method	Analyte
GC/MS	EPA 8270C/D SIM	2,4,5-Trichlorophenol
GC/MS	EPA 8270C/D SIM	2,4,6-Trichlorophenol
GC/MS	EPA 8270C/D SIM	2,4-Dichlorophenol
GC/MS	EPA 8270C/D SIM	2,4-Dimethylphenol
GC/MS	EPA 8270C/D SIM	2,4-Dinitrophenol
GC/MS	EPA 8270C/D SIM	2,4-Dinitrotoluene
GC/MS	EPA 8270C/D SIM	2,6-Dinitrotoluene
GC/MS	EPA 8270C/D SIM	2-Chloronaphthalene
GC/MS	EPA 8270C/D SIM	2-Chlorophenol
GC/MS	EPA 8270C/D SIM	2-Methylnaphthalene
GC/MS	EPA 8270C/D SIM	2-Methylphenol
GC/MS	EPA 8270C/D SIM	2-Nitroaniline
GC/MS	EPA 8270C/D SIM	2-Nitrophenol
GC/MS	EPA 8270C/D SIM	3&4-Methylphenol
GC/MS	EPA 8270C/D SIM	3,3'-Dichlorobenzidine
GC/MS	EPA 8270C/D SIM	3-Nitroaniline
GC/MS	EPA 8270C/D SIM	4,6-Dinitro-2-methylphenol
GC/MS	EPA 8270C/D SIM	4-Bromophenyl-phenylether
GC/MS	EPA 8270C/D SIM	4-Chloro-3-methylphenol
GC/MS	EPA 8270C/D SIM	4-Chloroaniline
GC/MS	EPA 8270C/D SIM	4-Chlorophenyl-phenylether
GC/MS	EPA 8270C/D SIM	4-Nitroaniline
GC/MS	EPA 8270C/D SIM	4-Nitrophenol
GC/MS	EPA 8270C/D SIM	Acenaphthene
GC/MS	EPA 8270C/D SIM	Acenaphthylene
GC/MS	EPA 8270C/D SIM	Acetophenone
GC/MS	EPA 8270C/D SIM	Anthracene
GC/MS	EPA 8270C/D SIM	Atrazine
GC/MS	EPA 8270C/D SIM	Benzaldehyde
GC/MS	EPA 8270C/D SIM	Benzo(a)anthracene
GC/MS	EPA 8270C/D SIM	Benzo(a)pyrene



Non-Potable Water		
Technology	Method	Analyte
GC/MS	EPA 8270C/D SIM	Benzo(b)fluoranthene
GC/MS	EPA 8270C/D SIM	Benzo(g,h,i)perylene
GC/MS	EPA 8270C/D SIM	Benzo(k)fluoranthene
GC/MS	EPA 8270C/D SIM	Bis(2-chloroethoxy)methane
GC/MS	EPA 8270C/D SIM	Bis(2-chloroethyl)ether
GC/MS	EPA 8270C/D SIM	Bis(2-ethylhexyl)phthalate
GC/MS	EPA 8270C/D SIM	Butylbenzylphthalate
GC/MS	EPA 8270C/D SIM	Caprolactam
GC/MS	EPA 8270C/D SIM	Carbazole
GC/MS	EPA 8270C/D SIM	Chrysene
GC/MS	EPA 8270C/D SIM	Dibenzo(a,h)anthracene
GC/MS	EPA 8270C/D SIM	Dibenzofuran
GC/MS	EPA 8270C/D SIM	Diethylphthalate
GC/MS	EPA 8270C/D SIM	Dimethyl phthalate
GC/MS	EPA 8270C/D SIM	Di-n-butylphthalate
GC/MS	EPA 8270C/D SIM	Di-n-octylphthalate
GC/MS	EPA 8270C/D SIM	Fluoranthene
GC/MS	EPA 8270C/D SIM	Fluorene
GC/MS	EPA 8270C/D SIM	Hexachlorobenzene
GC/MS	EPA 8270C/D SIM	Hexachlorobutadiene
GC/MS	EPA 8270C/D SIM	Hexachlorocyclopentadiene
GC/MS	EPA 8270C/D SIM	Hexachloroethane
GC/MS	EPA 8270C/D SIM	Indeno(1,2,3-cd)pyrene
GC/MS	EPA 8270C/D SIM	Isophorone
GC/MS	EPA 8270C/D SIM	Naphthalene
GC/MS	EPA 8270C/D SIM	Nitrobenzene
GC/MS	EPA 8270C/D SIM	n-Nitroso-di-n-propylamine
GC/MS	EPA 8270C/D SIM	n-Nitrosodiphenylamine
GC/MS	EPA 8270C/D SIM	Pentachlorophenol
GC/MS	EPA 8270C/D SIM	Phenanthrene
GC/MS	EPA 8270C/D SIM	Phenol



Non-Potable Water		
Technology	Method	Analyte
GC/MS	EPA 8270C/D SIM	Pyrene
HPLC/UV	EPA 8330A/B	1, 3, 5-Trinitrobenzene
HPLC/UV	EPA 8330A/B	1, 3-Dinitrobenzene
HPLC/UV	EPA 8330A/B	2, 4, 6-Trinitrotoluene
HPLC/UV	EPA 8330A/B	2, 4-Dinitrotoluene
HPLC/UV	EPA 8330A/B	2, 6-Dinitrotoluene
HPLC/UV	EPA 8330A/B	2-Amino-4, 6 -Dinitrotoluene
HPLC/UV	EPA 8330A/B	2-Nitrotoluene
HPLC/UV	EPA 8330A/B	3-Nitrotoluene
HPLC/UV	EPA 8330A/B	3,5-Dinitroaniline
HPLC/UV	EPA 8330A/B	4-Amino-2, 6-Dinitrotoluene
HPLC/UV	EPA 8330A/B	4-Nitrotoluene
HPLC/UV	EPA 8330A/B	Ethylene glycol dinitrate (EGDN)
HPLC/UV	EPA 8330A/B	Hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine (RDX)
HPLC/UV	EPA 8330A/B	Nitrobenzene
HPLC/UV	EPA 8330A MOD	Nitroglycerin
HPLC/UV	EPA 8330B	Nitroglycerin
HPLC/UV	EPA 8330A/B	Octahydro-1, 3, 5, 7-tetrazocine (HMX)
HPLC/UV	EPA 8330A/B	Pentaerythritol Tetranitrate (PETN)
HPLC/UV	EPA 8330A/B	Tetryl
CVAA	EPA 245.1; EPA 7470A	Mercury
CVAF	EPA 1631E	Low Level Mercury
ICP/AES	EPA 200.7; EPA 6010B/C	Aluminum
ICP/AES	EPA 200.7; EPA 6010B/C	Antimony
ICP/AES	EPA 200.7; EPA 6010B/C	Arsenic
ICP/AES	EPA 200.7; EPA 6010B/C	Barium
ICP/AES	EPA 200.7; EPA 6010B/C	Beryllium
ICP/AES	EPA 200.7; EPA 6010B/C	Boron
ICP/AES	EPA 200.7; EPA 6010B/C	Cadmium
ICP/AES	EPA 200.7; EPA 6010B/C	Calcium
ICP/AES	EPA 200.7; EPA 6010B/C	Chromium



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
ICP/AES	EPA 200.7; EPA 6010B/C	Cobalt
ICP/AES	EPA 200.7; EPA 6010B/C	Copper
ICP/AES	EPA 200.7; EPA 6010B/C	Iron
ICP/AES	EPA 200.7; EPA 6010B/C	Lead
ICP/AES	EPA 200.7; EPA 6010B/C	Magnesium
ICP/AES	EPA 200.7; EPA 6010B/C	Manganese
ICP/AES	EPA 200.7; EPA 6010B/C	Molybdenum
ICP/AES	EPA 200.7; EPA 6010B/C	Nickel
ICP/AES	EPA 200.7; EPA 6010B/C	Potassium
ICP/AES	EPA 200.7; EPA 6010B/C	Selenium
ICP/AES	EPA 200.7; EPA 6010B/C	Silicon
ICP/AES	EPA 200.7; EPA 6010B/C	Silver
ICP/AES	EPA 200.7; EPA 6010B/C	Sodium
ICP/AES	EPA 6010B/C	Strontium
ICP/AES	EPA 200.7; EPA 6010B/C	Thallium
ICP/AES	EPA 200.7; EPA 6010B/C	Tin
ICP/AES	EPA 200.7; EPA 6010B/C	Titanium
ICP/AES	EPA 200.7; EPA 6010B/C	Vanadium
ICP/AES	EPA 200.7; EPA 6010B/C	Zinc
ICP/MS	EPA 200.8; EPA 6020A	Aluminum
ICP/MS	EPA 200.8; EPA 6020A	Antimony
ICP/MS	EPA 200.8; EPA 6020A	Arsenic
ICP/MS	EPA 200.8; EPA 6020A	Barium
ICP/MS	EPA 200.8; EPA 6020A	Beryllium
ICP/MS	EPA 200.8; EPA 6020A	Boron
ICP/MS	EPA 200.8; EPA 6020A	Cadmium
ICP/MS	EPA 200.8; EPA 6020A	Calcium
ICP/MS	EPA 200.8; EPA 6020A	Chromium
ICP/MS	EPA 200.8; EPA 6020A	Cobalt
ICP/MS	EPA 200.8; EPA 6020A	Copper
ICP/MS	EPA 200.8; EPA 6020A	Iron



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
ICP/MS	EPA 200.8; EPA 6020A	Lead
ICP/MS	EPA 200.8; EPA 6020A	Magnesium
ICP/MS	EPA 200.8; EPA 6020A	Manganese
ICP/MS	EPA 200.8; EPA 6020A	Molybdenum
ICP/MS	EPA 200.8; EPA 6020A	Nickel
ICP/MS	EPA 200.8; EPA 6020A	Potassium
ICP/MS	EPA 200.8; EPA 6020A	Selenium
ICP/MS	EPA 200.8; EPA 6020A	Silicon
ICP/MS	EPA 200.8; EPA 6020A	Silver
ICP/MS	EPA 200.8; EPA 6020A	Sodium
ICP/MS	EPA 6020A	Strontium
ICP/MS	EPA 200.8; EPA 6020A	Thallium
ICP/MS	EPA 200.8; EPA 6020A	Tin
ICP/MS	EPA 200.8; EPA 6020A	Titanium
ICP/MS	EPA 200.8; EPA 6020A	Tungsten
ICP/MS	EPA 200.8	Uranium
ICP/MS	EPA 200.8; EPA 6020A	Vanadium
ICP/MS	EPA 200.8; EPA 6020A	Zinc
IC	EPA 300.0; EPA 9056A	Chloride
IC	EPA 300.0; EPA 9056A	Fluoride
IC	EPA 300.0; EPA 9056A	Nitrate as N
IC	EPA 300.0; EPA 9056A	Nitrite as N
IC	EPA 300.0; EPA 9056A	Nitrate + Nitrite
IC	EPA 300.0; EPA 9056A	Orthophosphate as P
IC	EPA 300.0; EPA 9056A	Sulfate
IC	SOP CA-776	Lactic Acid
IC	SOP CA-776	Acetic Acid
IC	SOP CA-776	Propionic Acid
IC	SOP CA-776	Formic Acid
IC	SOP CA-776	Butyric Acid
IC	SOP CA-776	Pyruvic Acid



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
IC	SOP CA-776	i-Pentanoic Acid
IC	SOP CA-776	Pentanoic Acid
IC	SOP CA-776	i-Hexanoic Acid
IC	SOP CA-776	Hexanoic Acid
Titration	EPA 310.1; SM 2320B	Alkalinity
Calculation	SM 2340B	Hardness
Gravimetric	EPA 1664A; EPA 9070A	Oil and Grease, Oil and Grease with SGT
Gravimetric	SM 2540B/C/D	Solids
ISE	EPA 120.1; SM 2510B	Conductivity
ISE	SM 2520B	Practical Salinity
ISE	SM 4500F- C	Fluoride
ISE	SM 4500H+ B	pH
ISE	SM 5210B	TBOD / CBOD
Physical	EPA 1010A	Ignitability
Physical	EPA 9040C	pH
Titration	SM 2340C	Hardness
Titration	SM 4500SO <sub>3</sub> B	Sulfite
Titration	EPA 9034; SM 4500S <sup>2-</sup> F	Sulfide
Titration	EPA SW-846 Chapter 7.3.4	Reactive Sulfide
IR	EPA 9060A; SM 5310B	Total organic carbon
Turbidimetric	EPA 180.1; SM 2130B	Turbidity
Turbidimetric	EPA 9038; ASTM 516-02	Sulfate
UV/VIS	EPA 335.4; EPA 9012B; SM 4500-CN G	Amenable cyanide
UV/VIS	EPA 350.1; SM 4500NH <sub>3</sub> H	Ammonia as N
UV/VIS	SM 3500Fe D	Ferrous Iron
UV/VIS	EPA 351.2	Kjeldahl nitrogen - total
UV/VIS	EPA 353.2; SM 4500NO <sub>3</sub> F	Nitrate + Nitrite
UV/VIS	EPA 353.2; SM 4500NO <sub>3</sub> F	Nitrate as N
UV/VIS	EPA 353.2; SM 4500NO <sub>3</sub> F	Nitrite as N
UV/VIS	EPA 365.2; SM 4500P E	Orthophosphate as P
UV/VIS	EPA 365.4	Phosphorus total



<b>Non-Potable Water</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
UV/VIS	EPA 821/R-91-100	AVS-SEM
UV/VIS	EPA 410.4	COD
UV/VIS	EPA 420.1; EPA 9065	Total Phenolics
UV/VIS	SM 4500Cl G	Total Residual Chlorine
UV/VIS	SM 5540C	MBAS
UV/VIS	EPA 7196A; SM 3500-Cr D	Chromium VI
UV/VIS	EPA 9012B; EPA 335.4	Total Cyanide
UV/VIS	EPA 9251; SM 4500Cl E	Chloride
UV/VIS	EPA SW-846 Chapter 7.3.4	Reactive Cyanide

<b>Preparation</b>	<b>Method</b>	<b>Type</b>
Cleanup Methods	EPA 3640A	Gel Permeation Clean-up
Cleanup Methods	EPA 3630C	Silica Gel
Cleanup Methods	EPA 3660B	Sulfur Clean-Up
Cleanup Methods	EPA 3665A	Sulfuric Acid Clean-Up
Organic Preparation	EPA 3510C	Separatory Funnel Extraction
Organic Preparation	EPA 3520C	Continuous Liquid-Liquid Extraction
Inorganic Preparation	EPA 3010A	Hotblock
Volatile Organic Preparation	EPA 5030C	Purge and Trap

<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/ECD	EPA 8081B	2,4'-DDD
GC/ECD	EPA 8081B	2,4'-DDE
GC/ECD	EPA 8081B	2,4'-DDT
GC/ECD	EPA 8081B	4,4'-DDD
GC/ECD	EPA 8081B	4,4'-DDE
GC/ECD	EPA 8081B	4,4'-DDT
GC/ECD	EPA 8081B	Aldrin
GC/ECD	EPA 8081B	alpha-BHC (alpha-Hexachlorocyclohexane)



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/ECD	EPA 8081B	Alpha-Chlordane
GC/ECD	EPA 8081B	beta-BHC (beta-Hexachlorocyclohexane)
GC/ECD	EPA 608; EPA 8081B	Chlordane (tech.)
GC/ECD	EPA 8081B	Cis-Nonachlor
GC/ECD	EPA 8081B	delta-BHC
GC/ECD	EPA 8081B	Dieldrin
GC/ECD	EPA 8081B	Endosulfan I
GC/ECD	EPA 8081B	Endosulfan II
GC/ECD	EPA 8081B	Endosulfan sulfate
GC/ECD	EPA 8081B	Endrin
GC/ECD	EPA 8081B	Endrin aldehyde
GC/ECD	EPA 8081B	Endrin Ketone
GC/ECD	EPA 8081B	gamma-BHC (Lindane gamma-Hexachlorocyclohexane)
GC/ECD	EPA 8081B	gamma-Chlordane
GC/ECD	EPA 8081B	Heptachlor
GC/ECD	EPA 8081B	Heptachlor epoxide
GC/ECD	EPA 8081B	Hexachlorobenzene
GC/ECD	EPA 8081B	Methoxychlor
GC/ECD	EPA 8081B	Mirex
GC/ECD	EPA 8081B	Oxychlordane
GC/ECD	EPA 8081B	Toxaphene (Chlorinated camphene)
GC/ECD	EPA 8081B	Trans-Nonachlor
GC/ECD	EPA 8082A	Aroclor-1016 (PCB-1016)
GC/ECD	EPA 8082A	Aroclor-1221 (PCB-1221)
GC/ECD	EPA 8082A	Aroclor-1232 (PCB-1232)
GC/ECD	EPA 8082A	Aroclor-1242 (PCB-1242)
GC/ECD	EPA 8082A	Aroclor-1248 (PCB-1248)
GC/ECD	EPA 8082A	Aroclor-1254 (PCB-1254)
GC/ECD	EPA 8082A	Aroclor-1260 (PCB-1260)
GC/ECD	EPA 8082A MOD	Aroclor-1262 (PCB-1262)
GC/ECD	EPA 8082A MOD	Aroclor-1268 (PCB-1268)



Solid and Chemical Waste		
Technology	Method	Analyte
GC/ECD	EPA 8082A	2, 2', 3, 3', 4, 4', 5, 5', 6-Nonachlorobiphenyl (BZ 206)
GC/ECD	EPA 8082A	2, 2', 3, 3', 4, 4', 5, 6-Octachlorobiphenyl (BZ 195)
GC/ECD	EPA 8082A	2, 2', 3, 3', 4, 4', 5-Heptachlorobiphenyl (BZ 170)
GC/ECD	EPA 8082A	2, 2', 3, 3', 4, 4'-Hexachlorobiphenyl (BZ 128)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 5, 5'-Heptachlorobiphenyl (BZ 180)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 5', 6-Heptachlorobiphenyl (BZ 183)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 5-Hexachlorobiphenyl (BZ 138)
GC/ECD	EPA 8082A	2, 2', 3, 4, 4', 6, 6'-Heptachlorobiphenyl (BZ 184)
GC/ECD	EPA 8082A	2, 2', 3, 4', 5, 5', 6-Heptachlorobiphenyl (BZ 187)
GC/ECD	EPA 8082A	2, 2', 3, 4, 5'-Pentachlorobiphenyl (BZ 87)
GC/ECD	EPA 8082A	2, 2', 3, 5'-Tetrachlorobiphenyl (BZ 44)
GC/ECD	EPA 8082A	2, 2', 4, 4', 5, 5'-Hexachlorobiphenyl (BZ 153)
GC/ECD	EPA 8082A	2, 2', 4, 5, 5'-Pentachlorobiphenyl (BZ 101)
GC/ECD	EPA 8082A	2, 2', 4, 5-Tetrachlorobiphenyl (BZ 48)
GC/ECD	EPA 8082A	2, 2', 4, 5'-Tetrachlorobiphenyl (BZ 49)
GC/ECD	EPA 8082A	2, 2', 5, 5'-Tetrachlorobiphenyl (BZ 52)
GC/ECD	EPA 8082A	2, 2', 5-Trichlorobiphenyl (BZ 18)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4', 5-Hexachlorobiphenyl (BZ 156)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4', 5'-Hexachlorobiphenyl (BZ 157)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4'-Pentachlorobiphenyl (BZ 105)
GC/ECD	EPA 8082A	2, 3, 3', 4, 4', 5, 5'-Heptachlorobiphenyl (BZ 189)
GC/ECD	EPA 8082A	2, 3', 4, 4', 5, 5'-Hexachlorobiphenyl (BZ 167)
GC/ECD	EPA 8082A	2, 3', 4, 4', 5-Pentachlorobiphenyl (BZ 118)
GC/ECD	EPA 8082A	2, 3', 4, 4', 5'-Pentachlorobiphenyl (BZ 123)
GC/ECD	EPA 8082A	2, 3', 4, 4'-Tetrachlorobiphenyl (BZ 66)
GC/ECD	EPA 8082A	2, 3, 4, 4', 5-Pentachlorobiphenyl (BZ 114)
GC/ECD	EPA 8082A	2, 4, 4'-Trichlorobiphenyl (BZ 28)
GC/ECD	EPA 8082A	2, 4'-Dichlorobiphenyl (BZ 8)
GC/ECD	EPA 8082A	3, 3', 4, 4', 5, 5'-Hexachlorobiphenyl (BZ 169)
GC/ECD	EPA 8082A	3, 3', 4, 4', 5-Pentachlorobiphenyl (BZ 126)
GC/ECD	EPA 8082A	3, 3', 4, 4'-Tetrachlorobiphenyl (BZ 77)



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/ECD	EPA 8082A	3, 4, 4', 5-Tetrachlorobiphenyl (BZ 81)
GC/ECD	EPA 8082A	Decachlorobiphenyl (BZ 209)
GC/ECD	EPA 8151A	2, 4, 5-T
GC/ECD	EPA 8151A	2, 4-D
GC/ECD	EPA 8151A	2, 4-DB
GC/ECD	EPA 8151A	Dalapon
GC/ECD	EPA 8151A	Dicamba
GC/ECD	EPA 8151A	Dichloroprop
GC/ECD	EPA 8151A	Dinoseb
GC/ECD	EPA 8151A	MCPA
GC/ECD	EPA 8151A	MCPP
GC/ECD	EPA 8151A	Pentachlorophenol
GC/ECD	EPA 8151A	Silvex (2, 4, 5-TP)
GC/FID	EPA 8015C/D	Diesel range organics (DRO)
GC/FID	EPA 8015C/D	Total Petroleum Hydrocarbons (TPH)
GC/FID	EPA 8015C/D	Gasoline range organics (GRO)
GC/FID/PID	MA DEP VPH	Volatile Organic Hydrocarbons
GC/FID	MA DEP EPH	Extractable Petroleum Hydrocarbons
GC/FID	MA DEP EPH EPA 3546	Extractable Petroleum Hydrocarbons Microwave Extraction Preparation
GC/FID	CT-ETPH	Total Petroleum Hydrocarbons
GC/FID	TNRCC Method 1005	Total Petroleum Hydrocarbons
GC/FID	FL-PRO	Petroleum Range Organics
GC/ECD	EPA 8011	1, 2-Dibromoethane (EDB)
GC/ECD	EPA 8011	1, 2-Dibromo-3-chloropropane
GC/MS	EPA 8260B/C	1, 1, 1, 2-Tetrachloroethane
GC/MS	EPA 8260B/C	1,1,2-Trichloro-1,2,2-trifluoroethane
GC/MS	EPA 8260B/C	1, 1, 1-Trichloroethane
GC/MS	EPA 8260B/C	1, 1, 2, 2-Tetrachloroethane
GC/MS	EPA 8260B/C	1, 1, 2-Trichloroethane
GC/MS	EPA 8260B/C	1, 1-Dichloroethane
GC/MS	EPA 8260B/C	1, 1-Dichloroethylene



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8260B/C	1, 1-Dichloropropene
GC/MS	EPA 8260B/C	1, 2, 3-Trichlorobenzene
GC/MS	EPA 8260B/C	1, 2, 3-Trichloropropane
GC/MS	EPA 8260B/C	1,2,3-Trimethylbenzene
GC/MS	EPA 8260B/C	1, 2, 4-Trichlorobenzene
GC/MS	EPA 8260B/C	1, 2, 4-Trimethylbenzene
GC/MS	EPA 8260B/C	1, 2-Dibromo-3-chloropropane
GC/MS	EPA 8260B/C	1, 2-Dibromoethane
GC/MS	EPA 8260B/C	1, 2-Dichlorobenzene
GC/MS	EPA 8260B/C	1, 2-Dichloroethane
GC/MS	EPA 8260B/C	1, 2-Dichloropropane
GC/MS	EPA 8260B/C	1,3,5-Trichlorobenzene
GC/MS	EPA 8260B/C	1, 3, 5-Trimethylbenzene
GC/MS	EPA 8260B/C	1, 3-Dichlorobenzene
GC/MS	EPA 8260B/C	1, 3-Dichloropropane
GC/MS	EPA 8260B/C	1, 4-Dichlorobenzene
GC/MS	EPA 8260B/C	1, 4-Dioxane
GC/MS	EPA 8260B/C	1-Chlorohexane
GC/MS	EPA 8260B/C	2, 2-Dichloropropane
GC/MS	EPA 8260B/C	2-Butanone
GC/MS	EPA 8260B/C	2-Chloroethyl vinyl ether
GC/MS	EPA 8260B/C	2-Chlorotoluene
GC/MS	EPA 8260B/C	2-Hexanone
GC/MS	EPA 8260B/C	4-Chlorotoluene
GC/MS	EPA 8260B/C	4-Methyl-2-pentanone
GC/MS	EPA 8260B/C	Acetone
GC/MS	EPA 8260B/C	Acetonitrile
GC/MS	EPA 8260B/C	Acrolein
GC/MS	EPA 8260B/C	Acrylonitrile
GC/MS	EPA 8260B/C	Allyl chloride
GC/MS	EPA 8260B/C	Benzene



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8260B/C	Benzyl chloride
GC/MS	EPA 8260B/C	Bromobenzene
GC/MS	EPA 8260B/C	Bromochloromethane
GC/MS	EPA 8260B/C	Bromodichloromethane
GC/MS	EPA 8260B/C	Bromoform
GC/MS	EPA 8260B/C	Carbon disulfide
GC/MS	EPA 8260B/C	Carbon tetrachloride
GC/MS	EPA 8260B/C	Chlorobenzene
GC/MS	EPA 8260B/C	Chloroethane
GC/MS	EPA 8260B/C	Chloroform
GC/MS	EPA 8260B/C	Chloroprene
GC/MS	EPA 8260B/C	cis-1, 2-Dichloroethene
GC/MS	EPA 8260B/C	cis-1, 3-Dichloropropene
GC/MS	EPA 8260B/C	cis-1,3-Dichloro-2-butene
GC/MS	EPA 8260B/C	Cyclohexane
GC/MS	EPA 8260B/C	Dibromochloromethane
GC/MS	EPA 8260B/C	Dibromomethane
GC/MS	EPA 8260B/C	Dichlorodifluoromethane
GC/MS	EPA 8260B/C	Diethyl ether
GC/MS	EPA 8260B/C	Di-isopropylether
GC/MS	EPA 8260B/C	1,2-Dibromoethane (EDB)
GC/MS	EPA 8260B/C	Ethyl methacrylate
GC/MS	EPA 8260B/C	Ethylbenzene
GC/MS	EPA 8260B/C	Ethyl-t-butylether
GC/MS	EPA 8260B/C	Hexachlorobutadiene
GC/MS	EPA 8260B/C	Iodomethane
GC/MS	EPA 8260B/C	Isobutyl alcohol
GC/MS	EPA 8260B/C	Isopropyl alcohol
GC/MS	EPA 8260B/C	Isopropyl benzene
GC/MS	EPA 8260B/C	m p-xylenes
GC/MS	EPA 8260B, C	Methyl acetate



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8260B/C	Methacrylonitrile
GC/MS	EPA 8260B/C	Methyl bromide (Bromomethane)
GC/MS	EPA 8260B/C	Methyl chloride (Chloromethane)
GC/MS	EPA 8260B/C	Methyl methacrylate
GC/MS	EPA 8260B/C	Methyl tert-butyl ether
GC/MS	EPA 8260B/C	Methylcyclohexane
GC/MS	EPA 8260B/C	Methylene chloride
GC/MS	EPA 8260B/C	Naphthalene
GC/MS	EPA 8260B/C	n-Butylbenzene
GC/MS	EPA 8260B/C	n-propylbenzene
GC/MS	EPA 8260B/C	o-Xylene
GC/MS	EPA 8260B/C	pentachloroethane
GC/MS	EPA 8260B/C	p-Isopropyltoluene
GC/MS	EPA 8260B/C	Propionitrile
GC/MS	EPA 8260B/C	sec-butylbenzene
GC/MS	EPA 8260B/C	Styrene
GC/MS	EPA 8260B/C	t-Amylmethylether
GC/MS	EPA 8260B/C	tert-Butyl alcohol
GC/MS	EPA 8260B/C	tert-Butylbenzene
GC/MS	EPA 8260B/C	Tetrachloroethylene (Perchloroethylene)
GC/MS	EPA 8260B/C	Tetrahydrofuran
GC/MS	EPA 8260B/C	Toluene
GC/MS	EPA 8260B/C	trans-1, 2-Dichloroethylene
GC/MS	EPA 8260B/C	trans-1, 3-Dichloropropylene
GC/MS	EPA 8260B/C	Trans-1, 4-Dichloro-2-butene
GC/MS	EPA 8260B/C	Trichloroethene (Trichloroethylene)
GC/MS	EPA 8260B/C	Trichlorofluoromethane
GC/MS	EPA 8260B/C	Vinyl acetate
GC/MS	EPA 8260B/C	Vinyl chloride
GC/MS	EPA 8260B/C	Xylene
GC/MS	EPA 8260B/C SIM	1,1,1,2-Tetrachloroethane



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8260B/C SIM	1,1,1-Trichloroethane
GC/MS	EPA 8260B/C SIM	1,1,2,2-Tetrachloroethane
GC/MS	EPA 8260B/C SIM	1, 1, 2-Trichloroethane
GC/MS	EPA 8260B/C SIM	1,2,3-Trichloropropane
GC/MS	EPA 8260B/C SIM	1,1-Dichloroethane
GC/MS	EPA 8260B/C SIM	1,1-Dichloroethene
GC/MS	EPA 8260B/C SIM	1,2,4-Trichlorobenzene
GC/MS	EPA 8260B/C SIM	1,2,4-Trimethylbenzene
GC/MS	EPA 8260B/C SIM	1,2-Dibromo-3-chloropropane
GC/MS	EPA 8260B/C SIM	1,2-Dibromoethane
GC/MS	EPA 8260B/C SIM	1,2-Dichlorobenzene
GC/MS	EPA 8260B/C SIM	1,2-Dichloroethane
GC/MS	EPA 8260B/C SIM	1,2-Dichloropropane
GC/MS	EPA 8260B/C SIM	1,3-Dichlorobenzene
GC/MS	EPA 8260B/C SIM	1,3-Dichloropropane
GC/MS	EPA 8260B/C SIM	1,4-Dichlorobenzene
GC/MS	EPA 8260B/C SIM	2-Hexanone
GC/MS	EPA 8260B/C SIM	4-Methyl-2-pentanone
GC/MS	EPA 8260B/C SIM	Benzene
GC/MS	EPA 8260B/C SIM	Bromodichloromethane
GC/MS	EPA 8260B/C SIM	Carbon Tetrachloride
GC/MS	EPA 8260B/C SIM	Chloroform
GC/MS	EPA 8260B/C SIM	Chloromethane
GC/MS	EPA 8260B/C SIM	cis-1,2-Dichloroethene
GC/MS	EPA 8260B/C SIM	cis-1,3-Dichloropropene
GC/MS	EPA 8260B/C SIM	Dibromochloromethane
GC/MS	EPA 8260B/C SIM	Ethylbenzene
GC/MS	EPA 8260B/C SIM	Isopropylbenzene
GC/MS	EPA 8260B/C SIM	Hexachlorobutadiene
GC/MS	EPA 8260B/C SIM	Methylcyclohexane
GC/MS	EPA 8260B/C SIM	m,p-Xylene



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8260B/C SIM	o-Xylene
GC/MS	EPA 8260B/C SIM	Tetrachloroethene
GC/MS	EPA 8260B/C SIM	trans-1,2-Dichloroethene
GC/MS	EPA 8260B/C SIM	Trans-1,3-Dichloropropene
GC/MS	EPA 8260B/C SIM	Trichloroethene
GC/MS	EPA 8260B/C SIM	Trichlorofluoromethane
GC/MS	EPA 8260B/C SIM	Vinyl Chloride
GC/MS	EPA 8260B/C SIM	Xylenes (total)
GC/MS	EPA 8270C/D	1, 2, 4, 5-Tetrachlorobenzene
GC/MS	EPA 8270C/D	1, 2, 4-Trichlorobenzene
GC/MS	EPA 8270C/D	1, 2-Dichlorobenzene
GC/MS	EPA 8270C/D	1, 2-Diphenylhydrazine
GC/MS	EPA 8270C/D	1, 3, 5-Trinitrobenzene
GC/MS	EPA 8270C/D	1, 3-Dichlorobenzene
GC/MS	EPA 8270C/D	1, 3-Dinitrobenzene
GC/MS	EPA 8270C/D	1, 4-Dichlorobenzene
GC/MS	EPA 8270C/D	1, 4-Dioxane
GC/MS	EPA 8270C/D	1, 4-Naphthoquinone
GC/MS	EPA 8270C/D	1, 4-Phenylenediamine
GC/MS	EPA 8270C/D	1,1-Biphenyl
GC/MS	EPA 8270C/D	1-Chloronaphthalene
GC/MS	EPA 8270C/D	1-Methylnaphthalene
GC/MS	EPA 8270C/D	1-Naphthylamine
GC/MS	EPA 8270C/D	2, 3, 4, 6-Tetrachlorophenol
GC/MS	EPA 8270C/D	2, 4, 5-Trichlorophenol
GC/MS	EPA 8270C/D	2, 4, 6-Trichlorophenol
GC/MS	EPA 8270C/D	2, 4-Dichlorophenol
GC/MS	EPA 8270C/D	2, 4-Dimethylphenol
GC/MS	EPA 8270C/D	2, 4-Dinitrophenol
GC/MS	EPA 8270C/D	2, 4-Dinitrotoluene (2 4-DNT)
GC/MS	EPA 8270C/D	2, 6-Dichlorophenol



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8270C/D	2, 6-Dinitrotoluene (2 6-DNT)
GC/MS	EPA 8270C/D	2-Acetylaminofluorene
GC/MS	EPA 8270C/D	2-Chloronaphthalene
GC/MS	EPA 8270C/D	2-Chlorophenol
GC/MS	EPA 8270C/D	2-Methyl-4, 6-dinitrophenol
GC/MS	EPA 8270C/D	2-Methylnaphthalene
GC/MS	EPA 8270C/D	2-Methylphenol
GC/MS	EPA 8270C/D	2-Naphthylamine
GC/MS	EPA 8270C/D	2-Nitroaniline
GC/MS	EPA 8270C/D	2-Nitrophenol
GC/MS	EPA 8270C/D	2-Picoline
GC/MS	EPA 8270C/D	3, 3'-Dichlorobenzidine
GC/MS	EPA 8270C/D	3, 3'-Dimethylbenzidine
GC/MS	EPA 8270C/D	3,4-Methylphenol
GC/MS	EPA 8270C/D	3-Methylcholanthrene
GC/MS	EPA 8270C/D	3-Nitroaniline
GC/MS	EPA 8270C/D	4-Aminobiphenyl
GC/MS	EPA 8270C/D	4-Bromophenyl phenyl ether
GC/MS	EPA 8270C/D	4-Chloro-3-methylphenol
GC/MS	EPA 8270C/D	4-Chloroaniline
GC/MS	EPA 8270C/D	4-Chlorophenyl phenylether
GC/MS	EPA 8270C/D	4-Dimethyl aminoazobenzene
GC/MS	EPA 8270C/D	4-Nitroaniline
GC/MS	EPA 8270C/D	4-Nitrophenol
GC/MS	EPA 8270C/D	4-Nitroquinoline-1-oxide
GC/MS	EPA 8270C/D	5-Nitro-o-toluidine
GC/MS	EPA 8270C/D	7,12-Dimethylbenz(a)anthracene
GC/MS	EPA 8270C/D	a a-Dimethylphenethylamine
GC/MS	EPA 8270C/D	Acenaphthene
GC/MS	EPA 8270C/D	Acenaphthylene
GC/MS	EPA 8270C/D	Acetophenone



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8270C/D	Aniline
GC/MS	EPA 8270C/D	Anthracene
GC/MS	EPA 8270C/D	Aramite
GC/MS	EPA 8270C/D	Atrazine
GC/MS	EPA 8270C/D	Azobenzene
GC/MS	EPA 8270C/D	Benzaldehyde
GC/MS	EPA 8270C/D	Benzidine
GC/MS	EPA 8270C/D	Benzo(a)anthracene
GC/MS	EPA 8270C/D	Benzo(a)pyrene
GC/MS	EPA 8270C/D	Benzo(b)fluoranthene
GC/MS	EPA 8270C/D	Benzo(g h i)perylene
GC/MS	EPA 8270C/D	Benzo(k)fluoranthene
GC/MS	EPA 8270C/D	Benzoic Acid
GC/MS	EPA 8270C/D	Benzyl alcohol
GC/MS	EPA 8270C/D	bis(2-Chloroethoxy)methane
GC/MS	EPA 8270C/D	bis(2-Chloroethyl) ether
GC/MS	EPA 8270C/D	bis(2-Chloroisopropyl) ether (2, 2'-Oxybis(1-chloropropane))
GC/MS	EPA 8270C/D	bis(2-Ethylhexyl) phthalate (DEHP)
GC/MS	EPA 8270C/D	Bis(2-Ethylhexyl)adipate
GC/MS	EPA 8270C/D	Butyl benzyl phthalate
GC/MS	EPA 8270C/D	Caprolactam
GC/MS	EPA 8270C/D	Carbazole
GC/MS	EPA 8270C/D	Chlorobenzilate
GC/MS	EPA 8270C/D	Chrysene
GC/MS	EPA 8270C/D	Diallate
GC/MS	EPA 8270C/D	Dibenz(a h)anthracene
GC/MS	EPA 8270C/D	Dibenzo(a,j)acridine
GC/MS	EPA 8270C/D	Dibenzofuran
GC/MS	EPA 8270C/D	Diethyl phthalate
GC/MS	EPA 8270C/D	Diethyladipate
GC/MS	EPA 8270C/D	Dimethoate



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA 8270C/D	Dimethyl phthalate
GC/MS	EPA 8270C/D	Di-n-butyl phthalate
GC/MS	EPA 8270C/D	Di-n-octyl phthalate
GC/MS	EPA 8270C/D	Dinoseb
GC/MS	EPA 8270C/D	Disulfoton
GC/MS	EPA 8270C/D	Ethyl methacrylate
GC/MS	EPA 8270C/D	Ethyl methanesulfonate
GC/MS	EPA 8270C/D	Ethyl parathion
GC/MS	EPA 8270C/D	Famfur
GC/MS	EPA 8270C/D	Fluoranthene
GC/MS	EPA 8270C/D	Fluorene
GC/MS	EPA 8270C/D	Hexachlorobenzene
GC/MS	EPA 8270C/D	Hexachlorobutadiene
GC/MS	EPA 8270C/D	Hexachlorocyclopentadiene
GC/MS	EPA 8270C/D	Hexachloroethane
GC/MS	EPA 8270C/D	Hexachlorophene
GC/MS	EPA 8270C/D	Hexachloropropene
GC/MS	EPA 8270C/D	Indeno(1, 2, 3-cd)pyrene
GC/MS	EPA 8270C/D	Isodrin
GC/MS	EPA 8270C/D	Isophorone
GC/MS	EPA 8270C/D	Isosafrole
GC/MS	EPA 8270C/D	Kepone
GC/MS	EPA 8270C/D	Methapyriline
GC/MS	EPA 8270C/D	Methyl methanesulfonate
GC/MS	EPA 8270C/D	Methyl parathion
GC/MS	EPA 8270C/D	Naphthalene
GC/MS	EPA 8270C/D	Nitrobenzene
GC/MS	EPA 8270C/D	n-Nitrosodiethylamine
GC/MS	EPA 8270C/D	n-Nitrosodimethylamine
GC/MS	EPA 8270C/D	n-Nitroso-di-n-butylamine
GC/MS	EPA 8270C/D	n-Nitrosodi-n-propylamine



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8270C/D	n-Nitrosodiphenylamine
GC/MS	EPA 8270C/D	n-Nitrosomethylethylamine
GC/MS	EPA 8270C/D	n-Nitrosomorpholine
GC/MS	EPA 8270C/D	n-Nitrosopiperidine
GC/MS	EPA 8270C/D	n-Nitrosopyrrolidine
GC/MS	EPA 8270C/D	O, O, O-Triethyl phosphorothioate
GC/MS	EPA 8270C/D	o,o-Diethyl o-2-pyrazinyl phosphorothioate
GC/MS	EPA 8270C/D	o-Toluidine
GC/MS	EPA 8270C/D	Pentachlorobenzene
GC/MS	EPA 8270C/D	Pentachloronitrobenzene
GC/MS	EPA 8270C/D	Pentachlorophenol
GC/MS	EPA 8270C/D	Phenacetin
GC/MS	EPA 8270C/D	Phenanthrene
GC/MS	EPA 8270C/D	Phenol
GC/MS	EPA 8270C/D	Phorate
GC/MS	EPA 8270C/D	Pronamide
GC/MS	EPA 8270C/D	Pyrene
GC/MS	EPA 8270C/D	Pyridine
GC/MS	EPA 8270C/D	Safrole
GC/MS	EPA 8270C/D	Sulfotepp
GC/MS	EPA 8270C/D	Thionazin
GC/MS	EPA 8270C/D SIM	1,1'-Biphenyl
GC/MS	EPA 8270C/D SIM	1,2,4,5-Tetrachlorobenzene
GC/MS	EPA 8270C/D SIM	1,4-Dioxane
GC/MS	EPA 8270C/D SIM	1-Methylnaphthalene
GC/MS	EPA 8270C/D SIM	2,2'-Oxybis(1-chloropropane
GC/MS	EPA 8270C/D SIM	2,3,4,6-Tetrachlorophenol
GC/MS	EPA 8270C/D SIM	2,4,5-Trichlorophenol
GC/MS	EPA 8270C/D SIM	2,4,6-Trichlorophenol
GC/MS	EPA 8270C/D SIM	2,4-Dichlorophenol
GC/MS	EPA 8270C/D SIM	2,4-Dimethylphenol



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8270C/D SIM	2,4-Dinitrophenol
GC/MS	EPA 8270C/D SIM	2,4-Dinitrotoluene
GC/MS	EPA 8270C/D SIM	2,6-Dinitrotoluene
GC/MS	EPA 8270C/D SIM	2-Chloronaphthalene
GC/MS	EPA 8270C/D SIM	2-Chlorophenol
GC/MS	EPA 8270C/D SIM	2-Methylnaphthalene
GC/MS	EPA 8270C/D SIM	2-Methylphenol
GC/MS	EPA 8270C/D SIM	2-Nitroaniline
GC/MS	EPA 8270C/D SIM	2-Nitrophenol
GC/MS	EPA 8270C/D SIM	3&4-Methylphenol
GC/MS	EPA 8270C/D SIM	3,3'-Dichlorobenzidine
GC/MS	EPA 8270C/D SIM	3-Nitroaniline
GC/MS	EPA 8270C/D SIM	4,6-Dinitro-2-methylphenol
GC/MS	EPA 8270C/D SIM	4-Bromophenyl-phenylether
GC/MS	EPA 8270C/D SIM	4-Chloro-3-methylphenol
GC/MS	EPA 8270C/D SIM	4-Chloroaniline
GC/MS	EPA 8270C/D SIM	4-Chlorophenyl-phenylether
GC/MS	EPA 8270C/D SIM	4-Nitroaniline
GC/MS	EPA 8270C/D SIM	4-Nitrophenol
GC/MS	EPA 8270C/D SIM	Acenaphthene
GC/MS	EPA 8270C/D SIM	Acenaphthylene
GC/MS	EPA 8270C/D SIM	Acetophenone
GC/MS	EPA 8270C/D SIM	Anthracene
GC/MS	EPA 8270C/D SIM	Atrazine
GC/MS	EPA 8270C/D SIM	Benzaldehyde
GC/MS	EPA 8270C/D SIM	Benzo(a)anthracene
GC/MS	EPA 8270C/D SIM	Benzo(a)pyrene
GC/MS	EPA 8270C/D SIM	Benzo(b)fluoranthene
GC/MS	EPA 8270C/D SIM	Benzo(g,h,i)perylene
GC/MS	EPA 8270C/D SIM	Benzo(k)fluoranthene
GC/MS	EPA 8270C/D SIM	Bis(2-chloroethoxy)methane



Solid and Chemical Waste		
Technology	Method	Analyte
GC/MS	EPA 8270C/D SIM	Bis(2-chloroethyl)ether
GC/MS	EPA 8270C/D SIM	Bis(2-ethylhexyl)phthalate
GC/MS	EPA 8270C/D SIM	Butylbenzylphthalate
GC/MS	EPA 8270C/D SIM	Caprolactam
GC/MS	EPA 8270C/D SIM	Carbazole
GC/MS	EPA 8270C/D SIM	Chrysene
GC/MS	EPA 8270C/D SIM	Dibenzo(a,h)anthracene
GC/MS	EPA 8270C/D SIM	Dibenzofuran
GC/MS	EPA 8270C/D SIM	Diethylphthalate
GC/MS	EPA 8270C/D SIM	Dimethyl phthalate
GC/MS	EPA 8270C/D SIM	Di-n-butylphthalate
GC/MS	EPA 8270C/D SIM	Di-n-octylphthalate
GC/MS	EPA 8270C/D SIM	Fluoranthene
GC/MS	EPA 8270C/D SIM	Fluorene
GC/MS	EPA 8270C/D SIM	Hexachlorobenzene
GC/MS	EPA 8270C/D SIM	Hexachlorobutadiene
GC/MS	EPA 8270C/D SIM	Hexachlorocyclopentadiene
GC/MS	EPA 8270C/D SIM	Hexachloroethane
GC/MS	EPA 8270C/D SIM	Indeno(1,2,3-cd)pyrene
GC/MS	EPA 8270C/D SIM	Isophorone
GC/MS	EPA 8270C/D SIM	Naphthalene
GC/MS	EPA 8270C/D SIM	Nitrobenzene
GC/MS	EPA 8270C/D SIM	n-Nitroso-di-n-propylamine
GC/MS	EPA 8270C/D SIM	n-Nitrosodiphenylamine
GC/MS	EPA 8270C/D SIM	Pentachlorophenol
GC/MS	EPA 8270C/D SIM	Phenanthrene
GC/MS	EPA 8270C/D SIM	Phenol
GC/MS	EPA 8270C/D SIM	Pyrene
HPLC/UV	EPA 8330A	1,3,5-Trinitrobenzene
HPLC/UV	EPA 8330A	1,3-Dinitrobenzene
HPLC/UV	EPA 8330A	2,4,6-Trinitrotoluene



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
HPLC/UV	EPA 8330A	2, 4-Dinitrotoluene
HPLC/UV	EPA 8330A	2, 6-Dinitrotoluene
HPLC/UV	EPA 8330A	2-Amino-4, 6-dinitrotoluene
HPLC/UV	EPA 8330A	2-Nitrotoluene
HPLC/UV	EPA 8330A	3-Nitrotoluene
HPLC/UV	EPA 8330A	3,5-Dinitroaniline
HPLC/UV	EPA 8330A	4-Amino-2,6-dinitrotoluene
HPLC/UV	EPA 8330A	4-Nitrotoluene
HPLC/UV	EPA 8330A	Ethylene glycol dinitrate (EGDN)
HPLC/UV	EPA 8330A	Hexahydr-1, 3, 5-trinitro-1, 3, 5-triazine (RDX)
HPLC/UV	EPA 8330A	Nitrobenzene
HPLC/UV	EPA 8330A MOD	Nitroglycerin
HPLC/UV	EPA 8330A	Octahydro-1, 3, 5, 7-tetrazocine (HMX)
HPLC/UV	EPA 8330A	Pentaerythritol Tetranitrate (PETN)
HPLC/UV	EPA 8330A	Tetryl
HPLC/UV	8330B (W/O Soil Grinding)	1, 3, 5-Trinitrobenzene
HPLC/UV	8330B (W/O Soil Grinding)	1, 3-Dinitrobenzene
HPLC/UV	8330B (W/O Soil Grinding)	2, 4, 6-Trinitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	2, 4-Dinitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	2, 6-Dinitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	2-Amino-4, 6 -Dinitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	2-Nitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	3-Nitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	3,5-Dinitroaniline
HPLC/UV	8330B (W/O Soil Grinding)	4-Amino-2,3-Dinitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	4-Nitrotoluene
HPLC/UV	8330B (W/O Soil Grinding)	Ethylene glycol dinitrate (EGDN)
HPLC/UV	8330B (W/O Soil Grinding)	Hexahydr-1, 3, 5-trinitro-1, 3, 5-triazine (RDX)
HPLC/UV	8330B (W/O Soil Grinding)	Nitrobenzene
HPLC/UV	8330B (W/O Soil Grinding)	Nitroglycerin
HPLC/UV	8330B (W/O Soil Grinding)	Octahydro-1, 3, 5, 7-tetrazocine (HMX)



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
HPLC/UV	8330B (W/O Soil Grinding)	Pentaerythritol Tetranitrate (PETN)
HPLC/UV	8330B (W/O Soil Grinding)	Tetryl
CVAA	EPA 7471B	Mercury
CVAF	EPA 1631E	Low Level Mercury
ICP/AES	EPA 6010B/C	Aluminum
ICP/AES	EPA 6010B/C	Antimony
ICP/AES	EPA 6010B/C	Arsenic
ICP/AES	EPA 6010B/C	Barium
ICP/AES	EPA 6010B/C	Beryllium
ICP/AES	EPA 6010B/C	Boron
ICP/AES	EPA 6010B/C	Cadmium
ICP/AES	EPA 6010B/C	Calcium
ICP/AES	EPA 6010B/C	Chromium
ICP/AES	EPA 6010B/C	Cobalt
ICP/AES	EPA 6010B/C	Copper
ICP/AES	EPA 6010B/C	Iron
ICP/AES	EPA 6010B/C	Lead
ICP/AES	EPA 6010B/C	Magnesium
ICP/AES	EPA 6010B/C	Manganese
ICP/AES	EPA 6010B/C	Molybdenum
ICP/AES	EPA 6010B/C	Nickel
ICP/AES	EPA 6010B/C	Potassium
ICP/AES	EPA 6010B/C	Selenium
ICP/AES	EPA 6010B/C	Silicon
ICP/AES	EPA 6010B/C	Silver
ICP/AES	EPA 6010B/C	Sodium
ICP/AES	EPA 6010B/C	Strontium
ICP/AES	EPA 6010B/C	Thallium
ICP/AES	EPA 6010B/C	Tin
ICP/AES	EPA 6010B/C	Titanium
ICP/AES	EPA 6010B/C	Vanadium



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
ICP/AES	EPA 6010B/C	Zinc
ICP/MS	EPA 6020A	Aluminum
ICP/MS	EPA 6020A	Antimony
ICP/MS	EPA 6020A	Arsenic
ICP/MS	EPA 6020A	Barium
ICP/MS	EPA 6020A	Beryllium
ICP/MS	EPA 6020A	Boron
ICP/MS	EPA 6020A	Cadmium
ICP/MS	EPA 6020A	Calcium
ICP/MS	EPA 6020A	Chromium
ICP/MS	EPA 6020A	Cobalt
ICP/MS	EPA 6020A	Copper
ICP/MS	EPA 6020A	Iron
ICP/MS	EPA 6020A	Lead
ICP/MS	EPA 6020A	Magnesium
ICP/MS	EPA 6020A	Manganese
ICP/MS	EPA 6020A	Molybdenum
ICP/MS	EPA 6020A	Nickel
ICP/MS	EPA 6020A	Potassium
ICP/MS	EPA 6020A	Selenium
ICP/MS	EPA 6020A	Silver
ICP/MS	EPA 6020A	Sodium
ICP/MS	EPA 6020A	Strontium
ICP/MS	EPA 6020A	Thallium
ICP/MS	EPA 6020A	Tin
ICP/MS	EPA 6020A	Titanium
ICP/MS	EPA 6020A	Tungsten
ICP/MS	EPA 6020A	Vanadium
ICP/MS	EPA 6020A	Zinc
IC	EPA 9056A	Chloride
IC	EPA 9056A	Fluoride



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
IC	EPA 9056A	Nitrate as N
IC	EPA 9056A	Nitrite as N
IC	EPA 9056A	Orthophosphate
IC	EPA 9056A	Sulfate
Gravimetric	EPA 9071A; EPA 9071B	Oil and Grease, Oil and Grease with SGT
Physical	EPA 1010A	Ignitability
Physical	EPA 9045D	pH
Titration	EPA SW-846 Chapter 7.3.4	Reactive Sulfide
Titration	Walkley-Black	Total Organic Carbon
IR	Lloyd Kahn	Total organic carbon
Turbidimetric	EPA 9038; ASTM 516-02	Sulfate
UV/VIS	EPA 350.1; SM 4500NH3 H	Ammonia as N
UV/VIS	EPA 9251; SM 4500Cl E	Chloride
UV/VIS	EPA SW-846 Chapter 7.3.4	Reactive Cyanide
UV/VIS	EPA 821/R-91-100	AVS-SEM
UV/VIS	SM 3500Fe D	Ferrous Iron
Cleanup Methods	EPA 3630C	Silica Gel
UV/VIS	EPA 7196	Chromium VI
UV/VIS	EPA 7196A	Chromium VI
UV/VIS	EPA 9012B	Total cyanide
<b>Preparation</b>	<b>Method</b>	<b>Type</b>
Preparation	EPA 1311	Toxicity Characteristic Leaching Procedure
Preparation	EPA 1312	Synthetic Precipitation Leaching Procedure
Cleanup Methods	EPA 3660B	Sulfur Clean-up
Cleanup Methods	EPA 3620C	Florsil Clean-up
Cleanup Methods	EPA 3630C	Silica Gel Clean-up
Cleanup Methods	EPA 3640A	GPC Clean-up
Organic Preparation	EPA 3540C	Soxhlet Extraction
Organic Preparation	EPA 3545A	Pressurized Fluid Extraction
Organic Preparation	EPA 3546	Microwave Extraction Preparation for EPA 8082A, 8081B and 8270C, D



<b>Solid and Chemical Waste</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
Organic Preparation	EPA 3550C	Sonication
Inorganics Preparation	EPA 3050B	Hotblock
Inorganics Preparation	EPA 3060A	Alkaline Digestion
Volatile Organics Preparation	EPA 5035/5035A	Closed System Purge and Trap

<b>Air</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA TO-15	Propene
GC/MS	EPA TO-15	1, 1, 1-Trichloroethane
GC/MS	EPA TO-15	1, 1, 2, 2-Tetrachloroethane
GC/MS	EPA TO-15	1, 1, 2-Trichloroethane
GC/MS	EPA TO-15	1, 1-Dichloroethane
GC/MS	EPA TO-15	1, 1-Dichloroethylene
GC/MS	EPA TO-15	1, 2, 4-Trichlorobenzene
GC/MS	EPA TO-15	1, 2, 4-Trimethylbenzene
GC/MS	EPA TO-15	1, 2-Dibromoethane (EDB)
GC/MS	EPA TO-15	1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)
GC/MS	EPA TO-15	1, 2-Dichlorobenzene
GC/MS	EPA TO-15	1, 2-Dichloroethane
GC/MS	EPA TO-15	1, 2-Dichloroethenes (Total)
GC/MS	EPA TO-15	1, 2-Dichloropropane
GC/MS	EPA TO-15	1, 3, 5-Trimethylbenzene
GC/MS	EPA TO-15	1, 3-Butadiene
GC/MS	EPA TO-15	1, 3-Dichlorobenzene
GC/MS	EPA TO-15	1, 4-Dichlorobenzene
GC/MS	EPA TO-15	1,4-Difluorobenzene
GC/MS	EPA TO-15	1, 4-Dioxane
GC/MS	EPA TO-15	2-Butanone
GC/MS	EPA TO-15	2-Hexanone
GC/MS	EPA TO-15	2-Propanol



<b>Air</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA TO-15	4-Ethyltoluene
GC/MS	EPA TO-15	4-Methyl-2-pentanone
GC/MS	EPA TO-15	Acetone
GC/MS	EPA TO-15	Acrolein
GC/MS	EPA TO-15	Benzene
GC/MS	EPA TO-15	Benzyl chloride
GC/MS	EPA TO-15	Bromochloromethane
GC/MS	EPA TO-15	Bromodichloromethane
GC/MS	EPA TO-15	Bromoform
GC/MS	EPA TO-15	Carbon disulfide
GC/MS	EPA TO-15	Carbon tetrachloride
GC/MS	EPA TO-15	Chlorobenzene
GC/MS	EPA TO-15	Chloroethane
GC/MS	EPA TO-15	Chloroform
GC/MS	EPA TO-15	Cis-1, 2-Dichloroethene
GC/MS	EPA TO-15	Cis-1, 3-Dichloropropene
GC/MS	EPA TO-15	Cyclohexane
GC/MS	EPA TO-15	Dibromochloromethane
GC/MS	EPA TO-15	Dichlorodifluoromethane (Freon 12)
GC/MS	EPA TO-15	Ethanol
GC/MS	EPA TO-15	Ethyl acetate
GC/MS	EPA TO-15	Ethylbenzene
GC/MS	EPA TO-15	Hexachlorobutadiene
GC/MS	EPA TO-15	Isopropyl alcohol
GC/MS	EPA TO-15	m, p-Xylene
GC/MS	EPA TO-15	Methyl bromide (Bromomethane)
GC/MS	EPA TO-15	Methyl chloride (Chloromethane)
GC/MS	EPA TO-15	Methyl methacrylate
GC/MS	EPA TO-15	Methyl tert-butyl ether
GC/MS	EPA TO-15	Methylene chloride
GC/MS	EPA TO-15	Naphthalene

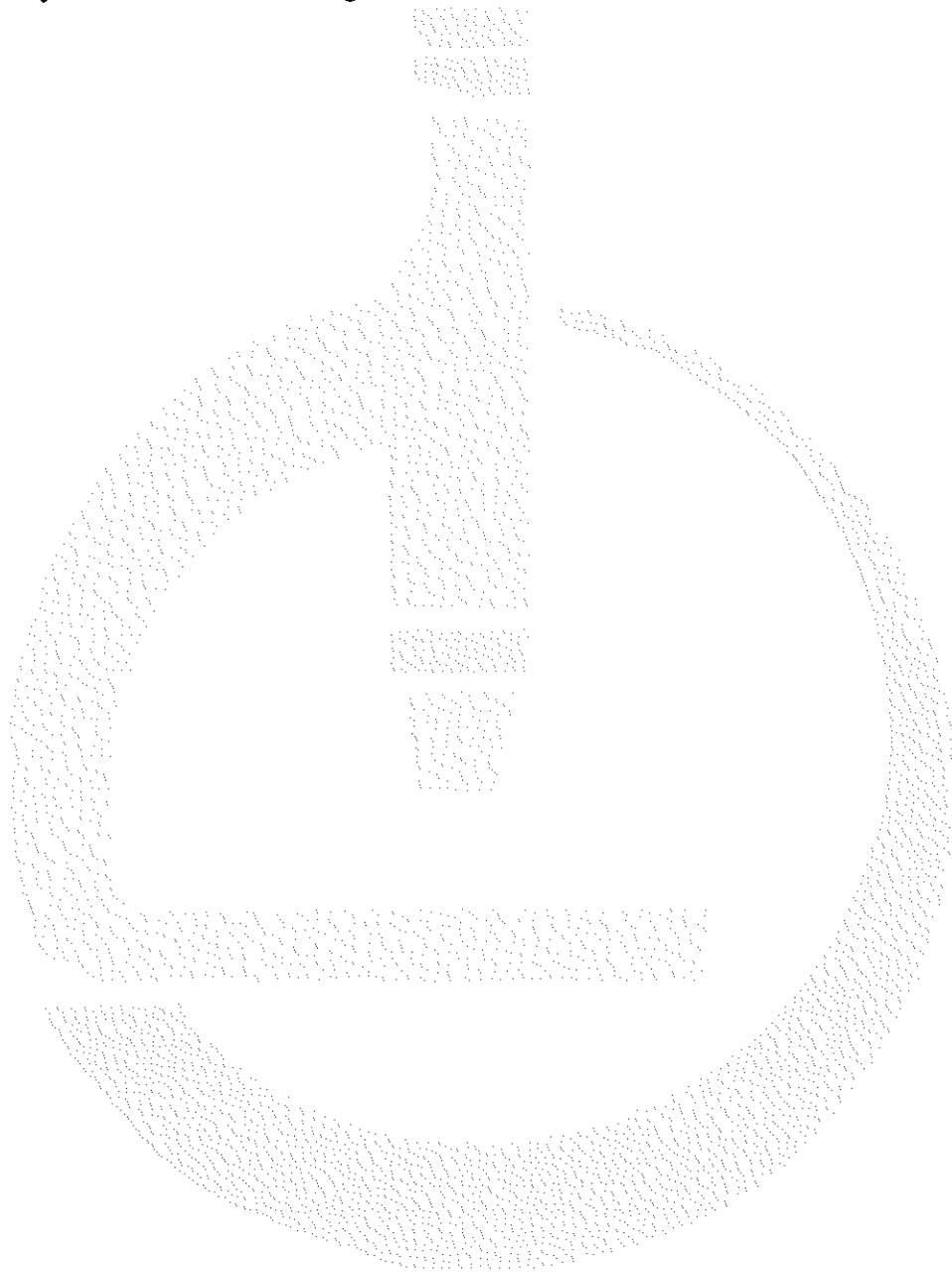


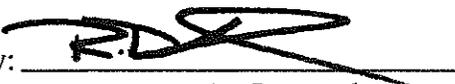
<b>Air</b>		
<b>Technology</b>	<b>Method</b>	<b>Analyte</b>
GC/MS	EPA TO-15	n-Heptane
GC/MS	EPA TO-15	n-Hexane
GC/MS	EPA TO-15	o-Xylene
GC/MS	EPA TO-15	Styrene
GC/MS	EPA TO-15	Tetrachloroethylene (Perchloroethylene)
GC/MS	EPA TO-15	Tetrahydrofuran
GC/MS	EPA TO-15	Toluene
GC/MS	EPA TO-15	trans-1, 2-Dichloroethylene
GC/MS	EPA TO-15	trans-1, 3-Dichloropropylene
GC/MS	EPA TO-15	Trichloroethene (Trichloroethylene)
GC/MS	EPA TO-15	Trichlorofluoromethane (Freon 11)
GC/MS	EPA TO-15	1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)
GC/MS	EPA TO-15	Vinyl acetate
GC/MS	EPA TO-15	Vinyl chloride
GC/MS	EPA TO-15	Xylenes (Total)
GC/MS	MA DEP APH	Aliphatic C5-C8 range
GC/MS	MA DEP APH	Aliphatic C9-C12 range
GC/MS	MA DEP APH	Aromatic C9-C10 range
GC/MS	MA DEP APH	1,3-Butadiene
GC/MS	MA DEP APH	Benzene
GC/MS	MA DEP APH	Ethylbenzene
GC/MS	MA DEP APH	m+p-Xylene
GC/MS	MA DEP APH	Methyl tert-butyl ether
GC/MS	MA DEP APH	Naphthalene
GC/MS	MA DEP APH	o-Xylene
GC/MS	MA DEP APH	Toluene



Notes:

- 1) This laboratory offers commercial testing service.



Approved by:   
R. Douglas Leonard  
Chief Technical Officer

Date: November 19, 2013

Re-issued: 2/1/13    Revised: 3/13/13    Revised: 11/19/13

*State of Maine*

*Laboratory Certification Program*

Awards Certification To

*Katahdin Analytical Services*

Located at

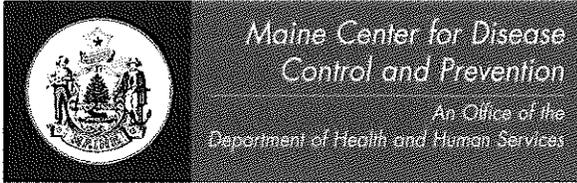
*600 Technology Way  
Scarborough, ME, 04074*

For the demonstration of capability of performing the analyses listed on the attached certified analytes list(s) as required by 22 M.R.S.A., Chapter 157-A.

Laboratory ID: ME00019  
Certificate Number: 2012018  
Date of Issue: 4/13/2012  
Expiration Date: 6/1/2014

  
\_\_\_\_\_  
Certification Officer

This certificate must be displayed with the corresponding analyte list.  
This certificate supersedes all previously issued certificates.  
Continuing certification status is dependent on successful ongoing participation in the program.  
Customers may verify the laboratory's current certification status by calling (207) 287-1929.



Department of Health and Human Services  
 Maine Center for Disease Control and Prevention  
 286 Water Street  
 # 11 State House Station  
 Augusta, Maine 04333-0011  
 Tel: (207) 287-1929; Fax: (207) 287-4172

**Field of Testing Summary for:**

**Katahdin Analytical Services**

(207) 874-2400

600 Technology Way  
 Scarborough ME 04074

As required by 22 M.R.S.A Chapter 157-A the laboratory demonstrated the capability to analyze analytes under 10-144 CMR 263, the rules for laboratory certification and is hereby granted certification for:

ASTM D516-02

Sulfate	Clean Water Program (NPW)
<u>EPA 1010A</u>	
Ignitability	Resource Conservation Recovery Program (NPW)
Ignitability	Resource Conservation Recovery Program (S)
<u>EPA 120.1</u>	
Conductivity	Clean Water Program (NPW)
<u>EPA 1311</u>	
Extraction/Preparation	Resource Conservation Recovery Program (NPW)
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 1312</u>	
Extraction/Preparation	Resource Conservation Recovery Program (NPW)
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 1631E</u>	
Mercury	Clean Water Program (NPW)
<u>EPA 1664A</u>	
Oil & Grease	Clean Water Program (NPW)
<u>EPA 1664A (HEM)</u>	
n-Hexane Extractable Material (O&G)	Clean Water Program (NPW)
<u>EPA 180.1.2</u>	
Turbidity	Safe Drinking Water Program (DW)
<u>EPA 200.7.4.4</u>	
Aluminum	Clean Water Program (NPW)
Aluminum	Safe Drinking Water Program (DW)
Antimony	Clean Water Program (NPW)
Arsenic	Clean Water Program (NPW)
Barium	Clean Water Program (NPW)
Barium	Safe Drinking Water Program (DW)
Beryllium	Clean Water Program (NPW)
Beryllium	Safe Drinking Water Program (DW)
Boron	Clean Water Program (NPW)
Cadmium	Clean Water Program (NPW)
Cadmium	Safe Drinking Water Program (DW)
Calcium	Clean Water Program (NPW)
Calcium	Safe Drinking Water Program (DW)
Chromium	Clean Water Program (NPW)
Chromium	Safe Drinking Water Program (DW)
Cobalt	Clean Water Program (NPW)
Copper	Clean Water Program (NPW)
Copper	Safe Drinking Water Program (DW)
Iron	Clean Water Program (NPW)
Iron	Safe Drinking Water Program (DW)

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Bromide	Clean Water Program (NPW)
Bromide	Safe Drinking Water Program (DW)
Chloride	Clean Water Program (NPW)
Chloride	Safe Drinking Water Program (DW)
Fluoride	Clean Water Program (NPW)
Fluoride	Safe Drinking Water Program (DW)
Nitrate as N	Clean Water Program (NPW)
Nitrate as N	Safe Drinking Water Program (DW)
Nitrite as N	Clean Water Program (NPW)
Nitrite as N	Safe Drinking Water Program (DW)
Orthophosphate as P	Clean Water Program (NPW)
Orthophosphate as P	Safe Drinking Water Program (DW)
Sulfate	Clean Water Program (NPW)
Sulfate	Safe Drinking Water Program (DW)
<u>EPA 3005A</u>	
Extraction/Preparation	Resource Conservation Recovery Program (NPW)
<u>EPA 3050A</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3050B</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3060A</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 335.4</u>	
Total Cyanide	Clean Water Program (NPW)
Total Cyanide	Safe Drinking Water Program (DW)
<u>EPA 350.1.2</u>	
Ammonia as N	Clean Water Program (NPW)
<u>EPA 351.2.2</u>	
Kjeldahl nitrogen - total	Clean Water Program (NPW)
<u>EPA 3510C</u>	
Extraction/Preparation	Resource Conservation Recovery Program (NPW)
<u>EPA 3520C</u>	
Extraction/Preparation	Resource Conservation Recovery Program (NPW)
<u>EPA 353.2.2</u>	
Nitrate as N	Clean Water Program (NPW)
Nitrate as N	Safe Drinking Water Program (DW)
Nitrite as N	Clean Water Program (NPW)
Nitrite as N	Safe Drinking Water Program (DW)
<u>EPA 3540C</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3545A</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3546</u>	
Extraction/Preparation	Resource Conservation Recovery Program (NPW)
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3550C</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3580A</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 3640A</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 365.4</u>	
Phosphorus, total	Clean Water Program (NPW)
<u>EPA 3660B</u>	
Extraction/Preparation	Resource Conservation Recovery Program (S)
<u>EPA 410.4.2</u>	
Chemical oxygen demand	Clean Water Program (NPW)
<u>EPA 420.1</u>	
Total Phenolics	Clean Water Program (NPW)

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Molybdenum	Resource Conservation Recovery Program (S)
Nickel	Resource Conservation Recovery Program (NPW)
Nickel	Resource Conservation Recovery Program (S)
Potassium	Resource Conservation Recovery Program (NPW)
Potassium	Resource Conservation Recovery Program (S)
Selenium	Resource Conservation Recovery Program (NPW)
Selenium	Resource Conservation Recovery Program (S)
Silicon	Resource Conservation Recovery Program (NPW)
Silicon	Resource Conservation Recovery Program (S)
Silver	Resource Conservation Recovery Program (NPW)
Silver	Resource Conservation Recovery Program (S)
Sodium	Resource Conservation Recovery Program (NPW)
Sodium	Resource Conservation Recovery Program (S)
Strontium	Resource Conservation Recovery Program (NPW)
Strontium	Resource Conservation Recovery Program (S)
Thallium	Resource Conservation Recovery Program (NPW)
Thallium	Resource Conservation Recovery Program (S)
Tin	Resource Conservation Recovery Program (NPW)
Tin	Resource Conservation Recovery Program (S)
Titanium	Resource Conservation Recovery Program (NPW)
Titanium	Resource Conservation Recovery Program (S)
Vanadium	Resource Conservation Recovery Program (NPW)
Vanadium	Resource Conservation Recovery Program (S)
Zinc	Resource Conservation Recovery Program (NPW)
Zinc	Resource Conservation Recovery Program (S)
<b>EPA 6020</b>	
Aluminum	Resource Conservation Recovery Program (NPW)
Aluminum	Resource Conservation Recovery Program (S)
Antimony	Resource Conservation Recovery Program (NPW)
Antimony	Resource Conservation Recovery Program (S)
Arsenic	Resource Conservation Recovery Program (NPW)
Arsenic	Resource Conservation Recovery Program (S)
Barium	Resource Conservation Recovery Program (NPW)
Barium	Resource Conservation Recovery Program (S)
Beryllium	Resource Conservation Recovery Program (NPW)
Beryllium	Resource Conservation Recovery Program (S)
Boron	Resource Conservation Recovery Program (NPW)
Boron	Resource Conservation Recovery Program (S)
Cadmium	Resource Conservation Recovery Program (NPW)
Cadmium	Resource Conservation Recovery Program (S)
Calcium	Resource Conservation Recovery Program (NPW)
Calcium	Resource Conservation Recovery Program (S)
Chromium	Resource Conservation Recovery Program (NPW)
Chromium	Resource Conservation Recovery Program (S)
Cobalt	Resource Conservation Recovery Program (NPW)
Cobalt	Resource Conservation Recovery Program (S)
Copper	Resource Conservation Recovery Program (NPW)
Copper	Resource Conservation Recovery Program (S)
Iron	Resource Conservation Recovery Program (NPW)
Iron	Resource Conservation Recovery Program (S)
Lead	Resource Conservation Recovery Program (NPW)
Lead	Resource Conservation Recovery Program (S)
Magnesium	Resource Conservation Recovery Program (NPW)
Magnesium	Resource Conservation Recovery Program (S)
Manganese	Resource Conservation Recovery Program (NPW)
Manganese	Resource Conservation Recovery Program (S)
Molybdenum	Resource Conservation Recovery Program (NPW)
Molybdenum	Resource Conservation Recovery Program (S)
Nickel	Resource Conservation Recovery Program (NPW)
Nickel	Resource Conservation Recovery Program (S)
Potassium	Resource Conservation Recovery Program (NPW)

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Potassium	Resource Conservation Recovery Program (S)
Selenium	Resource Conservation Recovery Program (NPW)
Selenium	Resource Conservation Recovery Program (S)
Silver	Resource Conservation Recovery Program (NPW)
Silver	Resource Conservation Recovery Program (S)
Sodium	Resource Conservation Recovery Program (NPW)
Sodium	Resource Conservation Recovery Program (S)
Strontium	Resource Conservation Recovery Program (NPW)
Strontium	Resource Conservation Recovery Program (S)
Thallium	Resource Conservation Recovery Program (NPW)
Thallium	Resource Conservation Recovery Program (S)
Tin	Resource Conservation Recovery Program (NPW)
Tin	Resource Conservation Recovery Program (S)
Uranium	Resource Conservation Recovery Program (NPW)
Uranium	Resource Conservation Recovery Program (S)
Vanadium	Resource Conservation Recovery Program (NPW)
Vanadium	Resource Conservation Recovery Program (S)
Zinc	Resource Conservation Recovery Program (NPW)
Zinc	Resource Conservation Recovery Program (S)
<b><u>EPA 6020A</u></b>	
Aluminum	Resource Conservation Recovery Program (NPW)
Aluminum	Resource Conservation Recovery Program (S)
Antimony	Resource Conservation Recovery Program (NPW)
Antimony	Resource Conservation Recovery Program (S)
Arsenic	Resource Conservation Recovery Program (NPW)
Arsenic	Resource Conservation Recovery Program (S)
Barium	Resource Conservation Recovery Program (NPW)
Barium	Resource Conservation Recovery Program (S)
Beryllium	Resource Conservation Recovery Program (NPW)
Beryllium	Resource Conservation Recovery Program (S)
Boron	Resource Conservation Recovery Program (NPW)
Boron	Resource Conservation Recovery Program (S)
Cadmium	Resource Conservation Recovery Program (NPW)
Cadmium	Resource Conservation Recovery Program (S)
Calcium	Resource Conservation Recovery Program (NPW)
Calcium	Resource Conservation Recovery Program (S)
Chromium	Resource Conservation Recovery Program (NPW)
Chromium	Resource Conservation Recovery Program (S)
Cobalt	Resource Conservation Recovery Program (NPW)
Cobalt	Resource Conservation Recovery Program (S)
Copper	Resource Conservation Recovery Program (NPW)
Copper	Resource Conservation Recovery Program (S)
Iron	Resource Conservation Recovery Program (NPW)
Iron	Resource Conservation Recovery Program (S)
Lead	Resource Conservation Recovery Program (NPW)
Lead	Resource Conservation Recovery Program (S)
Magnesium	Resource Conservation Recovery Program (NPW)
Magnesium	Resource Conservation Recovery Program (S)
Manganese	Resource Conservation Recovery Program (NPW)
Manganese	Resource Conservation Recovery Program (S)
Molybdenum	Resource Conservation Recovery Program (NPW)
Molybdenum	Resource Conservation Recovery Program (S)
Nickel	Resource Conservation Recovery Program (NPW)
Nickel	Resource Conservation Recovery Program (S)
Potassium	Resource Conservation Recovery Program (NPW)
Potassium	Resource Conservation Recovery Program (S)
Selenium	Resource Conservation Recovery Program (NPW)
Selenium	Resource Conservation Recovery Program (S)
Silicon	Resource Conservation Recovery Program (NPW)
Silicon	Resource Conservation Recovery Program (S)
Silver	Resource Conservation Recovery Program (NPW)

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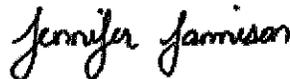
Silver	Resource Conservation Recovery Program (S)
Sodium	Resource Conservation Recovery Program (NPW)
Sodium	Resource Conservation Recovery Program (S)
Strontium	Resource Conservation Recovery Program (NPW)
Strontium	Resource Conservation Recovery Program (S)
Thallium	Resource Conservation Recovery Program (NPW)
Thallium	Resource Conservation Recovery Program (S)
Tin	Resource Conservation Recovery Program (NPW)
Tin	Resource Conservation Recovery Program (S)
Uranium	Resource Conservation Recovery Program (NPW)
Uranium	Resource Conservation Recovery Program (S)
Vanadium	Resource Conservation Recovery Program (NPW)
Vanadium	Resource Conservation Recovery Program (S)
Zinc	Resource Conservation Recovery Program (NPW)
Zinc	Resource Conservation Recovery Program (S)
<b>EPA 608</b>	
4,4'-DDD	Clean Water Program (NPW)
4,4'-DDE	Clean Water Program (NPW)
4,4'-DDT	Clean Water Program (NPW)
Aldrin	Clean Water Program (NPW)
alpha-BHC	Clean Water Program (NPW)
Aroclor-1016 (PCB-1016)	Clean Water Program (NPW)
Aroclor-1221 (PCB-1221)	Clean Water Program (NPW)
Aroclor-1232 (PCB-1232)	Clean Water Program (NPW)
Aroclor-1242 (PCB-1242)	Clean Water Program (NPW)
Aroclor-1248 (PCB-1248)	Clean Water Program (NPW)
Aroclor-1254 (PCB-1254)	Clean Water Program (NPW)
Aroclor-1260 (PCB-1260)	Clean Water Program (NPW)
beta-BHC	Clean Water Program (NPW)
Chlordane (tech.)	Clean Water Program (NPW)
delta-BHC	Clean Water Program (NPW)
Dieldrin	Clean Water Program (NPW)
Endosulfan I	Clean Water Program (NPW)
Endosulfan II	Clean Water Program (NPW)
Endosulfan sulfate	Clean Water Program (NPW)
Endrin	Clean Water Program (NPW)
Endrin aldehyde	Clean Water Program (NPW)
gamma-BHC	Clean Water Program (NPW)
Heptachlor	Clean Water Program (NPW)
Heptachlor epoxide	Clean Water Program (NPW)
Toxaphene	Clean Water Program (NPW)
<b>EPA 624</b>	
1,1,1-Trichloroethane	Clean Water Program (NPW)
1,1,2,2-Tetrachloroethane	Clean Water Program (NPW)
1,1,2-Trichloroethane	Clean Water Program (NPW)
1,1-Dichloroethane	Clean Water Program (NPW)
1,1-Dichloroethylene	Clean Water Program (NPW)
1,2-Dichlorobenzene	Clean Water Program (NPW)
1,2-Dichloroethane	Clean Water Program (NPW)
1,2-Dichloropropane	Clean Water Program (NPW)
1,3-Dichlorobenzene	Clean Water Program (NPW)
1,4-Dichlorobenzene	Clean Water Program (NPW)
2-Chloroethyl vinyl ether	Clean Water Program (NPW)
Acrolein	Clean Water Program (NPW)
Acrylonitrile	Clean Water Program (NPW)
Benzene	Clean Water Program (NPW)
Bromodichloromethane	Clean Water Program (NPW)
Bromoform	Clean Water Program (NPW)
Bromomethane (Methyl bromide)	Clean Water Program (NPW)
Carbon tetrachloride	Clean Water Program (NPW)
Chlorobenzene	Clean Water Program (NPW)

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Chloroethane	Clean Water Program (NPW)
Chloroform	Clean Water Program (NPW)
cis-1,3-Dichloropropene	Clean Water Program (NPW)
Dibromochloromethane	Clean Water Program (NPW)
Dichlorodifluoromethane	Clean Water Program (NPW)
Dichloromethane (Methylene chloride)	Clean Water Program (NPW)
Ethylbenzene	Clean Water Program (NPW)
Methyl chloride (Chloromethane)	Clean Water Program (NPW)
Tetrachloroethylene	Clean Water Program (NPW)
Toluene	Clean Water Program (NPW)
trans-1,2-Dichloroethylene	Clean Water Program (NPW)
trans-1,3-Dichloropropylene	Clean Water Program (NPW)
Trichloroethene (Trichloroethylene)	Clean Water Program (NPW)
Trichlorofluoromethane	Clean Water Program (NPW)
Vinyl chloride	Clean Water Program (NPW)

**EPA 825**

1,2,4-Trichlorobenzene	Clean Water Program (NPW)
1,2-Diphenylhydrazine	Clean Water Program (NPW)
2,4,6-Trichlorophenol	Clean Water Program (NPW)
2,4-Dichlorophenol	Clean Water Program (NPW)
2,4-Dimethylphenol	Clean Water Program (NPW)
2,4-Dinitrophenol	Clean Water Program (NPW)
2,4-Dinitrotoluene (2,4-DNT)	Clean Water Program (NPW)
2,6-Dinitrotoluene (2,6-DNT)	Clean Water Program (NPW)
2-Chloronaphthalene	Clean Water Program (NPW)
2-Chlorophenol	Clean Water Program (NPW)
2-Nitrophenol	Clean Water Program (NPW)
3,3'-Dichlorobenzidine	Clean Water Program (NPW)
4,6-Dinitro-2-methylphenol	Clean Water Program (NPW)
4-Bromophenyl phenyl ether	Clean Water Program (NPW)
4-Chloro-3-methylphenol	Clean Water Program (NPW)
4-Chlorophenyl phenylether	Clean Water Program (NPW)
4-Nitrophenol	Clean Water Program (NPW)
Acenaphthene	Clean Water Program (NPW)
Acenaphthylene	Clean Water Program (NPW)
Anthracene	Clean Water Program (NPW)
Benzdine	Clean Water Program (NPW)
Benzo[a]anthracene	Clean Water Program (NPW)
Benzo[a]pyrene	Clean Water Program (NPW)
Benzo[b]fluoranthene	Clean Water Program (NPW)
Benzo[g,h,i]perylene	Clean Water Program (NPW)
Benzo[k]fluoranthene	Clean Water Program (NPW)
bis(2-Chloroethoxy)methane	Clean Water Program (NPW)
bis(2-Chloroethyl)ether	Clean Water Program (NPW)
bis(2-Chloroisopropyl)ether	Clean Water Program (NPW)
bis(2-Ethylhexyl)phthalate (DEHP)	Clean Water Program (NPW)
Butyl benzyl phthalate	Clean Water Program (NPW)
Chrysene	Clean Water Program (NPW)
Dibenz[a,h]anthracene	Clean Water Program (NPW)
Diethyl phthalate	Clean Water Program (NPW)
Dimethyl phthalate	Clean Water Program (NPW)
Di-n-butyl phthalate	Clean Water Program (NPW)
Di-n-octyl phthalate	Clean Water Program (NPW)
Fluoranthene	Clean Water Program (NPW)
Fluorene	Clean Water Program (NPW)
Hexachlorobenzene	Clean Water Program (NPW)
Hexachlorobutadiene	Clean Water Program (NPW)
Hexachlorocyclopentadiene	Clean Water Program (NPW)
Hexachloroethane	Clean Water Program (NPW)
Indeno[1,2,3-cd]pyrene	Clean Water Program (NPW)
Isophorone	Clean Water Program (NPW)

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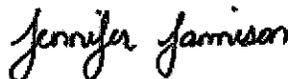
  
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Naphthalene	Clean Water Program (NPW)
Nitrobenzene	Clean Water Program (NPW)
n-Nitrosodimethylamine	Clean Water Program (NPW)
n-Nitroso-di-n-propylamine	Clean Water Program (NPW)
n-Nitrosodiphenylamine	Clean Water Program (NPW)
Pentachlorophenol	Clean Water Program (NPW)
Phenanthrene	Clean Water Program (NPW)
Phenol	Clean Water Program (NPW)
Pyrene	Clean Water Program (NPW)
<b><u>EPA 7196A 1</u></b>	
Chromium VI	Resource Conservation Recovery Program (NPW)
Chromium VI	Resource Conservation Recovery Program (S)
<b><u>EPA 7470A</u></b>	
Mercury	Resource Conservation Recovery Program (NPW)
<b><u>EPA 7471A</u></b>	
Mercury	Resource Conservation Recovery Program (S)
<b><u>EPA 7471B</u></b>	
Mercury	Resource Conservation Recovery Program (S)
<b><u>EPA 8011</u></b>	
1,2-Dibromoethane (EDB, Ethylene dibromide)	Resource Conservation Recovery Program (NPW)
1,2-Dibromoethane (EDB, Ethylene dibromide)	Resource Conservation Recovery Program (S)
Dibromochloropropane	Resource Conservation Recovery Program (NPW)
Dibromochloropropane	Resource Conservation Recovery Program (S)
<b><u>EPA 8015B</u></b>	
Ethylene glycol	Resource Conservation Recovery Program (S)
Propylene Glycol	Resource Conservation Recovery Program (NPW)
Propylene Glycol	Resource Conservation Recovery Program (S)
<b><u>EPA 8015C</u></b>	
Ethanol	Resource Conservation Recovery Program (NPW)
Ethylene glycol	Resource Conservation Recovery Program (NPW)
Ethylene glycol	Resource Conservation Recovery Program (S)
Isopropanol	Resource Conservation Recovery Program (NPW)
Methanol	Resource Conservation Recovery Program (NPW)
<b><u>EPA 8081A</u></b>	
4,4'-DDD	Resource Conservation Recovery Program (NPW)
4,4'-DDD	Resource Conservation Recovery Program (S)
4,4'-DDE	Resource Conservation Recovery Program (NPW)
4,4'-DDE	Resource Conservation Recovery Program (S)
4,4'-DDT	Resource Conservation Recovery Program (NPW)
4,4'-DDT	Resource Conservation Recovery Program (S)
Aldrin	Resource Conservation Recovery Program (NPW)
Aldrin	Resource Conservation Recovery Program (S)
alpha-BHC	Resource Conservation Recovery Program (NPW)
alpha-BHC	Resource Conservation Recovery Program (S)
alpha-Chlordane	Resource Conservation Recovery Program (NPW)
alpha-Chlordane	Resource Conservation Recovery Program (S)
beta-BHC	Resource Conservation Recovery Program (NPW)
beta-BHC	Resource Conservation Recovery Program (S)
Chlordane (tech.)	Resource Conservation Recovery Program (NPW)
Chlordane (tech.)	Resource Conservation Recovery Program (S)
delta-BHC	Resource Conservation Recovery Program (NPW)
delta-BHC	Resource Conservation Recovery Program (S)
Dieldrin	Resource Conservation Recovery Program (NPW)
Dieldrin	Resource Conservation Recovery Program (S)
Endosulfan I	Resource Conservation Recovery Program (NPW)
Endosulfan I	Resource Conservation Recovery Program (S)
Endosulfan II	Resource Conservation Recovery Program (NPW)
Endosulfan II	Resource Conservation Recovery Program (S)
Endosulfan sulfate	Resource Conservation Recovery Program (NPW)
Endosulfan sulfate	Resource Conservation Recovery Program (S)

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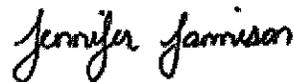
  
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Endrin	Resource Conservation Recovery Program (NPW)
Endrin	Resource Conservation Recovery Program (S)
Endrin aldehyde	Resource Conservation Recovery Program (NPW)
Endrin aldehyde	Resource Conservation Recovery Program (S)
Endrin ketone	Resource Conservation Recovery Program (NPW)
Endrin ketone	Resource Conservation Recovery Program (S)
gamma-BHC	Resource Conservation Recovery Program (NPW)
gamma-BHC	Resource Conservation Recovery Program (S)
gamma-Chlordane	Resource Conservation Recovery Program (NPW)
gamma-Chlordane	Resource Conservation Recovery Program (S)
Heptachlor	Resource Conservation Recovery Program (NPW)
Heptachlor	Resource Conservation Recovery Program (S)
Heptachlor epoxide	Resource Conservation Recovery Program (NPW)
Heptachlor epoxide	Resource Conservation Recovery Program (S)
Methoxychlor	Resource Conservation Recovery Program (NPW)
Methoxychlor	Resource Conservation Recovery Program (S)
Toxaphene	Resource Conservation Recovery Program (NPW)
Toxaphene	Resource Conservation Recovery Program (S)
<b>EPA 8081B</b>	
4,4'-DDD	Resource Conservation Recovery Program (NPW)
4,4'-DDD	Resource Conservation Recovery Program (S)
4,4'-DDE	Resource Conservation Recovery Program (NPW)
4,4'-DDE	Resource Conservation Recovery Program (S)
4,4'-DDT	Resource Conservation Recovery Program (NPW)
4,4'-DDT	Resource Conservation Recovery Program (S)
Aldrin	Resource Conservation Recovery Program (NPW)
Aldrin	Resource Conservation Recovery Program (S)
alpha-BHC	Resource Conservation Recovery Program (NPW)
alpha-BHC	Resource Conservation Recovery Program (S)
alpha-Chlordane	Resource Conservation Recovery Program (NPW)
alpha-Chlordane	Resource Conservation Recovery Program (S)
beta-BHC	Resource Conservation Recovery Program (NPW)
beta-BHC	Resource Conservation Recovery Program (S)
Chlordane (tech.)	Resource Conservation Recovery Program (NPW)
Chlordane (tech.)	Resource Conservation Recovery Program (S)
delta-BHC	Resource Conservation Recovery Program (NPW)
delta-BHC	Resource Conservation Recovery Program (S)
Dieldrin	Resource Conservation Recovery Program (NPW)
Dieldrin	Resource Conservation Recovery Program (S)
Endosulfan I	Resource Conservation Recovery Program (NPW)
Endosulfan I	Resource Conservation Recovery Program (S)
Endosulfan II	Resource Conservation Recovery Program (NPW)
Endosulfan II	Resource Conservation Recovery Program (S)
Endosulfan sulfate	Resource Conservation Recovery Program (NPW)
Endosulfan sulfate	Resource Conservation Recovery Program (S)
Endrin	Resource Conservation Recovery Program (NPW)
Endrin	Resource Conservation Recovery Program (S)
Endrin aldehyde	Resource Conservation Recovery Program (NPW)
Endrin aldehyde	Resource Conservation Recovery Program (S)
Endrin ketone	Resource Conservation Recovery Program (NPW)
Endrin ketone	Resource Conservation Recovery Program (S)
gamma-BHC	Resource Conservation Recovery Program (NPW)
gamma-BHC	Resource Conservation Recovery Program (S)
gamma-Chlordane	Resource Conservation Recovery Program (NPW)
gamma-Chlordane	Resource Conservation Recovery Program (S)
Heptachlor	Resource Conservation Recovery Program (NPW)
Heptachlor	Resource Conservation Recovery Program (S)
Heptachlor epoxide	Resource Conservation Recovery Program (NPW)
Heptachlor epoxide	Resource Conservation Recovery Program (S)
Methoxychlor	Resource Conservation Recovery Program (NPW)
Methoxychlor	Resource Conservation Recovery Program (S)

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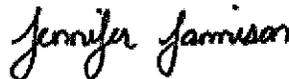
Dalapon	Resource Conservation Recovery Program (S)
Dicamba	Resource Conservation Recovery Program (NPW)
Dicamba	Resource Conservation Recovery Program (S)
Dichloroprop	Resource Conservation Recovery Program (NPW)
Dichloroprop	Resource Conservation Recovery Program (S)
Dinoseb	Resource Conservation Recovery Program (NPW)
Dinoseb	Resource Conservation Recovery Program (S)
MCPA	Resource Conservation Recovery Program (NPW)
MCPA	Resource Conservation Recovery Program (S)
MCPP	Resource Conservation Recovery Program (NPW)
MCPP	Resource Conservation Recovery Program (S)
Pentachlorophenol	Resource Conservation Recovery Program (NPW)
Pentachlorophenol	Resource Conservation Recovery Program (S)
Sivex (2,4,5-TP)	Resource Conservation Recovery Program (NPW)
Sivex (2,4,5-TP)	Resource Conservation Recovery Program (S)
<b>EPA 8260B</b>	
1,1,1,2-Tetrachloroethane	Resource Conservation Recovery Program (NPW)
1,1,1,2-Tetrachloroethane	Resource Conservation Recovery Program (S)
1,1,1-Trichloroethane	Resource Conservation Recovery Program (NPW)
1,1,1-Trichloroethane	Resource Conservation Recovery Program (S)
1,1,2,2-Tetrachloroethane	Resource Conservation Recovery Program (NPW)
1,1,2,2-Tetrachloroethane	Resource Conservation Recovery Program (S)
1,1,2-Trichloro-1,2,2-trifluoroethane	Resource Conservation Recovery Program (NPW)
1,1,2-Trichloro-1,2,2-trifluoroethane	Resource Conservation Recovery Program (S)
1,1,2-Trichloroethane	Resource Conservation Recovery Program (NPW)
1,1,2-Trichloroethane	Resource Conservation Recovery Program (S)
1,1-Dichloroethane	Resource Conservation Recovery Program (NPW)
1,1-Dichloroethane	Resource Conservation Recovery Program (S)
1,1-Dichloroethylene	Resource Conservation Recovery Program (NPW)
1,1-Dichloroethylene	Resource Conservation Recovery Program (S)
1,1-Dichloropropene	Resource Conservation Recovery Program (NPW)
1,1-Dichloropropene	Resource Conservation Recovery Program (S)
1,2,3-Trichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2,3-Trichlorobenzene	Resource Conservation Recovery Program (S)
1,2,3-Trichloropropane	Resource Conservation Recovery Program (NPW)
1,2,3-Trichloropropane	Resource Conservation Recovery Program (S)
1,2,4-Trichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2,4-Trichlorobenzene	Resource Conservation Recovery Program (S)
1,2,4-Trimethylbenzene	Resource Conservation Recovery Program (NPW)
1,2,4-Trimethylbenzene	Resource Conservation Recovery Program (S)
1,2-Dibromo-3-chloropropane (DBCP)	Resource Conservation Recovery Program (NPW)
1,2-Dibromo-3-chloropropane (DBCP)	Resource Conservation Recovery Program (S)
1,2-Dibromoethane (EDB, Ethylene dibromide)	Resource Conservation Recovery Program (NPW)
1,2-Dibromoethane (EDB, Ethylene dibromide)	Resource Conservation Recovery Program (S)
1,2-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,2-Dichloroethane	Resource Conservation Recovery Program (NPW)
1,2-Dichloroethane	Resource Conservation Recovery Program (S)
1,2-Dichloropropane	Resource Conservation Recovery Program (NPW)
1,2-Dichloropropane	Resource Conservation Recovery Program (S)
1,3,5-Trichlorobenzene	Resource Conservation Recovery Program (NPW)
1,3,5-Trichlorobenzene	Resource Conservation Recovery Program (S)
1,3,5-Trimethylbenzene	Resource Conservation Recovery Program (NPW)
1,3,5-Trimethylbenzene	Resource Conservation Recovery Program (S)
1,3-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,3-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,3-Dichloropropane	Resource Conservation Recovery Program (NPW)
1,3-Dichloropropane	Resource Conservation Recovery Program (S)
1,4-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,4-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,4-Dioxane (1,4-Diethyleneoxide)	Resource Conservation Recovery Program (NPW)

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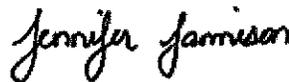


Dibromomethane	Resource Conservation Recovery Program (NPW)
Dibromomethane	Resource Conservation Recovery Program (S)
Dichlorodifluoromethane	Resource Conservation Recovery Program (NPW)
Dichlorodifluoromethane	Resource Conservation Recovery Program (S)
Dichloromethane (Methylene chloride)	Resource Conservation Recovery Program (NPW)
Dichloromethane (Methylene chloride)	Resource Conservation Recovery Program (S)
Diethyl ether	Resource Conservation Recovery Program (NPW)
Diethyl ether	Resource Conservation Recovery Program (S)
Diisopropylether (DIPE)	Resource Conservation Recovery Program (NPW)
Diisopropylether (DIPE)	Resource Conservation Recovery Program (S)
Ethyl methacrylate	Resource Conservation Recovery Program (NPW)
Ethyl methacrylate	Resource Conservation Recovery Program (S)
Ethylbenzene	Resource Conservation Recovery Program (NPW)
Ethylbenzene	Resource Conservation Recovery Program (S)
Ethyl-tert-butyl ether (ETBE)	Resource Conservation Recovery Program (NPW)
Ethyl-tert-butyl ether (ETBE)	Resource Conservation Recovery Program (S)
Freon-113 (Trichlorotrifluoroethane)	Resource Conservation Recovery Program (NPW)
Freon-113 (Trichlorotrifluoroethane)	Resource Conservation Recovery Program (S)
Hexachlorobutadiene	Resource Conservation Recovery Program (NPW)
Hexachlorobutadiene	Resource Conservation Recovery Program (S)
Iodomethane (Methyl iodide)	Resource Conservation Recovery Program (NPW)
Iodomethane (Methyl iodide)	Resource Conservation Recovery Program (S)
Isobutyl alcohol	Resource Conservation Recovery Program (NPW)
Isobutyl alcohol	Resource Conservation Recovery Program (S)
Isopropylbenzene	Resource Conservation Recovery Program (NPW)
Isopropylbenzene	Resource Conservation Recovery Program (S)
Methacrylonitrile	Resource Conservation Recovery Program (NPW)
Methacrylonitrile	Resource Conservation Recovery Program (S)
Methyl acetate	Resource Conservation Recovery Program (NPW)
Methyl acetate	Resource Conservation Recovery Program (S)
Methyl chloride (Chloromethane)	Resource Conservation Recovery Program (NPW)
Methyl chloride (Chloromethane)	Resource Conservation Recovery Program (S)
Methyl isobutyl ketone (MIBK)	Resource Conservation Recovery Program (NPW)
Methyl isobutyl ketone (MIBK)	Resource Conservation Recovery Program (S)
Methyl methacrylate	Resource Conservation Recovery Program (NPW)
Methyl methacrylate	Resource Conservation Recovery Program (S)
Methyl tert-butyl ether (MTBE)	Resource Conservation Recovery Program (NPW)
Methyl tert-butyl ether (MTBE)	Resource Conservation Recovery Program (S)
Methylcyclohexane	Resource Conservation Recovery Program (NPW)
Methylcyclohexane	Resource Conservation Recovery Program (S)
m-Xylene	Resource Conservation Recovery Program (NPW)
m-Xylene	Resource Conservation Recovery Program (S)
Naphthalene	Resource Conservation Recovery Program (NPW)
Naphthalene	Resource Conservation Recovery Program (S)
n-Butylbenzene	Resource Conservation Recovery Program (NPW)
n-Butylbenzene	Resource Conservation Recovery Program (S)
n-Propylbenzene	Resource Conservation Recovery Program (NPW)
n-Propylbenzene	Resource Conservation Recovery Program (S)
Pentachloroethane	Resource Conservation Recovery Program (NPW)
Pentachloroethane	Resource Conservation Recovery Program (S)
p-Isopropyltoluene	Resource Conservation Recovery Program (NPW)
p-Isopropyltoluene	Resource Conservation Recovery Program (S)
Propionitrile (Ethyl cyanide)	Resource Conservation Recovery Program (NPW)
Propionitrile (Ethyl cyanide)	Resource Conservation Recovery Program (S)
p-Xylene	Resource Conservation Recovery Program (NPW)
p-Xylene	Resource Conservation Recovery Program (S)
sec-Butylbenzene	Resource Conservation Recovery Program (NPW)
sec-Butylbenzene	Resource Conservation Recovery Program (S)
Styrene	Resource Conservation Recovery Program (NPW)
Styrene	Resource Conservation Recovery Program (S)
tert-Amyl methyl ether (TAME)	Resource Conservation Recovery Program (NPW)

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Chloroprene	Resource Conservation Recovery Program (NPW)
Chloroprene	Resource Conservation Recovery Program (S)
cis-1,2-Dichloroethylene	Resource Conservation Recovery Program (NPW)
cis-1,2-Dichloroethylene	Resource Conservation Recovery Program (S)
cis-1,3-Dichloropropene	Resource Conservation Recovery Program (NPW)
cis-1,3-Dichloropropene	Resource Conservation Recovery Program (S)
cis-1,4-Dichloro-2-butene	Resource Conservation Recovery Program (NPW)
cis-1,4-Dichloro-2-butene	Resource Conservation Recovery Program (S)
Cyclohexane	Resource Conservation Recovery Program (NPW)
Cyclohexane	Resource Conservation Recovery Program (S)
Dibromochloromethane	Resource Conservation Recovery Program (NPW)
Dibromochloromethane	Resource Conservation Recovery Program (S)
Dibromomethane	Resource Conservation Recovery Program (NPW)
Dibromomethane	Resource Conservation Recovery Program (S)
Dichlorodifluoromethane	Resource Conservation Recovery Program (NPW)
Dichlorodifluoromethane	Resource Conservation Recovery Program (S)
Dichloromethane (Methylene chloride)	Resource Conservation Recovery Program (NPW)
Dichloromethane (Methylene chloride)	Resource Conservation Recovery Program (S)
Diethyl ether	Resource Conservation Recovery Program (NPW)
Diethyl ether	Resource Conservation Recovery Program (S)
Diisopropylether (DIPE)	Resource Conservation Recovery Program (NPW)
Diisopropylether (DIPE)	Resource Conservation Recovery Program (S)
Ethyl methacrylate	Resource Conservation Recovery Program (NPW)
Ethyl methacrylate	Resource Conservation Recovery Program (S)
Ethylbenzene	Resource Conservation Recovery Program (NPW)
Ethylbenzene	Resource Conservation Recovery Program (S)
Ethyl-tert-butyl ether (ETBE)	Resource Conservation Recovery Program (NPW)
Ethyl-tert-butyl ether (ETBE)	Resource Conservation Recovery Program (S)
Freon-113 (Trichlorotrifluoroethane)	Resource Conservation Recovery Program (NPW)
Freon-113 (Trichlorotrifluoroethane)	Resource Conservation Recovery Program (S)
Hexachlorobutadiene	Resource Conservation Recovery Program (NPW)
Hexachlorobutadiene	Resource Conservation Recovery Program (S)
Iodomethane (Methyl iodide)	Resource Conservation Recovery Program (NPW)
Iodomethane (Methyl iodide)	Resource Conservation Recovery Program (S)
Isobutyl alcohol	Resource Conservation Recovery Program (NPW)
Isobutyl alcohol	Resource Conservation Recovery Program (S)
Isopropylbenzene	Resource Conservation Recovery Program (NPW)
Isopropylbenzene	Resource Conservation Recovery Program (S)
Methacrylonitrile	Resource Conservation Recovery Program (NPW)
Methacrylonitrile	Resource Conservation Recovery Program (S)
Methyl acetate	Resource Conservation Recovery Program (NPW)
Methyl acetate	Resource Conservation Recovery Program (S)
Methyl chloride (Chloromethane)	Resource Conservation Recovery Program (NPW)
Methyl chloride (Chloromethane)	Resource Conservation Recovery Program (S)
Methyl isobutyl ketone (MIBK)	Resource Conservation Recovery Program (NPW)
Methyl isobutyl ketone (MIBK)	Resource Conservation Recovery Program (S)
Methyl methacrylate	Resource Conservation Recovery Program (NPW)
Methyl methacrylate	Resource Conservation Recovery Program (S)
Methyl tert-butyl ether (MTBE)	Resource Conservation Recovery Program (NPW)
Methyl tert-butyl ether (MTBE)	Resource Conservation Recovery Program (S)
Methycyclohexane	Resource Conservation Recovery Program (NPW)
Methycyclohexane	Resource Conservation Recovery Program (S)
m-Xylene	Resource Conservation Recovery Program (NPW)
m-Xylene	Resource Conservation Recovery Program (S)
Naphthalene	Resource Conservation Recovery Program (NPW)
Naphthalene	Resource Conservation Recovery Program (S)
n-Butylbenzene	Resource Conservation Recovery Program (NPW)
n-Butylbenzene	Resource Conservation Recovery Program (S)
n-Propylbenzene	Resource Conservation Recovery Program (NPW)
n-Propylbenzene	Resource Conservation Recovery Program (S)
Pentachloroethane	Resource Conservation Recovery Program (NPW)

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Pentachloroethane	Resource Conservation Recovery Program (S)
p-Isopropyltoluene	Resource Conservation Recovery Program (NPW)
p-Isopropyltoluene	Resource Conservation Recovery Program (S)
Propionitrile (Ethyl cyanide)	Resource Conservation Recovery Program (NPW)
Propionitrile (Ethyl cyanide)	Resource Conservation Recovery Program (S)
p-Xylene	Resource Conservation Recovery Program (NPW)
p-Xylene	Resource Conservation Recovery Program (S)
sec-Butylbenzene	Resource Conservation Recovery Program (NPW)
sec-Butylbenzene	Resource Conservation Recovery Program (S)
Styrene	Resource Conservation Recovery Program (NPW)
Styrene	Resource Conservation Recovery Program (S)
tert-Amyl methyl ether (TAME)	Resource Conservation Recovery Program (NPW)
tert-Amyl methyl ether (TAME)	Resource Conservation Recovery Program (S)
tert-Butyl alcohol	Resource Conservation Recovery Program (NPW)
tert-Butyl alcohol	Resource Conservation Recovery Program (S)
tert-Butylbenzene	Resource Conservation Recovery Program (NPW)
tert-Butylbenzene	Resource Conservation Recovery Program (S)
Tetrachloroethylene	Resource Conservation Recovery Program (NPW)
Tetrachloroethylene	Resource Conservation Recovery Program (S)
Tetrahydrofuran (THF)	Resource Conservation Recovery Program (NPW)
Tetrahydrofuran (THF)	Resource Conservation Recovery Program (S)
Toluene	Resource Conservation Recovery Program (NPW)
Toluene	Resource Conservation Recovery Program (S)
trans-1,2-Dichloroethylene	Resource Conservation Recovery Program (NPW)
trans-1,2-Dichloroethylene	Resource Conservation Recovery Program (S)
trans-1,3-Dichloropropylene	Resource Conservation Recovery Program (NPW)
trans-1,3-Dichloropropylene	Resource Conservation Recovery Program (S)
trans-1,4-Dichloro-2-butene	Resource Conservation Recovery Program (NPW)
trans-1,4-Dichloro-2-butene	Resource Conservation Recovery Program (S)
Trichloroethene (Trichloroethylene)	Resource Conservation Recovery Program (NPW)
Trichloroethene (Trichloroethylene)	Resource Conservation Recovery Program (S)
Trichlorofluoromethane	Resource Conservation Recovery Program (NPW)
Trichlorofluoromethane	Resource Conservation Recovery Program (S)
Vinyl acetate	Resource Conservation Recovery Program (NPW)
Vinyl acetate	Resource Conservation Recovery Program (S)
Vinyl chloride	Resource Conservation Recovery Program (NPW)
Vinyl chloride	Resource Conservation Recovery Program (S)
Xylene (total)	Resource Conservation Recovery Program (NPW)
Xylene (total)	Resource Conservation Recovery Program (S)
<b>EPA 8270C</b>	
1,1'-Biphenyl	Resource Conservation Recovery Program (NPW)
1,1'-Biphenyl	Resource Conservation Recovery Program (S)
1,2,4,5-Tetrachlorobenzene	Resource Conservation Recovery Program (NPW)
1,2,4,5-Tetrachlorobenzene	Resource Conservation Recovery Program (S)
1,2,4-Trichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2,4-Trichlorobenzene	Resource Conservation Recovery Program (S)
1,2-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,2-Diphenylhydrazine	Resource Conservation Recovery Program (NPW)
1,2-Diphenylhydrazine	Resource Conservation Recovery Program (S)
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (NPW)
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (S)
1,3-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,3-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (NPW)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (S)
1,4-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,4-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,4-Dioxane (1,4- Diethyleneoxide)	Resource Conservation Recovery Program (NPW)
1,4-Dioxane (1,4- Diethyleneoxide)	Resource Conservation Recovery Program (S)
1,4-Naphthoquinone	Resource Conservation Recovery Program (NPW)

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4-Chloro-3-methylphenol	Resource Conservation Recovery Program (NPW)
4-Chloro-3-methylphenol	Resource Conservation Recovery Program (S)
4-Chloroaniline	Resource Conservation Recovery Program (NPW)
4-Chloroaniline	Resource Conservation Recovery Program (S)
4-Chlorophenyl phenylether	Resource Conservation Recovery Program (NPW)
4-Chlorophenyl phenylether	Resource Conservation Recovery Program (S)
4-Nitroaniline	Resource Conservation Recovery Program (NPW)
4-Nitroaniline	Resource Conservation Recovery Program (S)
4-Nitrophenol	Resource Conservation Recovery Program (NPW)
4-Nitrophenol	Resource Conservation Recovery Program (S)
4-Nitroquinoline 1-oxide	Resource Conservation Recovery Program (NPW)
4-Nitroquinoline 1-oxide	Resource Conservation Recovery Program (S)
5-Nitro-o-toluidine	Resource Conservation Recovery Program (NPW)
5-Nitro-o-toluidine	Resource Conservation Recovery Program (S)
7,12-Dimethylbenz[a]anthracene	Resource Conservation Recovery Program (NPW)
7,12-Dimethylbenz[a]anthracene	Resource Conservation Recovery Program (S)
a-a-Dimethylphenethylamine	Resource Conservation Recovery Program (NPW)
a-a-Dimethylphenethylamine	Resource Conservation Recovery Program (S)
Acenaphthene	Resource Conservation Recovery Program (NPW)
Acenaphthene	Resource Conservation Recovery Program (S)
Acenaphthylene	Resource Conservation Recovery Program (NPW)
Acenaphthylene	Resource Conservation Recovery Program (S)
Acetophenone	Resource Conservation Recovery Program (NPW)
Acetophenone	Resource Conservation Recovery Program (S)
Aniline	Resource Conservation Recovery Program (NPW)
Aniline	Resource Conservation Recovery Program (S)
Anthracene	Resource Conservation Recovery Program (NPW)
Anthracene	Resource Conservation Recovery Program (S)
Aramite	Resource Conservation Recovery Program (NPW)
Aramite	Resource Conservation Recovery Program (S)
Atrazine	Resource Conservation Recovery Program (NPW)
Atrazine	Resource Conservation Recovery Program (S)
Azobenzene	Resource Conservation Recovery Program (NPW)
Azobenzene	Resource Conservation Recovery Program (S)
Benzaldehyde	Resource Conservation Recovery Program (NPW)
Benzaldehyde	Resource Conservation Recovery Program (S)
Benzidine	Resource Conservation Recovery Program (NPW)
Benzidine	Resource Conservation Recovery Program (S)
Benzo[a]anthracene	Resource Conservation Recovery Program (NPW)
Benzo[a]anthracene	Resource Conservation Recovery Program (S)
Benzo[a]pyrene	Resource Conservation Recovery Program (NPW)
Benzo[a]pyrene	Resource Conservation Recovery Program (S)
Benzo[b]fluoranthene	Resource Conservation Recovery Program (NPW)
Benzo[b]fluoranthene	Resource Conservation Recovery Program (S)
Benzo[g,h,i]perylene	Resource Conservation Recovery Program (NPW)
Benzo[g,h,i]perylene	Resource Conservation Recovery Program (S)
Benzo[k]fluoranthene	Resource Conservation Recovery Program (NPW)
Benzo[k]fluoranthene	Resource Conservation Recovery Program (S)
Benzoic acid	Resource Conservation Recovery Program (NPW)
Benzoic acid	Resource Conservation Recovery Program (S)
Benzyl alcohol	Resource Conservation Recovery Program (NPW)
Benzyl alcohol	Resource Conservation Recovery Program (S)
bis(2-Chloroethoxy)methane	Resource Conservation Recovery Program (NPW)
bis(2-Chloroethoxy)methane	Resource Conservation Recovery Program (S)
bis(2-Chloroethyl)ether	Resource Conservation Recovery Program (NPW)
bis(2-Chloroethyl)ether	Resource Conservation Recovery Program (S)
bis(2-Ethylhexyl)adipate	Resource Conservation Recovery Program (NPW)
bis(2-Ethylhexyl)adipate	Resource Conservation Recovery Program (S)
bis(2-Ethylhexyl)phthalate (DEHP)	Resource Conservation Recovery Program (NPW)
bis(2-Ethylhexyl)phthalate (DEHP)	Resource Conservation Recovery Program (S)
Butyl benzyl phthalate	Resource Conservation Recovery Program (NPW)

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Butyl benzyl phthalate	Resource Conservation Recovery Program (S)
Caprolactam	Resource Conservation Recovery Program (NPW)
Caprolactam	Resource Conservation Recovery Program (S)
Carbazole	Resource Conservation Recovery Program (NPW)
Carbazole	Resource Conservation Recovery Program (S)
Chlorobenzilate	Resource Conservation Recovery Program (NPW)
Chlorobenzilate	Resource Conservation Recovery Program (S)
Chrysene	Resource Conservation Recovery Program (NPW)
Chrysene	Resource Conservation Recovery Program (S)
Diallate	Resource Conservation Recovery Program (NPW)
Diallate	Resource Conservation Recovery Program (S)
Dibenz[a,h]anthracene	Resource Conservation Recovery Program (NPW)
Dibenz[a,h]anthracene	Resource Conservation Recovery Program (S)
Dibenz[a,j]acridine	Resource Conservation Recovery Program (NPW)
Dibenz[a,j]acridine	Resource Conservation Recovery Program (S)
Dibenzofuran	Resource Conservation Recovery Program (NPW)
Dibenzofuran	Resource Conservation Recovery Program (S)
Diethyl phthalate	Resource Conservation Recovery Program (NPW)
Diethyl phthalate	Resource Conservation Recovery Program (S)
Dimethoate	Resource Conservation Recovery Program (NPW)
Dimethoate	Resource Conservation Recovery Program (S)
Dimethyl phthalate	Resource Conservation Recovery Program (NPW)
Dimethyl phthalate	Resource Conservation Recovery Program (S)
Di-n-butyl phthalate	Resource Conservation Recovery Program (NPW)
Di-n-butyl phthalate	Resource Conservation Recovery Program (S)
Di-n-octyl phthalate	Resource Conservation Recovery Program (NPW)
Di-n-octyl phthalate	Resource Conservation Recovery Program (S)
Dinoseb	Resource Conservation Recovery Program (NPW)
Dinoseb	Resource Conservation Recovery Program (S)
Disulfoton	Resource Conservation Recovery Program (NPW)
Disulfoton	Resource Conservation Recovery Program (S)
Ethyl methanesulfonate	Resource Conservation Recovery Program (NPW)
Ethyl methanesulfonate	Resource Conservation Recovery Program (S)
Famphur	Resource Conservation Recovery Program (NPW)
Famphur	Resource Conservation Recovery Program (S)
Fluoranthene	Resource Conservation Recovery Program (NPW)
Fluoranthene	Resource Conservation Recovery Program (S)
Fluorene	Resource Conservation Recovery Program (NPW)
Fluorene	Resource Conservation Recovery Program (S)
Hexachlorobenzene	Resource Conservation Recovery Program (NPW)
Hexachlorobenzene	Resource Conservation Recovery Program (S)
Hexachlorobutadiene	Resource Conservation Recovery Program (NPW)
Hexachlorobutadiene	Resource Conservation Recovery Program (S)
Hexachlorocyclopentadiene	Resource Conservation Recovery Program (NPW)
Hexachlorocyclopentadiene	Resource Conservation Recovery Program (S)
Hexachloroethane	Resource Conservation Recovery Program (NPW)
Hexachloroethane	Resource Conservation Recovery Program (S)
Hexachlorophene	Resource Conservation Recovery Program (NPW)
Hexachlorophene	Resource Conservation Recovery Program (S)
Hexachloropropene	Resource Conservation Recovery Program (NPW)
Hexachloropropene	Resource Conservation Recovery Program (S)
Indeno[1,2,3-cd]pyrene	Resource Conservation Recovery Program (NPW)
Indeno[1,2,3-cd]pyrene	Resource Conservation Recovery Program (S)
Isodrin	Resource Conservation Recovery Program (NPW)
Isodrin	Resource Conservation Recovery Program (S)
Isophorone	Resource Conservation Recovery Program (NPW)
Isophorone	Resource Conservation Recovery Program (S)
Isosafrole	Resource Conservation Recovery Program (NPW)
Isosafrole	Resource Conservation Recovery Program (S)
Kepon	Resource Conservation Recovery Program (NPW)
Kepon	Resource Conservation Recovery Program (S)

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Methapyrilene	Resource Conservation Recovery Program (NPW)
Methapyrilene	Resource Conservation Recovery Program (S)
Methyl methanesulfonate	Resource Conservation Recovery Program (NPW)
Methyl methanesulfonate	Resource Conservation Recovery Program (S)
Methyl parathion	Resource Conservation Recovery Program (NPW)
Methyl parathion	Resource Conservation Recovery Program (S)
Naphthalene	Resource Conservation Recovery Program (NPW)
Naphthalene	Resource Conservation Recovery Program (S)
Nitrobenzene	Resource Conservation Recovery Program (NPW)
Nitrobenzene	Resource Conservation Recovery Program (S)
n-Nitrosodiethylamine	Resource Conservation Recovery Program (NPW)
n-Nitrosodiethylamine	Resource Conservation Recovery Program (S)
n-Nitrosodimethylamine	Resource Conservation Recovery Program (NPW)
n-Nitrosodimethylamine	Resource Conservation Recovery Program (S)
n-Nitroso-di-n-butylamine	Resource Conservation Recovery Program (NPW)
n-Nitroso-di-n-butylamine	Resource Conservation Recovery Program (S)
n-Nitroso-di-n-propylamine	Resource Conservation Recovery Program (NPW)
n-Nitroso-di-n-propylamine	Resource Conservation Recovery Program (S)
n-Nitrosodiphenylamine	Resource Conservation Recovery Program (NPW)
n-Nitrosodiphenylamine	Resource Conservation Recovery Program (S)
n-Nitrosomethylethylamine	Resource Conservation Recovery Program (NPW)
n-Nitrosomethylethylamine	Resource Conservation Recovery Program (S)
n-Nitrosomorpholine	Resource Conservation Recovery Program (NPW)
n-Nitrosomorpholine	Resource Conservation Recovery Program (S)
n-Nitrosopiperidine	Resource Conservation Recovery Program (NPW)
n-Nitrosopiperidine	Resource Conservation Recovery Program (S)
n-Nitrosopyrrolidine	Resource Conservation Recovery Program (NPW)
n-Nitrosopyrrolidine	Resource Conservation Recovery Program (S)
o,o,o-Triethyl phosphorothioate	Resource Conservation Recovery Program (NPW)
o,o,o-Triethyl phosphorothioate	Resource Conservation Recovery Program (S)
o-Toluidine	Resource Conservation Recovery Program (NPW)
o-Toluidine	Resource Conservation Recovery Program (S)
Parathion	Resource Conservation Recovery Program (NPW)
Parathion	Resource Conservation Recovery Program (S)
Pentachlorobenzene	Resource Conservation Recovery Program (NPW)
Pentachlorobenzene	Resource Conservation Recovery Program (S)
Pentachloronitrobenzene	Resource Conservation Recovery Program (NPW)
Pentachloronitrobenzene	Resource Conservation Recovery Program (S)
Pentachlorophenol	Resource Conservation Recovery Program (NPW)
Pentachlorophenol	Resource Conservation Recovery Program (S)
Phenacetin	Resource Conservation Recovery Program (NPW)
Phenacetin	Resource Conservation Recovery Program (S)
Phenanthrene	Resource Conservation Recovery Program (NPW)
Phenanthrene	Resource Conservation Recovery Program (S)
Phenol	Resource Conservation Recovery Program (NPW)
Phenol	Resource Conservation Recovery Program (S)
Phorate	Resource Conservation Recovery Program (NPW)
Phorate	Resource Conservation Recovery Program (S)
p-Phenylenediamine	Resource Conservation Recovery Program (NPW)
p-Phenylenediamine	Resource Conservation Recovery Program (S)
Pronamide (Kerb)	Resource Conservation Recovery Program (NPW)
Pronamide (Kerb)	Resource Conservation Recovery Program (S)
Pyrene	Resource Conservation Recovery Program (NPW)
Pyrene	Resource Conservation Recovery Program (S)
Pyridine	Resource Conservation Recovery Program (NPW)
Pyridine	Resource Conservation Recovery Program (S)
Safrole	Resource Conservation Recovery Program (NPW)
Safrole	Resource Conservation Recovery Program (S)
Sulfotepp	Resource Conservation Recovery Program (NPW)
Sulfotepp	Resource Conservation Recovery Program (S)

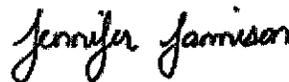
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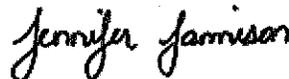
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1,1'-Biphenyl	Resource Conservation Recovery Program (NPW)
1,1'-Biphenyl	Resource Conservation Recovery Program (S)
1,2,4,5-Tetrachlorobenzene	Resource Conservation Recovery Program (NPW)
1,2,4,5-Tetrachlorobenzene	Resource Conservation Recovery Program (S)
1,2,4-Trichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2,4-Trichlorobenzene	Resource Conservation Recovery Program (S)
1,2-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,2-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,2-Diphenylhydrazine	Resource Conservation Recovery Program (NPW)
1,2-Diphenylhydrazine	Resource Conservation Recovery Program (S)
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (NPW)
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (S)
1,3-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,3-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (NPW)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (S)
1,4-Dichlorobenzene	Resource Conservation Recovery Program (NPW)
1,4-Dichlorobenzene	Resource Conservation Recovery Program (S)
1,4-Dioxane (1,4-Diethyleneoxide)	Resource Conservation Recovery Program (NPW)
1,4-Dioxane (1,4-Diethyleneoxide)	Resource Conservation Recovery Program (S)
1,4-Naphthoquinone	Resource Conservation Recovery Program (NPW)
1,4-Naphthoquinone	Resource Conservation Recovery Program (S)
1-Chloronaphthalene	Resource Conservation Recovery Program (NPW)
1-Chloronaphthalene	Resource Conservation Recovery Program (S)
1-Methylnaphthalene	Resource Conservation Recovery Program (NPW)
1-Methylnaphthalene	Resource Conservation Recovery Program (S)
1-Naphthylamine	Resource Conservation Recovery Program (NPW)
1-Naphthylamine	Resource Conservation Recovery Program (S)
2,2'-Oxybis(1-chloropropane)	Resource Conservation Recovery Program (NPW)
2,2'-Oxybis(1-chloropropane)	Resource Conservation Recovery Program (S)
2,3,4,6-Tetrachlorophenol	Resource Conservation Recovery Program (NPW)
2,3,4,6-Tetrachlorophenol	Resource Conservation Recovery Program (S)
2,4,5-Trichlorophenol	Resource Conservation Recovery Program (NPW)
2,4,5-Trichlorophenol	Resource Conservation Recovery Program (S)
2,4,6-Trichlorophenol	Resource Conservation Recovery Program (NPW)
2,4,6-Trichlorophenol	Resource Conservation Recovery Program (S)
2,4-Dichlorophenol	Resource Conservation Recovery Program (NPW)
2,4-Dichlorophenol	Resource Conservation Recovery Program (S)
2,4-Dimethylphenol	Resource Conservation Recovery Program (NPW)
2,4-Dimethylphenol	Resource Conservation Recovery Program (S)
2,4-Dinitrophenol	Resource Conservation Recovery Program (NPW)
2,4-Dinitrophenol	Resource Conservation Recovery Program (S)
2,4-Dinitrotoluene (2,4-DNT)	Resource Conservation Recovery Program (NPW)
2,4-Dinitrotoluene (2,4-DNT)	Resource Conservation Recovery Program (S)
2,6-Dichlorophenol	Resource Conservation Recovery Program (NPW)
2,6-Dichlorophenol	Resource Conservation Recovery Program (S)
2,6-Dinitrotoluene (2,6-DNT)	Resource Conservation Recovery Program (NPW)
2,6-Dinitrotoluene (2,6-DNT)	Resource Conservation Recovery Program (S)
2-Acetylaminofluorene	Resource Conservation Recovery Program (NPW)
2-Acetylaminofluorene	Resource Conservation Recovery Program (S)
2-Chloronaphthalene	Resource Conservation Recovery Program (NPW)
2-Chloronaphthalene	Resource Conservation Recovery Program (S)
2-Chlorophenol	Resource Conservation Recovery Program (NPW)
2-Chlorophenol	Resource Conservation Recovery Program (S)
2-Methylnaphthalene	Resource Conservation Recovery Program (NPW)
2-Methylnaphthalene	Resource Conservation Recovery Program (S)
2-Methylphenol (o-Cresol)	Resource Conservation Recovery Program (NPW)
2-Methylphenol (o-Cresol)	Resource Conservation Recovery Program (S)
2-Naphthylamine	Resource Conservation Recovery Program (NPW)
2-Naphthylamine	Resource Conservation Recovery Program (S)
2-Nitroaniline	Resource Conservation Recovery Program (NPW)

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Benzo[a]pyrene	Resource Conservation Recovery Program (NPW)
Benzo[a]pyrene	Resource Conservation Recovery Program (S)
Benzo[b]fluoranthene	Resource Conservation Recovery Program (NPW)
Benzo[b]fluoranthene	Resource Conservation Recovery Program (S)
Benzo[g,h,i]perylene	Resource Conservation Recovery Program (NPW)
Benzo[g,h,i]perylene	Resource Conservation Recovery Program (S)
Benzo[k]fluoranthene	Resource Conservation Recovery Program (NPW)
Benzo[k]fluoranthene	Resource Conservation Recovery Program (S)
Benzoic acid	Resource Conservation Recovery Program (NPW)
Benzoic acid	Resource Conservation Recovery Program (S)
Benzyl alcohol	Resource Conservation Recovery Program (NPW)
Benzyl alcohol	Resource Conservation Recovery Program (S)
bis(2-Chloroethoxy)methane	Resource Conservation Recovery Program (NPW)
bis(2-Chloroethoxy)methane	Resource Conservation Recovery Program (S)
bis(2-Chloroethyl)ether	Resource Conservation Recovery Program (NPW)
bis(2-Chloroethyl)ether	Resource Conservation Recovery Program (S)
bis(2-Ethylhexyl)adipate	Resource Conservation Recovery Program (NPW)
bis(2-Ethylhexyl)adipate	Resource Conservation Recovery Program (S)
bis(2-Ethylhexyl)phthalate (DEHP)	Resource Conservation Recovery Program (NPW)
bis(2-Ethylhexyl)phthalate (DEHP)	Resource Conservation Recovery Program (S)
Butyl benzyl phthalate	Resource Conservation Recovery Program (NPW)
Butyl benzyl phthalate	Resource Conservation Recovery Program (S)
Caprolactam	Resource Conservation Recovery Program (NPW)
Caprolactam	Resource Conservation Recovery Program (S)
Carbazole	Resource Conservation Recovery Program (NPW)
Carbazole	Resource Conservation Recovery Program (S)
Chlorobenzilate	Resource Conservation Recovery Program (NPW)
Chlorobenzilate	Resource Conservation Recovery Program (S)
Chrysene	Resource Conservation Recovery Program (NPW)
Chrysene	Resource Conservation Recovery Program (S)
Diallylate	Resource Conservation Recovery Program (NPW)
Diallylate	Resource Conservation Recovery Program (S)
Dibenz[a,h]anthracene	Resource Conservation Recovery Program (NPW)
Dibenz[a,h]anthracene	Resource Conservation Recovery Program (S)
Dibenz[a,j]acridine	Resource Conservation Recovery Program (NPW)
Dibenz[a,j]acridine	Resource Conservation Recovery Program (S)
Dibenzofuran	Resource Conservation Recovery Program (NPW)
Dibenzofuran	Resource Conservation Recovery Program (S)
Diethyl phthalate	Resource Conservation Recovery Program (NPW)
Diethyl phthalate	Resource Conservation Recovery Program (S)
Dimethoate	Resource Conservation Recovery Program (NPW)
Dimethoate	Resource Conservation Recovery Program (S)
Dimethyl phthalate	Resource Conservation Recovery Program (NPW)
Dimethyl phthalate	Resource Conservation Recovery Program (S)
Di-n-butyl phthalate	Resource Conservation Recovery Program (NPW)
Di-n-butyl phthalate	Resource Conservation Recovery Program (S)
Di-n-octyl phthalate	Resource Conservation Recovery Program (NPW)
Di-n-octyl phthalate	Resource Conservation Recovery Program (S)
Dinoseb	Resource Conservation Recovery Program (NPW)
Dinoseb	Resource Conservation Recovery Program (S)
Disulfoton	Resource Conservation Recovery Program (NPW)
Disulfoton	Resource Conservation Recovery Program (S)
Ethyl methanesulfonate	Resource Conservation Recovery Program (NPW)
Ethyl methanesulfonate	Resource Conservation Recovery Program (S)
Famphur	Resource Conservation Recovery Program (NPW)
Famphur	Resource Conservation Recovery Program (S)
Fluoranthene	Resource Conservation Recovery Program (NPW)
Fluoranthene	Resource Conservation Recovery Program (S)
Fluorene	Resource Conservation Recovery Program (NPW)
Fluorene	Resource Conservation Recovery Program (S)
Hexachlorobenzene	Resource Conservation Recovery Program (NPW)

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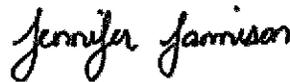


Phenacetin	Resource Conservation Recovery Program (NPW)
Phenacetin	Resource Conservation Recovery Program (S)
Phenanthrene	Resource Conservation Recovery Program (NPW)
Phenanthrene	Resource Conservation Recovery Program (S)
Phenol	Resource Conservation Recovery Program (NPW)
Phenol	Resource Conservation Recovery Program (S)
Phorate	Resource Conservation Recovery Program (NPW)
Phorate	Resource Conservation Recovery Program (S)
p-Phenylenediamine	Resource Conservation Recovery Program (NPW)
p-Phenylenediamine	Resource Conservation Recovery Program (S)
Pronamide (Kerb)	Resource Conservation Recovery Program (NPW)
Pronamide (Kerb)	Resource Conservation Recovery Program (S)
Pyrene	Resource Conservation Recovery Program (NPW)
Pyrene	Resource Conservation Recovery Program (S)
Pyridine	Resource Conservation Recovery Program (NPW)
Pyridine	Resource Conservation Recovery Program (S)
Safrole	Resource Conservation Recovery Program (NPW)
Safrole	Resource Conservation Recovery Program (S)
Sulfotep	Resource Conservation Recovery Program (NPW)
Sulfotep	Resource Conservation Recovery Program (S)
<b>EPA 8330</b>	
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (NPW)
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (S)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (NPW)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (S)
2,4,6-Trinitrotoluene (2,4,6-TNT)	Resource Conservation Recovery Program (NPW)
2,4,6-Trinitrotoluene (2,4,6-TNT)	Resource Conservation Recovery Program (S)
2,4-Dinitrotoluene (2,4-DNT)	Resource Conservation Recovery Program (NPW)
2,4-Dinitrotoluene (2,4-DNT)	Resource Conservation Recovery Program (S)
2,6-Dinitrotoluene (2,6-DNT)	Resource Conservation Recovery Program (NPW)
2,6-Dinitrotoluene (2,6-DNT)	Resource Conservation Recovery Program (S)
2-Amino-4,6-dinitrotoluene (2-am-dnt)	Resource Conservation Recovery Program (NPW)
2-Amino-4,6-dinitrotoluene (2-am-dnt)	Resource Conservation Recovery Program (S)
2-Nitrotoluene	Resource Conservation Recovery Program (NPW)
2-Nitrotoluene	Resource Conservation Recovery Program (S)
3-Nitrotoluene	Resource Conservation Recovery Program (NPW)
3-Nitrotoluene	Resource Conservation Recovery Program (S)
4-Amino-2,6-dinitrotoluene (4-am-dnt)	Resource Conservation Recovery Program (NPW)
4-Amino-2,6-dinitrotoluene (4-am-dnt)	Resource Conservation Recovery Program (S)
4-Nitrotoluene	Resource Conservation Recovery Program (NPW)
4-Nitrotoluene	Resource Conservation Recovery Program (S)
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	Resource Conservation Recovery Program (NPW)
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	Resource Conservation Recovery Program (S)
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	Resource Conservation Recovery Program (NPW)
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	Resource Conservation Recovery Program (S)
Nitrobenzene	Resource Conservation Recovery Program (NPW)
Nitrobenzene	Resource Conservation Recovery Program (S)
Nitroglycerin	Resource Conservation Recovery Program (NPW)
Nitroglycerin	Resource Conservation Recovery Program (S)
Pentaerythritol tetranitrate	Resource Conservation Recovery Program (NPW)
Pentaerythritol tetranitrate	Resource Conservation Recovery Program (S)
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	Resource Conservation Recovery Program (NPW)
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	Resource Conservation Recovery Program (S)
Tetryl (methyl-2,4,6-trinitrophenylnitramine)	Resource Conservation Recovery Program (NPW)
Tetryl (methyl-2,4,6-trinitrophenylnitramine)	Resource Conservation Recovery Program (S)
<b>EPA 8330A</b>	
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (NPW)
1,3,5-Trinitrobenzene (1,3,5-TNB)	Resource Conservation Recovery Program (S)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (NPW)
1,3-Dinitrobenzene (1,3-DNB)	Resource Conservation Recovery Program (S)
2,4,6-Trinitrotoluene (2,4,6-TNT)	Resource Conservation Recovery Program (NPW)

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2,4,6-Trinitrotoluene (2,4,6-TNT)	Resource Conservation Recovery Program (S)
2,4-Dinitrotoluene (2,4-DNT)	Resource Conservation Recovery Program (NPW)
2,4-Dinitrotoluene (2,4-DNT)	Resource Conservation Recovery Program (S)
2,6-Dinitrotoluene (2,6-DNT)	Resource Conservation Recovery Program (NPW)
2,6-Dinitrotoluene (2,6-DNT)	Resource Conservation Recovery Program (S)
2-Amino-4,6-dinitrotoluene (2-am-dnt)	Resource Conservation Recovery Program (NPW)
2-Amino-4,6-dinitrotoluene (2-am-dnt)	Resource Conservation Recovery Program (S)
2-Nitrotoluene	Resource Conservation Recovery Program (NPW)
2-Nitrotoluene	Resource Conservation Recovery Program (S)
3-Nitrotoluene	Resource Conservation Recovery Program (NPW)
3-Nitrotoluene	Resource Conservation Recovery Program (S)
4-Amino-2,6-dinitrotoluene (4-am-dnt)	Resource Conservation Recovery Program (NPW)
4-Amino-2,6-dinitrotoluene (4-am-dnt)	Resource Conservation Recovery Program (S)
4-Nitrotoluene	Resource Conservation Recovery Program (NPW)
4-Nitrotoluene	Resource Conservation Recovery Program (S)
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	Resource Conservation Recovery Program (NPW)
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	Resource Conservation Recovery Program (S)
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	Resource Conservation Recovery Program (NPW)
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	Resource Conservation Recovery Program (S)
Nitrobenzene	Resource Conservation Recovery Program (NPW)
Nitrobenzene	Resource Conservation Recovery Program (S)
Nitroglycerin	Resource Conservation Recovery Program (NPW)
Nitroglycerin	Resource Conservation Recovery Program (S)
Pentaerythritoltetranitrate	Resource Conservation Recovery Program (NPW)
Pentaerythritoltetranitrate	Resource Conservation Recovery Program (S)
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	Resource Conservation Recovery Program (NPW)
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	Resource Conservation Recovery Program (S)
Tetryl (methyl-2,4,6-trinitrophenylnitramine)	Resource Conservation Recovery Program (NPW)
Tetryl (methyl-2,4,6-trinitrophenylnitramine)	Resource Conservation Recovery Program (S)
<b><u>EPA 9012A</u></b>	
Total Cyanide	Resource Conservation Recovery Program (NPW)
Total Cyanide	Resource Conservation Recovery Program (S)
<b><u>EPA 9012B</u></b>	
Total Cyanide	Resource Conservation Recovery Program (NPW)
Total Cyanide	Resource Conservation Recovery Program (S)
<b><u>EPA 9038</u></b>	
Sulfate	Resource Conservation Recovery Program (NPW)
Sulfate	Resource Conservation Recovery Program (S)
<b><u>EPA 9040C</u></b>	
pH	Resource Conservation Recovery Program (S)
<b><u>EPA 9045D</u></b>	
pH	Resource Conservation Recovery Program (S)
<b><u>EPA 9056A</u></b>	
Bromide	Resource Conservation Recovery Program (NPW)
Bromide	Resource Conservation Recovery Program (S)
Chloride	Resource Conservation Recovery Program (NPW)
Chloride	Resource Conservation Recovery Program (S)
Fluoride	Resource Conservation Recovery Program (NPW)
Fluoride	Resource Conservation Recovery Program (S)
Nitrate	Resource Conservation Recovery Program (NPW)
Nitrate	Resource Conservation Recovery Program (S)
Nitrate as N	Resource Conservation Recovery Program (NPW)
Nitrate as N	Resource Conservation Recovery Program (S)
Nitrite	Resource Conservation Recovery Program (NPW)
Nitrite	Resource Conservation Recovery Program (S)
Nitrite as N	Resource Conservation Recovery Program (NPW)
Nitrite as N	Resource Conservation Recovery Program (S)
Orthophosphate as P	Resource Conservation Recovery Program (NPW)
Orthophosphate as P	Resource Conservation Recovery Program (S)
Sulfate	Resource Conservation Recovery Program (NPW)
Sulfate	Resource Conservation Recovery Program (S)

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Styrene	QAPP Required Air
Tetrachloroethylene	QAPP Required Air
Tetrahydrofuran (THF)	QAPP Required Air
Toluene	QAPP Required Air
trans-1,2-Dichloroethylene	QAPP Required Air
trans-1,3-Dichloropropylene	QAPP Required Air
Trichloroethene (Trichloroethylene)	QAPP Required Air
Trichlorofluoromethane	QAPP Required Air
Vinyl acetate	QAPP Required Air
Vinyl chloride	QAPP Required Air
Xylene (total)	QAPP Required Air

**MA EPH**

2-Methylnaphthalene	Leaking Underground Storage Tank Program (NPW)
2-Methylnaphthalene	Leaking Underground Storage Tank Program (S)
Acenaphthene	Leaking Underground Storage Tank Program (NPW)
Acenaphthene	Leaking Underground Storage Tank Program (S)
Acenaphthylene	Leaking Underground Storage Tank Program (NPW)
Acenaphthylene	Leaking Underground Storage Tank Program (S)
Anthracene	Leaking Underground Storage Tank Program (NPW)
Anthracene	Leaking Underground Storage Tank Program (S)
Benzo[a]anthracene	Leaking Underground Storage Tank Program (NPW)
Benzo[a]anthracene	Leaking Underground Storage Tank Program (S)
Benzo[a]pyrene	Leaking Underground Storage Tank Program (NPW)
Benzo[a]pyrene	Leaking Underground Storage Tank Program (S)
Benzo[b]fluoranthene	Leaking Underground Storage Tank Program (NPW)
Benzo[b]fluoranthene	Leaking Underground Storage Tank Program (S)
Benzo[g,h,i]perylene	Leaking Underground Storage Tank Program (NPW)
Benzo[g,h,i]perylene	Leaking Underground Storage Tank Program (S)
Benzo[k]fluoranthene	Leaking Underground Storage Tank Program (NPW)
Benzo[k]fluoranthene	Leaking Underground Storage Tank Program (S)
Chrysene	Leaking Underground Storage Tank Program (NPW)
Chrysene	Leaking Underground Storage Tank Program (S)
Dibenz[a,h]anthracene	Leaking Underground Storage Tank Program (NPW)
Dibenz[a,h]anthracene	Leaking Underground Storage Tank Program (S)
EPH Aliphatic C19-C36	Leaking Underground Storage Tank Program (NPW)
EPH Aliphatic C19-C36	Leaking Underground Storage Tank Program (S)
EPH Aliphatic C9-C18	Leaking Underground Storage Tank Program (NPW)
EPH Aliphatic C9-C18	Leaking Underground Storage Tank Program (S)
EPH Aromatic C11-C22	Leaking Underground Storage Tank Program (NPW)
EPH Aromatic C11-C22	Leaking Underground Storage Tank Program (S)
Fluoranthene	Leaking Underground Storage Tank Program (NPW)
Fluoranthene	Leaking Underground Storage Tank Program (S)
Fluorene	Leaking Underground Storage Tank Program (NPW)
Fluorene	Leaking Underground Storage Tank Program (S)
Indeno[1,2,3-cd]pyrene	Leaking Underground Storage Tank Program (NPW)
Indeno[1,2,3-cd]pyrene	Leaking Underground Storage Tank Program (S)
Naphthalene	Leaking Underground Storage Tank Program (NPW)
Naphthalene	Leaking Underground Storage Tank Program (S)
Phenanthrene	Leaking Underground Storage Tank Program (NPW)
Phenanthrene	Leaking Underground Storage Tank Program (S)
Pyrene	Leaking Underground Storage Tank Program (NPW)
Pyrene	Leaking Underground Storage Tank Program (S)

**MA VPH**

Benzene	Leaking Underground Storage Tank Program (NPW)
Benzene	Leaking Underground Storage Tank Program (S)
Ethylbenzene	Leaking Underground Storage Tank Program (NPW)
Ethylbenzene	Leaking Underground Storage Tank Program (S)
Methyl tert-butyl ether (MTBE)	Leaking Underground Storage Tank Program (NPW)
Methyl tert-butyl ether (MTBE)	Leaking Underground Storage Tank Program (S)
Naphthalene	Leaking Underground Storage Tank Program (NPW)
Naphthalene	Leaking Underground Storage Tank Program (S)

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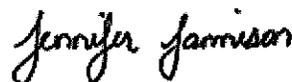
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Toluene	Leaking Underground Storage Tank Program (NPW)
Toluene	Leaking Underground Storage Tank Program (S)
VPH Aliphatic C5-C8	Leaking Underground Storage Tank Program (NPW)
VPH Aliphatic C5-C8	Leaking Underground Storage Tank Program (S)
VPH Aliphatic C9-C12	Leaking Underground Storage Tank Program (NPW)
VPH Aliphatic C9-C12	Leaking Underground Storage Tank Program (S)
VPH Aromatic C9-C10	Leaking Underground Storage Tank Program (NPW)
VPH Aromatic C9-C10	Leaking Underground Storage Tank Program (S)
Xylene (total)	Leaking Underground Storage Tank Program (NPW)
Xylene (total)	Leaking Underground Storage Tank Program (S)
<b>MADEP APH</b>	
1,3-Butadiene	QAPP Required Air
APH Aliphatic C5-C8	QAPP Required Air
APH Aliphatic C9-C12	QAPP Required Air
APH Aromatic C9-C10	QAPP Required Air
Benzene	QAPP Required Air
Ethylbenzene	QAPP Required Air
m+p-Xylene	QAPP Required Air
Methyl tert-butyl ether (MTBE)	QAPP Required Air
Naphthalene	QAPP Required Air
o-Xylene	QAPP Required Air
Toluene	QAPP Required Air
<b>ME HETL 4.1.25</b>	
Diesel range organics (DRO)	Leaking Underground Storage Tank Program (NPW)
Diesel range organics (DRO)	Leaking Underground Storage Tank Program (S)
<b>ME HETL 4.2.17</b>	
Gasoline range organics (GRO)	Leaking Underground Storage Tank Program (NPW)
Gasoline range organics (GRO)	Leaking Underground Storage Tank Program (S)
<b>SimPlate®</b>	
Heterotrophic plate count	Safe Drinking Water Program (DW)
<b>SM 2120 B 21st ED</b>	
Color	Clean Water Program (NPW)
Color	Safe Drinking Water Program (DW)
<b>SM 2130 B 21st ED</b>	
Turbidity	Clean Water Program (NPW)
<b>SM 2310 B 21st ED</b>	
Acidity, as CaCO <sub>3</sub>	Clean Water Program (NPW)
<b>SM 2320 B 21st ED</b>	
Alkalinity as CaCO <sub>3</sub>	Clean Water Program (NPW)
Alkalinity as CaCO <sub>3</sub>	Safe Drinking Water Program (DW)
<b>SM 2340 B 21st ED</b>	
Hardness	Clean Water Program (NPW)
<b>SM 2540 B 21st ED</b>	
Residue-total (TS)	Clean Water Program (NPW)
<b>SM 2540 C 21st ED</b>	
Residue-filterable (TDS)	Clean Water Program (NPW)
Residue-filterable (TDS)	Safe Drinking Water Program (DW)
<b>SM 2540 D 21st ED</b>	
Residue-nonfilterable (TSS)	Clean Water Program (NPW)
<b>SM 2540 F 21st ED</b>	
Residue-settleable	Clean Water Program (NPW)
<b>SM 3500-Cr D 19th ED</b>	
Chromium VI	Clean Water Program (NPW)
<b>SM 3500-Fe D 19th ED</b>	
Iron	Clean Water Program (NPW)
<b>SM 4500-Cl G 20th ED</b>	
Chlorine	Clean Water Program (NPW)
<b>SM 4500-Cl<sup>-</sup> E 21st ED</b>	
Chloride	Clean Water Program (NPW)

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<u>SM 4500-CN G 20th ED</u> Amenable cyanide	Clean Water Program (NPW)
<u>SM 4500-F<sup>-</sup> B 21st ED</u> Fluoride	Safe Drinking Water Program (DW)
<u>SM 4500-F<sup>-</sup> C 21st ED</u> Fluoride	Clean Water Program (NPW)
<u>SM 4500-H+ B 21st ED</u> pH	Clean Water Program (NPW)
	Safe Drinking Water Program (DW)
<u>SM 4500-NH3 H 21st ED</u> Ammonia as N	Clean Water Program (NPW)
<u>SM 4500-P E 20th ED</u> Orthophosphate as P	Clean Water Program (NPW)
<u>SM 4500-S2<sup>-</sup> E 18th ED</u> Sulfide	Clean Water Program (NPW)
<u>SM 4500-SO3<sup>-</sup> B 21st ED</u> Sulfite	Clean Water Program (NPW)
<u>SM 5210 B 21st ED</u> Biochemical oxygen demand	Clean Water Program (NPW)
Carbonaceous BOD, CBOD	Clean Water Program (NPW)
<u>SM 5310 B 21st ED</u> Total Organic Carbon	Clean Water Program (NPW)
<u>SM 5540 C 20th ED</u> Surfactants - MBAS	Clean Water Program (NPW)
<u>SM 9222 D (m-FC) 21st ED</u> Fecal coliforms	Clean Water Program (NPW)
Fecal coliforms	Safe Drinking Water Program (DW)
<u>SM 9223 B (Colilert® Quanti-Tray®) 21st ED</u> Escherichia coli	Clean Water Program (NPW)
Escherichia coli	Safe Drinking Water Program (DW)
Total coliforms	Safe Drinking Water Program (DW)
<u>SM 9223 B (Colilert®) 21st ED</u> Escherichia coli	Safe Drinking Water Program (DW)
Total coliforms	Safe Drinking Water Program (DW)
<u>SM 9223 B (Colilert®-18 Quanti-Tray®) 21st ED</u> Escherichia coli	Clean Water Program (NPW)

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**APPENDIX E**

**RESPONSES TO COMMENTS ON THE DRAFT SAP**



TETRA TECH

PITT-09-14-048

September 18, 2014

Project Number 112G03270

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Mail Code OSRR07-3  
Boston, Massachusetts 02109-3912

Mr. Iver McLeod  
Maine Department of Environmental Protection  
State House Station 17  
Augusta, Maine 04333-0017

Reference: Contract No. N62470-08-D-1001 (CLEAN)  
Contract Task Order No. WE32

Subject: Responses to Comments on the Draft Sampling and Analysis Plan for  
Operable Unit 8 Remedial Investigation  
Portsmouth Naval Shipyard (PNS), Kittery, Maine

Dear Mr. Audet/Mr. McLeod:

On behalf of the U.S. Navy, Tetra Tech is pleased to provide to U.S. Environmental Protection Agency Region I (USEPA) and Maine Department of Environmental Protection (MEDEP) 1 and 2 copies, respectively, of the subject responses to MEDEP comments dated June 11, 2014. An electronic copy is also being submitted via e-mail. USEPA e-mail dated June 24, 2014 indicated no comments on the draft document. In accordance with the project schedule, comments are due by **October 20, 2014**.

If you have any comments or questions, or if additional information is required, please contact Ms. Linda Cole at 757.341.2011.

For the Community Restoration Advisory Board (RAB) members; if you have any comments or questions on these issues, they can be provided to the Navy at a RAB meeting, by calling the Public Affairs office at 207.438.1140 or by writing to:

Portsmouth Naval Shipyard  
Public Affairs Office  
Attn: Danna Eddy  
Portsmouth, NH 03804-5000

Sincerely,

Deborah J. Cohen, PE  
Project Manager

DJC/clm  
Enclosure



**TETRA TECH**

Mr. Matthew Audet  
Environmental Protection Agency  
Mr. Iver McLeod  
Maine Department of Environmental Protection  
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**Without Enclosure**

Mr. Doug Bogen (e-mail)  
Ms. Mary Marshall (e-mail)  
Mr. Peter Britz (e-mail)  
NH Fish & Game (D. Grout) (e-mail)  
ME Dept. of Marine Resources (D. Nault) (e-mail)  
Dr. Roger Wells (e-mail)  
PNS Code 100PAO (e-mail)  
Ms. Diana McNabb (e-mail)  
Mr. Jack McKenna  
Ms. Lisa Joy (e-mail)  
Mr. Paul Dombrowski (e-mail)  
NOAA (K. Finkelstein) (e-mail)  
U.S. Fish and Wildlife (K. Munney)(e-mail)

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Ms. Jennifer Obrin, Katahdin (e-mail)  
Mr. Doug Bogen /TAG recipient (e-mail)  
NIRIS RDM

**RESPONSES TO MEDEP COMMENTS DATED JUNE 11, 2014  
DRAFT SAMPLING AND ANALYSIS PLAN FOR OPERABLE UNIT 8 REMEDIAL  
INVESTIGATION  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**

1. **Comment:** Although the general boundary of the site is described by the quay wall, it is evident from the data at MW/SB05 and potentially from the disposal data from the recent utility work at Building 174 that the fill placed west of the quay wall is also impacted. It is unclear whether impacts are from Shipyard activity after the filling occurred or from the fill itself. If access can be established additional borings are warranted to characterize soils west of the quay wall. Disposal data from the utility excavation needs to be added to the SAP as an appendix and evaluated to determine if it is consistent with the CSM and the likely COCs. If this data indicate that there are data gaps in the CSM then adjustments need to be made to the SAP.

**Response:** No text revision is proposed. Based on site history, the location of the quay walls, and data available for OU8, MW/SB05 is not considered within the boundary of OU8 and characterization of soil west of the quay wall is not planned as part of the investigation for OU8.

Data from MW/SB05 and from the recent construction project at Building 174 do not indicate that fill placed west of the quay wall has been impacted by OU8. With the exception of mercury in the surface soil at SB05, chemical concentrations are low. Mercury in the surface soil at SB05 was elevated; however, mercury concentrations were low in the soil samples within OU8. The site history for OU8 also does not indicate that mercury was associated with operations at OU8.

Based on further discussion with the IR Program Manager, PWD-Maine Environmental Division, regarding the construction project, soil samples had non-hazardous (TCLP) results west of the quay wall where SB05 is located. Soil samples with TCLP exceedances were collected east of the quay (inside of OU8) and only lead had TCLP exceedances. Because of the TCLP exceedances, disposal of excavated soil from within OU8 was sent to a hazardous waste disposal facility and no further characterization of soil was conducted as part of the project. To support potential offsite disposal at a non-hazardous facility, pre-excavation characterization of soil west of the quay wall (referred to as Zone 2 soil) was conducted. The Navy collected composite soil samples from 12 test pits in the excavation area west of the quay wall and analyzed the samples for the required disposal characterization analytes, including VOCs, SVOCs, pesticides, herbicides, PCBs, RCRA metals, and cyanide. Four of the test pits were in the vicinity of MW/SB05. Concentrations of organics and inorganics were low or non-detected. The data showed low concentrations of mercury.

The physical boundary of the site is known. Because it isn't possible to separate CERLCA activities from the fill material within the OU8 boundaries, the Navy will need to accept the physical boundaries as the limit. But because fill material outside of the site boundaries is not related to CERLCA activities at OU8, the Navy does not need to determine chemical concentrations in fill material outside the OU8 boundary. However, the Navy recognizes that if data from the RI indicate that there are elevated mercury concentrations within OU8, then further discussion will be needed to determine the appropriate action to address site-related mercury.

2. **Comment:** Executive Summary, 1<sup>st</sup> and 2<sup>nd</sup> sentence. These sentences give the impression that the RI has already been started. Please change the words completing/complete to

performing/perform.

**Response:** The text of the first two sentences will be revised to read as follows.

“This Operable Unit (OU) 8 Remedial Investigation (RI) Sampling and Analysis Plan (SAP) provides the basis and methods for conducting an RI for OU8 at Portsmouth Naval Shipyard (PNS), Kittery, Maine. Information necessary to complete the RI Report and Feasibility Study for OU8 will be collected during this investigation.”

- Comment:** 10.3, History of Environmental Investigations: The former fuel tanks in the area near Building 92 are identified as potential sources in Section 10.4.3. TPH was detected in soil and groundwater and was identified in the SI as needing additional data collection. In addition to the PAHs please add MADEP EPH method for evaluation of the TPH previously detected at the site.

**Response:** No TPH (DRO or GRO) data will be collected for OU8 as part of the RI. PAHs are sufficient to evaluate potential risks for the RI and therefore DRO data are not necessary. There is no indication that VOCs are contaminants associated with OU8 (based on site history and SSI data) and GRO data showed low concentrations or non-detects in soil and groundwater; therefore, neither VOC nor GRO data are necessary for the RI.

The tanks mentioned in Section 10.4.3 are not located at OU8; these were located upgradient of the site. The former fuel oil tanks were present at Building 92, east (upgradient) of the former timber basin eastern quay wall and were located where the building has since been expanded. To eliminate the confusion, the Navy will remove the tanks from the CSM as being a potential source, as they are not sources at OU8.

- Comment:** 10.3, p. 20, 3<sup>rd</sup> para. Change “... concentrations exceeding industrial risk-based screening...” to “concentrations exceeding USEPA industrial risk-based screening...” since Tables 1 does not indicate that the Navy made any comparison to Maine Remedial Action Guidelines for Soil (RAGS).

**Response:** The clarification will be made as noted, to read as follows.

“...concentrations exceeding USEPA industrial risk-based screening...”

- Comment:** 10.4.4, p. 23. The previous data collection suggests some tidal influence on groundwater at the site, but it does not necessarily mean there is an influx of river water to the site each tidal cycle. The groundwater data do not indicate that in-situ the soils are not leaching significant concentrations of contaminants under current conditions. However, the TCLP data from the utility project may show that management of any future excavated soil will be needed for disposal.

**Response:** No text revision is proposed. The Navy agrees that there may not be an influx of river water throughout the site during high tidal periods, except along the edges of the site. As discussed in Worksheet 11, as part of the RI, tidal information will be collected as part of characterization of groundwater conditions. The Navy agrees that if soil is to be excavated as part of a future remedial action, the soil would be tested and handled appropriately.

- Comment:** 10.4.4, p. 24, 2<sup>nd</sup> para. The impacts to the offshore are also contingent on conditions such as buildings and asphalt remaining in place. The concentrations won't increase but the mobility could increase if soil were exposed, excavated, etc. Text should be added to note that factor.

**Response:** No text revision is proposed. The unsaturated zone at OU8 has been exposed previously, as the asphalt has not always been present. Also, the fill material at OU8 is already in contact with groundwater. Therefore, migration is not expected to be of concern. Impacts to the offshore area were investigated as part of the OU4 investigation, and no impacts to the offshore attributable to OU8 were identified.

7. **Comment:** Section 11.2, Project Action Limits and Section 11.4, Decision Rule #3: Maine DEP considers acceptable risk to meet an Incremental Lifetime Cancer Risk (ILCR) of 10<sup>-5</sup> for carcinogens for purposes of human health risk assessment, please revise as needed.

**Response:** No text revision is proposed. As the Navy has discussed with MEDEP previous (for example see the Navy's response to MEDEP Comment No. 37 on the draft OU7 RI Report, provided in Appendix E.1 of the final OU7 RI Report, Tetra Tech, July 2011), the Navy makes risks decisions based on the USEPA risk range and not State of Maine risk guidelines because Maine's risk assessment guidelines are not promulgated. However, as part of the risk assessment, the Navy will discuss exceedances of the Maine guideline for informational purposes.

8. **Comment:** Section 11.3, Study Area Boundaries and Figure 8: As noted above, soil data indicate that the boundary of contamination to the west is not defined. It is unclear if Site 3 is the source of elevated concentrations. Additional data are needed to quantify concentrations in the fill, if access is possible, unless data are available for the geotechnical borings around Building 174. At a minimum the area needs to be qualitatively discussed since it borders the currently identified site boundary.

**Response:** No text revision is proposed. There is a known physical boundary for the site soil, and the mercury exceedance that was detected outside of the boundary is not from site-related activities based on the available site information. No additional sampling outside of the site boundary is proposed, as it is not within the scope of the project to quantify potential contamination in fill outside of OU8.

9. **Comment:** Section 11.4, Groundwater EPCs: Approval of the groundwater EPCs will be determined when the Navy risk assessor proposes criteria.

**Response:** No text revision is proposed. The risk assessment will provide the selection of EPCs and the risk assessment will be included in the RI Report that will be distributed to the regulators for review and comment.

10. **Comment:** Section 11.4, Decision Rule #1: MEDEP does not typically allow compounds to be screened out of a risk assessment based on background concentrations. At a minimum, the implication of leaving out such compounds must be discussed in the uncertainty section of the risk assessment. For comparisons of risk-based values to background MEDEP suggests that the 95% UCL statistics would be an appropriate background value to consider. If another value is used please provide rationale.

**Response:** No text revision is proposed. For qualitative evaluation of data, the Navy will use the 95% UCL for the facility background data set as a representative concentration to provide an understanding of nature and extent of contamination. For risk assessment, the selection of chemicals of potential concern (COPCs) and uncertainty based on screening out of background will be conducted consistent with risk assessments for other PNS sites (e.g., OU7 RI Report), where risks from chemicals that are screened out as COPCs based on background (based on a dataset to dataset comparison) are evaluated in the uncertainty section.

11. **Comment:** Worksheet #13: Please provide the boring logs referenced from construction at Building 92 and Building 174 as an electronic appendix to the SAP.

**Response:** Electronic copies of the boring logs referenced from the construction projects will be included on the CD provided in the SAP.

12. **Comment:** Worksheet #15: Several PAHs do not have brackish/saline PSLs available. What screening levels will be used for these compounds in the likely scenario that the water is brackish/saline?

**Response:** The updated Worksheet 15 is attached and it reflects updates to the screening levels based on updates to USEPA RSLs in May 2014 and recalculation of facility-specific screening levels.

The facility-specific screening levels for construction worker exposure will be used as the PSLs for brackish/saline water. The Navy re-calculated the screening levels to account for both dermal and incidental ingestion exposure pathways consistent with the lead screening level calculation. The methodology is based on Risk Assessment for Superfund, Volume I, Human Health Evaluation Manual Part A, (Interim Final RAGS Part A, USEPA, December 1989, 2010 updates) and Risk Assessment for Superfund, Volume I, Human Health Evaluation Manual Part E, Supplemental Guidance for Dermal Risk Assessment (RAGS Part E, USEPA, July 2004). With the inclusion of incidental ingestion in the screening level calculation, all of the PAHs now have brackish/saline PSLs. The methodology and worksheets showing the calculation of construction worker groundwater screening levels will be provided in Appendix A of the SAP. In addition, Tables 1, 2, and 3 in Appendix A will be updated to include the May 2014 USEPA RSLs and the updated facility-specific screening levels for groundwater.

13. **Comment:** Worksheet #15 and Worksheet #17:

- Please add EPH to the groundwater and soil collection and add the MEDEP reference limits to Worksheet 15. Rather than sample all soil locations for EPH a subset of samples are warranted for locations where there is field evidence of petroleum impacts in the soil. As a minimum locations adjacent SB-02, SB-05, or SB-06 may warrant sampling, based on earlier data.
- Groundwater, hydraulic conductivity – The general approach is acceptable, although there appear to be some errors in the text. (MW005 is west of the site, and MW-03 is in the east central portion of the site) Based on the proximity or inclusion of MW-02 and MW-05 in the backfill material from the recent construction at the site, only one of these wells is warranted for the study, to see if the newer fill has a hydraulic conductivity distinct from the historic fill in the area. MW-06 should also be considered, based on its location near the last timber basin area filled, and to provide spatial coverage from other wells prepared.

**Response:** The Navy will evaluate PAHs as part of the RI, but will not add EPH to the analysis proposed, as discussed in the Navy's response to MEDEP Comment No. 3.

Regarding hydraulic conductivity testing, the Navy agrees with the suggested revisions. The text will be revised as follows: "...include WTB-MW02 or WTB-MW07 (depending on the lithology encountered during drilling of WTB-MW07) in the northern portion of the site, WTB-~~MW02~~MW03 in the east-central portion of the site, and WTB-~~MW05~~MW06 south of the site."

14. **Comment:** Worksheet 18 and Figure 8: Soil samples also are needed from SB-07, to support the groundwater data, and to provide additional soil characterization west of the quay wall.

Please add to the table and revise as needed. A subset of EPH samples is also needed as an addition to the table. If trailers or other items have been moved following completion of the work at Building 174 then the three “middle” borings to the south and roughly in line with WTB-MW-04 should be shifted west to the other side of the rail or crank lines for greater spatial coverage of the site.

**Response:** As part of the SSI, soil samples were collected from WTB-SB07. The new proposed monitoring well WTB-MW07 is located outside of the site boundary and soil sample will not be collected at this location. Because of the various utilities, it may be difficult to install a boring east of WTB-MW07; however, the Navy will move the proposed boring location shown south of WTB-SB07 to the east of WTB-MW07/west of WTB-MW02. Locations of the proposed borings are approximate, and will be shifted as needed and as allowed by the current site configuration. A utility clearance will be conducted before field work and significant modifications to proposed boring locations will be provided to the regulators as part of regular project discussions (e.g., weekly RPM calls).

15. **Comment:** Appendix A: The table associated with the sensitivity analysis indicated that a more desirable 10% alpha error can be achieved with only a small increase in the number of samples, 23 vs 18. The previous page notes that MARSSIM recommends that the number of samples be increased by 20% to account for uncertainty and potential missing/unusable samples, but in this case no increase was included. Based on these factors adding soils data from MW/SB-07 and perhaps adding an additional boring west of the quay wall is consistent with the approach taken to evaluate the number of samples needed. These locations would also provide adequate data collection if some of the proposed sample point(s) prove to be inaccessible.

**Response:** No additional borings are planned at this time. Soil samples will be collected within the boundary of OU8 for the RI; no soil samples are planned to the west of the western quay wall. As discussed in the Navy’s response to MEDEP Comment No. 14, soil samples have been collected at WTB-SB07 and none are planned for the new monitoring well location (WTB-MW07), which is located outside of the OU8 boundary. Sample locations may need to be shifted based on site conditions as discussed above.

For the calculation of number of samples, this is an estimate based on the input assumptions to get the minimum number of samples in a general ballpark to meet the project goals. The Navy recognizes that different alpha and beta errors can be selected to identify the number of samples. Site conditions, existing data, and accessibility are also factors that should be considered in developing the sampling plan. For OU8, the sampling plan is based on 18 new boring locations and 5 existing boring locations within OU8. The new boring locations were identified to provide spatial coverage of the site with consideration of the presence of underground utilities and other structures that could impeded or prevent collection of soil samples. Based on the planned soil sampling from new borings and the existing soil samples, the anticipated OU8 data set will consist of 21 surface soil samples and 51 subsurface soil samples. Therefore, the Navy believes that the planned sampling will exceed the minimum number of samples identified in the calculation.

## SAP WORKSHEET #15: REFERENCE LIMITS AND EVALUATION TABLES

[\(UFP-QAPP Manual Section 2.8.1\)](#)

Matrix: Soil

Analytical Group: TAL Metals **SW-846 Method 6010 limits with the exception of arsenic, cobalt, thallium (SW-846 Method 6020 limits presented), and mercury by SW-846 Method 7471B**

Analyte	CAS No.	PSLs (mg/kg) <sup>1</sup>	PSL Reference <sup>1</sup>	Project QL Goal (mg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ(mg/kg)	LOD (mg/kg)	DL (mg/kg)
Aluminum	7429-90-5	7700 N	USEPA RSL	2600	30	10	0.71
Antimony	7440-36-0	3.1 N	USEPA RSL	1.0	0.8	0.5	0.07
Arsenic	7440-38-2	0.67 C	USEPA RSL	0.22	0.5	0.4	0.15
Barium	7440-39-3	1500 N	USEPA RSL	500	0.5	0.3	0.03
Beryllium	7440-41-7	16 N	USEPA RSL	5.3	0.5	0.05	0.007
Cadmium	7440-43-9	7 N	USEPA RSL	2.3	1.0	0.3	0.008
Calcium	7440-70-2	NA	USEPA RSL	NA	10	8.0	1.78
Chromium	7440-47-3	12000 N	USEPA RSL	4000	1.5	0.4	0.03
Cobalt	7440-48-4	2.3 N	USEPA RSL	0.77	0.1	0.03	0.0054
Copper	7440-50-8	310 N	USEPA RSL	100	2.5	1.0	0.16
Iron	7439-89-6	5500 N	USEPA RSL	1800	10	8.0	1.4
Lead	7439-92-1	400	USEPA RSL	130	0.5	0.4	0.09
Magnesium	7439-95-4	NA	USEPA RSL	NA	10	8.0	0.68
Manganese	7439-96-5	180 N	USEPA RSL	60	0.5	0.4	0.16
Mercury	7439-97-6	0.94 N (elemental)	USEPA RSL	0.31	0.033	0.017	0.0052

Matrix: Soil

Analytical Group: TAL Metals **SW-846 Method 6010 limits with the exception of arsenic, cobalt, thallium (SW-846 Method 6020 limits presented), and mercury by SW-846 Method 7471B**

Analyte	CAS No.	PSLs (mg/kg) <sup>1</sup>	PSL Reference <sup>1</sup>	Project QL Goal (mg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ(mg/kg)	LOD (mg/kg)	DL (mg/kg)
Nickel	7440-02-0	150 N	USEPA RSL	50	4	0.4	0.044
Potassium	7440-09-7	NA	USEPA RSL	NA	100	50	2.9
Selenium	7782-49-2	39 N	USEPA RSL	13	1.0	0.7	0.17
Silver	7440-22-4	39 N	USEPA RSL	13	1.5	0.4	0.03
Sodium	7440-23-5	NA	USEPA RSL	NA	100	50	1.48
<b>Thallium<sup>3</sup></b>	<b>7440-28-0</b>	<b>0.078 N</b>	<b>USEPA RSL</b>	<b>0.026</b>	<b>0.1</b>	<b>0.04</b>	<b>0.0094</b>
Vanadium	7440-62-2	39 N	USEPA RSL	13	2.5	0.4	0.04
Zinc	7440-66-6	2300 N	USEPA RSL	770	2.5	1.0	0.17

Notes:

- 1 The PSLs are for use as part of COPC screening in the risk assessment. Chemicals with concentrations that exceed PSLs and facility background levels (based on a statistical comparison of the site data set to the facility background data set) will be selected as COPCs. The PSLs are the USEPA residential Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C). PSLs are NA for chemicals that do not have screening levels.
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data.
- 3 Thallium toxicity criterion is only suitable for screening and is not used for quantifying risks.

Matrix: Soil

Analytical Group: PAHs  
 Selected Ion Monitoring (SIM) **SW-846 Method 8270D SIM**  
 Analysis

Analyte	CAS No.	PSL (µg/kg)	PSL Reference <sup>1</sup>	Project QL Goal (µg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ (µg/kg)	LOD (µg/kg)	DL (µg/kg)
Acenaphthene	83-32-9	350000 N	USEPA RSL	120000	20	10	1.5
Acenaphthylene	208-96-8	350000 N (based on acenaphthene)	USEPA RSL	120000	20	10	1.2
Anthracene	120-12-7	1700000 N	USEPA RSL	570000	20	10	1.2
Benzo(a)anthracene	56-55-3	150 C	USEPA RSL	50	20	10	1.9
<b>Benzo(a)pyrene</b>	<b>50-32-8</b>	<b>15 C</b>	<b>USEPA RSL</b>	<b>5</b>	<b>20</b>	<b>10</b>	<b>3.3</b>
Benzo(b)fluoranthene	205-99-2	150 C	USEPA RSL	50	20	10	2.4
Benzo(g,h,i)perylene	191-24-2	170000 N (based on pyrene)	USEPA RSL	57000	20	10	2.0
Benzo(k)fluoranthene	207-08-9	1500 C	USEPA RSL	500	20	10	3.1
Chrysene	218-01-9	15000 C	USEPA RSL	5000	20	10	1.7
<b>Dibenzo(a,h)anthracene</b>	<b>189-64-0</b>	<b>15 C</b>	<b>USEPA RSL</b>	<b>5</b>	<b>20</b>	<b>10</b>	<b>1.8</b>
Fluoranthene	206-44-0	230000 N	USEPA RSL	77000	20	10	1.8
Fluorene	86-73-7	230000 N	USEPA RSL	77000	20	10	3.2
Indeno(1,2,3-CD)pyrene	193-39-5	150 C	USEPA RSL	50	20	10	1.9
Naphthalene	91-20-3	3800 C	USEPA RSL	1300	20	10	2.6

Matrix: Soil

Analytical Group: PAHs  
Selected Ion Monitoring (SIM) SW-846 Method 8270D SIM  
Analysis

Analyte	CAS No.	PSL (µg/kg)	PSL Reference <sup>1</sup>	Project QL Goal (µg/kg)	Laboratory Specific Limits <sup>2</sup>		
					LOQ (µg/kg)	LOD (µg/kg)	DL (µg/kg)
Phenanthrene	85-01-8	170000 N (based on pyrene)	USEPA RSL	57000	20	10	1.8
Pyrene	129-00-0	170000 N	USEPA RSL	57000	20	10	2.1

Notes:

- 1 The PSLs are for use as part of COPC screening in the risk assessment. Chemicals with concentrations that exceed the PSLs and facility background levels (based on a statistical comparison of the site data set to the facility background data set) will be selected as COPCs. The PSLs are the USEPA residential RSLs for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C).
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data.

Matrix: Groundwater

Analytical Group: TAL  
Metals (Total and  
Dissolved)

SW-846 Method 6010 limits with the exception of antimony, arsenic, beryllium, cadmium, cobalt, selenium, silver, thallium and vanadium (SW-846 Method 6020 limits presented). Mercury by SW-846 Method 7470A.

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Aluminum	7429-90-5	2000 N	1150000 N	USEPA RSL/ PNS CW SL	670	300	100	14.8
<b>Antimony</b>	<b>7440-36-0</b>	<b>0.78 N</b>	<b>138 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.26</b>	<b>1.0</b>	<b>0.5</b>	<b>0.054</b>
<b>Arsenic</b>	<b>7440-38-2</b>	<b>0.052 C</b>	<b>345 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.017</b>	<b>5.0</b>	<b>4.0</b>	<b>2.25</b>
Barium	7440-39-3	380 N	35700 N	USEPA RSL/ PNS CW SL	130	5.0	3.0	0.23
Beryllium	7440-41-7	2.5 N	97.2 N	PNS CW SL	0.83	1.0	0.2	0.034
<b>Cadmium</b>	<b>7440-43-9</b>	<b>0.92 N</b>	<b>65.4 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.31</b>	<b>1.0</b>	<b>0.2</b>	<b>0.03</b>
Calcium	7440-70-2	NA	NA	USEPA RSL/ PNS CW SL	NA	100	80	11.2
Chromium	7440-47-3	2200 N	27100 N	USEPA RSL/ PNS CW SL	730	10	4.0	0.36
<b>Cobalt</b>	<b>7440-48-4</b>	<b>0.6 N</b>	<b>4570 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.20</b>	<b>1.0</b>	<b>0.3</b>	<b>0.06</b>
Copper	7440-50-8	80 N	46000 N	USEPA RSL/ PNS CW SL	27	25	10	0.63
Iron	7439-89-6	1400 N	804000 N	USEPA RSL/ PNS CW SL	470	100	80	5.42
Lead	7439-92-1	15	1340	USEPA RSL/ PNS CW SL	5	5.0	4.0	1.07
Magnesium	7439-95-4	NA	NA	USEPA RSL/ PNS CW SL	NA	100	80	7.8

Matrix: Groundwater

Analytical Group: TAL  
Metals (Total and  
Dissolved)

SW-846 Method 6010 limits with the exception of antimony, arsenic, beryllium, cadmium, cobalt, selenium, silver, thallium and vanadium (SW-846 Method 6020 limits presented). Mercury by SW-846 Method 7470A.

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Manganese	7439-96-5	43 N	2550 N	USEPA RSL/ PNS CW SL	14	5.0	4.0	1.06
Mercury	7439-97-6	0.57 (mercuric chloride)	357 (mercuric chloride)	USEPA RSL/ PNS CW SL	0.19	0.2	0.1	0.013
Nickel	7440-02-0	39 N	8710 N	USEPA RSL/ PNS CW SL	13	10	4.0	0.28
Potassium	7440-09-7	NA	NA	USEPA RSL/ PNS CW SL	NA	1000	500	41
Selenium	7782-49-2	10 N	5750 N	USEPA RSL/ PNS CW SL	3.3	5.0	3.0	0.19
Silver	7440-22-4	9.4 N	853 N	PNS CW SL	3.1	1.0	0.4	0.05
Sodium	7440-23-5	NA	NA	USEPA RSL/ PNS CW SL	NA	1000	500	23.7
<b>Thallium</b> <sup>3</sup>	<b>7440-28-0</b>	<b>0.020 N</b>	<b>46.0 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.0067</b>	<b>1.0</b>	<b>0.4</b>	<b>0.06</b>
Vanadium	7440-62-2	8.6 N	703 N	USEPA RSL/ PNS CW SL	2.9	5.0	4.0	0.51
Zinc	7440-66-6	600 N	412000 N	USEPA RSL/ PNS CW SL	200	20	10	0.73

Notes:

- 1 If the majority of groundwater at the site is fresh water, the PSLs for fresh water will be used as part of COPC selection. Otherwise, the PSLs for brackish or saline water will be used as part of COPC selection. The PSLs for fresh water are the USEPA Tap water RSLs for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The PSLs for brackish or saline water are PNS-specific screening levels for construction worker contact (dermal) with groundwater (PNS CW SL) that were calculated using the methodology provided in Appendix A.4. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C). PSLs are NA for chemicals that do not have screening levels.

- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data. If the LOQ and LOD exceed the PSL, bold text and shading are used for the entire row of data.
- 3 Thallium toxicity criterion is only suitable for screening and is not used for quantifying risks.

Matrix: Groundwater

Analytical Group: PAHs  
(Sim Analysis) **SW-846 Method 8270D SIM**

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Acenaphthene	83-32-9	53 N	3760 N	USEPA RSL/ PNS CW SL	18	0.2	0.1	0.064
Acenaphthylene	208-96-8	53 N (based on acenaphthene)	1080 N	USEPA RSL/ PNS CW SL	18	0.2	0.1	0.054
Anthracene	120-12-7	180 N	10100 N	USEPA RSL/ PNS CW SL	60	0.2	0.1	0.044
<b>Benzo(a)anthracene</b>	<b>56-55-3</b>	<b>0.034 C</b>	<b>1870 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.046</b>
<b>Benzo(a)pyrene</b>	<b>50-32-8</b>	<b>0.0034 C</b>	<b>187 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.0011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.066</b>
<b>Benzo(b)fluoranthene</b>	<b>205-99-2</b>	<b>0.034 C</b>	<b>1870 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.089</b>
Benzo(g,h,i)perylene	191-24-2	12 N (based on pyrene)	21.0 N	USEPA RSL/ PNS CW SL	4.0	0.2	0.1	0.065
Benzo(k)fluoranthene	207-08-9	0.34 C	18700 C	USEPA RSL/ PNS CW SL	0.11	0.2	0.1	0.049
Chrysene	218-01-9	3.4 C	187000 C	USEPA RSL/ PNS CW SL	1.1	0.2	0.1	0.036
<b>Dibenzo(a,h)anthracene</b>	<b>189-64-0</b>	<b>0.0034 C</b>	<b>187 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.0011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.070</b>
Fluoranthene	206-44-0	80 N	779000 N	USEPA RSL/ PNS CW SL	27	0.2	0.1	0.073
Fluorene	86-73-7	29 N	5650 N	USEPA RSL/ PNS CW SL	9.7	0.2	0.1	0.061
<b>Indeno(1,2,3-CD)pyrene</b>	<b>193-39-5</b>	<b>0.034 C</b>	<b>1870 C</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.011</b>	<b>0.2</b>	<b>0.1</b>	<b>0.052</b>

Matrix: Groundwater

Analytical Group: PAHs **SW-846 Method 8270D SIM**  
 (Sim Analysis)

Analyte	CAS No.	PSL Freshwater (µg/L) <sup>1</sup>	PSL Brackish or Saline Water (µg/L) <sup>1</sup>	PSL Reference Freshwater/ Brackish or Saline Water <sup>1</sup>	Project QL Goal (µg/L)	Laboratory Specific Limits <sup>2</sup>		
						LOQ (µg/L)	LOD (µg/L)	DL (µg/L)
Naphthalene	91-20-3	<b>0.17 C</b>	<b>23600 N</b>	<b>USEPA RSL/ PNS CW SL</b>	<b>0.057</b>	<b>0.2</b>	<b>0.1</b>	<b>0.064</b>
Phenanthrene	85-01-8	12 N (based on pyrene)	58400 N	USEPA RSL/ PNS CW SL	4.0	0.2	0.1	0.051
Pyrene	129-00-0	12 N	1850 N	USEPA RSL/ PNS CW SL	4.0	0.2	0.1	0.059

Notes:

- 1 If the majority of groundwater at the site is fresh water, the PSLs for fresh water will be used as part of COPC selection. Otherwise, the PSLs for brackish or saline water will be used as part of COPC selection. The PSLs for fresh water are the USEPA Tap water RSLs for Chemical Contaminants at Superfund Sites, RSL Table, May 2014. The PSLs for brackish or saline water are PNS-specific screening levels for construction worker contact (ingestion and dermal) with groundwater (PNS CW SL) that were calculated using the methodology provided in Appendix A.4. The values shown are based on a target hazard quotient of 0.1 for non-carcinogens (N) and an ILCR of  $1 \times 10^{-6}$  for carcinogens (C). PSLs are NA for chemicals that do not have screening levels.
- 2 Laboratory-specific DLs, LODs, and LOQs are limits that the selected laboratory can achieve when performing a specific analytical method. If the LOQ exceeds the PSL, bold text is used for the entire row of data. If the LOQ and LOD exceed the PSL, bold text and shading are used for the entire row of data.

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**Subject:** PNS OU8 Uniform Federal Policy-Sampling and Analysis Plan for Remedial Investigation, Red-line  
**Date:** Friday, January 23, 2015 3:36:00 PM  
**Attachments:** [Portsmouth OU8 RI SAP redline.doc](#)  
[Figure 8 updated.pdf](#)  
[Figure 3 updated.pdf](#)  
[1998 SSI boring and well logs.pdf](#)  
[UPDATED App A Table 3 updated 091014.xlsx](#)  
[UPDATED App ATABLE 1 AND TABLE 2 091014.xls](#)

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Team,

First, to refresh everyone on where the UFP-SAP for OU8 stands and how to we got to where we are currently:

The UFP-SAP for Remedial Investigation at OU8 was submitted to the team as a draft on April 29, 2014. EPA had no comments on the draft, and MEDEP comments were received June 11. A Response to Comments was sent on September 18, 2014. Discussion followed between Navy, Tetra Tech, and MEDEP focused primarily on the question of whether EPH would be added as an analysis during the investigation.

After discussions between MEDEP and the Navy on the MEDEP comments on the OU8 UFP-SAP for Remedial Investigation, the Navy has agreed to sample and analyze for EPH per MEDEP's request, with the results not being used to make decisions in the risk assessment and RI, but discussed in the uncertainty section of the risk assessment, as required. All other comments from the MEDEP Response have been resolved. A red-line version of the updated UFP-SAP showing all changes made based on the comments received is attached, along with figures and items for the appendices that have been changed based on the resolution of the comments. The only other changes made to the UFP-SAP from the previous version were editorial or minor.

Please review this red-line version and let us know if you have questions or follow-on comments. We are aiming to conduct the work this Spring before further construction at the Site, and ask that you provide us with your follow-on comments or approval of the updated version within two weeks so that the UFP-SAP can be prepared as Final to allow for the field work to be conducted when possible.

Thank you!

Megan

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**RESPONSES TO MEDEP FOLLOW-ON COMMENTS DATED FEBRUARY 12, 2015  
SAMPLING AND ANALYSIS PLAN FOR OPERABLE UNIT 8 REMEDIAL INVESTIGATION,  
RED-LINE STRIKEOUT VERSION  
PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE**

1. **Comment:** 11.4 Analytic Approach. “There is no decision rule for the EPH data collected, as the data is being collected for informational purposes and no decisions for remedial action will be made based on the results.” MEDEP disagrees that the EPH data are for informational purposes only. MEDEP’s EPH criteria are risk-based and therefore an exceedance of these criteria in soil indicates unacceptable risk. Should EPH values in soil at OU8 exceed MEDEP Tier II values for Outdoor Commercial Worker and Excavation Construction Worker further discussion will be required. It may be necessary for the Navy to remove soil based on exceedances of EPH criteria.

**Response:** The Navy will present the EPH results in the Remedial Investigation (RI) Report and will evaluate the results in the uncertainty analysis of the risk assessment that will be provided in the RI Report to provide the information MEDEP requested. However, the Navy will not make decisions under CERCLA based on the EPH data for OU8. Therefore, no text revision is proposed based on this comment. The Navy recommends that if additional discussion is needed regarding EPH data for OU8, that it be held after data are available for OU8.

Under CERCLA, the Navy responds to releases of “hazardous substances,” as defined by 42 U.S. Code §9601(14) [CERCLA §101(14)]. That definition, however, explicitly excludes petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance. (The term “oil” here includes refined petroleum products such as gasoline, diesel, jet fuel, etc.). Therefore, spills and leaks of only such petroleum products are not considered in this chapter because these types of sites would not be addressed under the CERCLA process. However, some waste oil tanks may contain chlorinated solvents or other CERCLA hazardous substances, or the releases may be commingled with other CERCLA hazardous substances, in which case the petroleum exclusion does not apply. Historical records indicate there were two fuel oil underground storage tanks (State Registration #s 11863-4 and 11863-5) located North of Building 92 and that they were removed in 1986. These tanks were identified as fuel oil tanks and not as waste oil tanks, therefore, the exclusion applies.

2. **Comment:** Section 10.4.3. Please explain why the Navy removed the fuel oil tanks as potential sources.

**Response:** The text in Section 10.4.3 regarding fuel oil tanks being potential sources was removed because the fuel oil tanks were known to have been located upgradient of OU8 and not within the site. The tanks were initially included as a potential source with the intention to be comprehensive in the conceptual site model (CSM); however, further investigation into the tanks has shown that any activities involving the fuel oil tanks were not related to OU8. The RI is focused specifically on OU8 and contamination within the site boundaries and due to site activities; thus, tanks have been removed from the CSM as being a potential source of contamination. Please also refer to the Navy’s response to MEDEP comment no. 1.

3. **Comment:** Thank you for providing the logs from the 1998 SI. However, our June 11, 2014

comment was referring to the borings logs associated with the work at Buildings 92 and 174 that are mentioned in Worksheet 13. Those logs need to be in the final SAP, or at least in the report for the investigation (logs and data were provided to MEDEP via email 11/6/2013 for the 2011 test pits, however the other 2010 boring logs referenced in the SAP are not included). Please include them as an appendix as they will contribute to the characterization of the site for the remedial investigation.

**Response:** Agreed. The boring logs associated with work at Buildings 92 and 174 that are mentioned in Worksheet 13 will be included in Appendix A.