



Environment

Submitted to:
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Sarasota, FL

Submitted by:
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November 1, 2013

Supplemental Phase II Scope of Work

Former General Electric Facility

50 Fordham Road
Wilmington, MA
RTN 3-0518

AECOM Project No: 60283655

Revision 0

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DOCUMENT CHANGE HISTORY				
Revision Number	Prepared / Approved By	Release Date	Change Description	
			Section	Narrative of Items Affected
0	Scott Olson/Lori Herberich Daniel Folan/Art Taddeo	11/1/2013	-----	Initial Release

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List of Acronyms

%R	Percent Recovery
AC	Air Conditioning
ASTM	American Society For Testing And Materials
ASTs	Aboveground Storage Tanks
bgs	Below ground surface
BTEX	Benzene, toluene, ethyl benzene, and xylenes
CAM	Compendium of Analytical Methods
CLP	Contract Laboratory Program
COC	Chain-Of-Custody Form
Converse	Converse, Inc.
CVOCs	Chlorinated Volatile Organic Compounds
DI	Deionized Water
DNAPL	Dense non-aqueous phase liquid
DO	Dissolved Oxygen
DOT	Department of Transportation
DQL	Data Quality Level
DQO	Data Quality Objectives
EDD	Electronic Data Deliverables
EDR	Environmental Database Report
EM	Electromagnetic
EPL	Eastern Parking Lot
ESH	Environmental Safety and Health
FID	Flame ionization detector
GC/MS	Gas chromatography/mass spectrometry
GE	General Electric
gpm	Gallons per minute
GPR	Ground Penetrating Radar
Hager-Richter GI	Hager-Richter Geosciences, Inc.
HASP	Health and Safety Plan
HAZWOPER	OSHA Hazardous Waste Operations
Hg	Mercury
HSA	Hollow Stem Auger
HVAC	Heating/ventilation/air conditioning
ID	Inner diameter
IDW	Investigation-Derived Waste

ISRM	International Society for Rock Mechanics
IWPA	Interim Wellhead Protection Area
kg/month	Kilograms per month
LCS	Laboratory Control Sample
LNAPL	Light non-aqueous phase liquid
Lockheed Martin	Lockheed Martin Corporation
LSP	Licensed Site Professional
MassDEP	Massachusetts Department of Environmental Protection
MCP	Massachusetts Contingency Plan
MERC	Methanol Extraction Rock Chip
mg/L	Milligrams per liter
ml/min	milliliters per minute
MS/MSD	Matrix spike/matrix spike duplicate
MTBE	Methyl tertiary butyl ether
NGVD	National Geodetic Vertical Datum
O&M	Operation and Maintenance
ORP	Oxidation Reduction Potential
PARCC	precision, accuracy, representativeness, comparability, and completeness
PCE	Tetrachloroethylene
PDB	Passive Diffusion Bag
PE	Performance Evaluation
PID	Photoionization Detector
PIP	Public Involvement Plan
PM	Project Manager
PPE	Personal Protective Equipment
ppm	Parts per Million
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAO	Response Action Outcome
RAP	Remedial Action Plan
RAPS	Response Action Performance Standards
RCs	Reportable Concentrations
RFP	Request for Proposal
ROS	Remedy Operation Status
RPD	Relative Percent Difference

RSSB	Regulated Substances Storage Building
RTN	Release Tracking Number
SAP	Sampling and Analysis Plan
SIM	Selected Ion Monitoring
SOPs	Standard Operating Procedures
SOW	Scope of Work
SVOC	Semi-volatile organic compounds
T&FR	Technical and Functional Requirements
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Program
TPH	Total Petroleum Hydrocarbons
TRC	TRC Environmental Corporation
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USTs	Underground Storage Tanks
VOA	Volatile organic analysis
VOCs	Volatile organic compounds
VPBs	Volatile Petroleum Hydrocarbons
WMP	Waste Management Plan
WRT	Wilmington Realty Trust

1.0 INTRODUCTION

This Supplemental Phase II Scope of Work (SOW) details the scope, objectives, and procedures to implement remedial investigation activities on behalf of Lockheed Martin Corporation (Lockheed Martin) at the former General Electric (GE) disposal site located in the towns of Wilmington and North Reading, Middlesex County, Massachusetts (site). This SOW was developed per 310 CMR 40.0834 and has been prepared to meet the requirements of the Response Action Performance Standards (RAPS, 310 CMR 40.019).

1.1 PROJECT OBJECTIVES

The objectives of the activities outlined in this SOW are to:

- Further characterize soil, bedrock, and groundwater conditions and assess contaminant concentrations in support of modifying the conceptual site model to support future risk characterizations and a revised Phase III Remedial Action Plan (RAP).
- Collect data to support mass discharge calculations of chlorinated solvents in overburden and bedrock groundwater along the down-gradient property boundary and in the off-site wetlands.
- Assess chlorinated solvent impacts in soil and groundwater in both overburden and bedrock beneath Building 1 to determine the nature and extent of this area of concern, and its relationship, if any, to impacts in the vicinity of the former Tank F as well as the former tank farm area on site.
- Collect additional rounds of indoor air data to further assess the indoor air exposure pathway at Building 1.
- Collect additional data to support the site-wide assessment of arsenic and 1,4-dioxane, and monitored natural attenuation evaluation of chlorinated solvents in groundwater.
- Maintain the packer pressure within bedrock extraction well TRC-202R to prevent communication between the overburden and bedrock groundwater.
- Meet the performance standards of the Massachusetts Contingency Plan (MCP).

1.2 SCOPE OF WORK ORGANIZATION

This SOW has been prepared as a comprehensive document and includes the Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), and Waste Management Plan (WMP) as outlined below.

A Site-Specific Health and Safety Plan (HASP) has been prepared as a companion document separate from this SOW to outline the procedures that will be undertaken to protect AECOM staff from potential hazards that may exist as a result of the fieldwork performed at the site.

Details of the proposed activities are provided in the following sections:

- Section 2 provides a description of the site and surroundings, a summary of the geology and hydrogeology, a summary of the site ownership and operational history, and a summary of the regulatory and remedial response history previously performed at the site.
- Section 3 presents the SOW and description of the specific tasks that will be undertaken to gather sufficient information to meet the project objectives through 2015.
- Section 4 is the SAP which provides the detailed methods and procedures for performing the investigation activities.
- Section 5 is the QAPP which specifies the quality assurance (QA)/quality control (QC) procedures that will be implemented during the fieldwork and for the laboratories that will perform analyses of the samples collected during the investigation.
- Section 6 presents the WMP which outlines the procedures by which investigation-derived waste (IDW) will be managed (stored, profiled, transported and disposed).
- Section 7 provides a list of the references cited in this SOW.

Appendices to the SOW include the following:

- Appendix A – Lockheed Martin Minimum Requirements for Intrusive Field Work
- Appendix B – Project Operation Plans (POPs)
- Appendices C through G – Subcontractor Standard Operating Procedures (SOPs)
- Appendix H – Example Field Records
- Appendix I – Waste Management Procedure and Forms

2.0 SITE BACKGROUND

This section presents a description of the site and surrounding properties, information regarding site ownership and operational history, and the regulatory history and results of the previous investigation work at the former GE property.

2.1 SITE AND AREA DESCRIPTION

The property is located on a 13-acre parcel east of Fordham Road and north of Concord Street, within an industrial park at 50 Fordham Road, in the towns of Wilmington and North Reading, in Middlesex County, Massachusetts. The property is at 42° 33' 39.14"N latitude and 71° 8' 9.88"W longitude; the Universal Transverse Mercator coordinates in meters are 324,654 E and 4,714,264 N in Zone 19T. The property is identified as Map 91, Parcel 131A on the Wilmington, Massachusetts Assessor's Maps.

The property is located in a mixed commercial, industrial, and residential area. The property is bounded by wooded wetlands to the east and north, beyond which are residential properties. Fordham Road is located along the western property boundary with commercial/industrial parcels further west and north along Fordham Road. The former Converse, Inc. (Converse) property and other commercial/industrial properties are located to the south along Concord Street. A site location map is provided as **Figure 2-1**.

The property contains a number of industrial buildings, paved parking areas, and an active sewage and wastewater treatment plant. The buildings are identified as Building 1 and 1A, which are attached, and Building 2. Ancillary structures still present include the Guard Shack, the former Pump House/Vault, and the Treatment Building/Shed that houses the inactive groundwater treatment system. Building 3, the Oil House (formerly referred to by GE as the Regulated Substances Storage Building – RSSB), the Tank Farm, and the original Tank Farm area groundwater treatment building have been removed. The current site plan is depicted in **Figure 2-2**.

The property is located within an Interim Wellhead Protection Area (IWPA) for the inactive North Reading Stickney public water supply (PWS) well and a Zone II WPA for nine emergency backup PWS wells in Reading (Revay Well #1, Well #2, Well #3, B Line Well, Town Forest, Well # 82-20, Well # 66-8, Well #13, and Well #15). The Town of Reading has discontinued use of the Town Forest Wells and dismantled the water treatment facility there but the wells are still listed as backup water supplies. Wetlands and surface water bodies mapped by MassDEP are collocated in the eastern portion of the property. No other sensitive receptors have been identified on the property.

As provided in 310 CMR 40.0006 of the MCP, the term “site” refers to any place or area where oil or hazardous material has come to be located. The “site” designation for MassDEP-required response actions at the Former GE facility consists of a large portion of the 50 Fordham Road property and that portion of the off-property wetlands area to the east where the groundwater plume has been delineated. This formal delineation of the “site” boundary under the MCP is shown on **Figure 2-2**.

2.2 PROPERTY HISTORY

Prior to 1968, the 50 Fordham Road property was reportedly used for gravel mining. The property was developed from 1968 through 1970. GE Aerospace Instruments Control Systems Department used the facility (Buildings 1, 1A, 2, 3, the Oil House, and the Pump House) for manufacturing and supporting research and development from the time of development through August 1989. A portion of Building 2 was subleased to Converse, a sports shoe manufacturer, from 1973 to 1986, and a portion of Building 1 was subleased to Hamilton Standard, a manufacturer of hydrogen generators, from 1983 to 1985. In August 1989, GE’s operations at the facility were sold to Ametek, Inc.; however GE retained environmental liability.

Martin Marietta acquired GE Aerospace on April 2, 1993, which was subsequently merged with Lockheed Corporation to form Lockheed Martin on March 15, 1995 (MassDEP, 2000). Ametek occupied the entire site until 1997 when General Scanning moved into Building 2. General Scanning occupied Building 2 for 11 years and vacated Building 2 in 2008. In 2008, Ametek moved out of Buildings 1 and 1A and into Building 2, which they still occupy today. Buildings 1 and 1A were vacant from 2008 through May 2013.

The Wilmington Realty Trust (WRT), formerly the Barbo Realty Trust (BRT), is the current owner of the property and has been since the property was developed in the late 1960s. The Town of Wilmington Assessor’s property card shows the owner of record as Rosemarie Stanieich. WRT has leased portions of Building 1 to a tenant, Got Books, who has occupied approximately 95% of the first floor and approximately 20% of the second floor of Building 1 since around June 1, 2013. The majority of the second floor of Building 1 and all of Building 1A remain vacant while WRT considers additional prospective tenants.

2.3 FORMER SITE OPERATIONS

The following information was obtained primarily from the Public Involvement Plan (PIP) generated by the MassDEP dated November 17, 2000, as confirmed and augmented with details obtained from copies of other historical reports and site plans (MassDEP 2000).

Two aboveground storage tanks (ASTs A and B) were located within the former Oil House. Both tanks were 5,000-gallon capacity; Tank A reportedly contained jet fuel, and Tank B reportedly contained waste oil (TRC, 2001a).

Tank C is described as a small concrete pit located in the former Pump House, also referred to as the Vault, and reportedly received waste through concrete chase troughs from Buildings 1 and 3 prior to transfer to the waste oil tank (Tank B) in the Oil House. This Pump House, or Vault, is still present on site today.

From 1969 through June 1987, four underground storage tanks (USTs) (Tanks D, G, H, and I), referred to as the Tank Farm, were located between Buildings 1 and 3 (**Figure 2-2**). These tanks were located in an area of shallow bedrock such that some of the bedrock had to be removed to install the tanks.

- Tank D was a 10,000-gallon “waste fuel” UST that received waste fuel and oil, thinners, and solvents from the facility.
- Tank G was a 10,000-gallon UST that stored jet fuel and oil (Stoddard Fuel or Stoddard Solvent).
- Tank H was a 1,000 gallon UST and contained JP-4 jet fuel.
- Tank I was a 500-gallon methanol storage tank.

According to GE personnel, Tank D did not receive any waste fluids after 1979, although it was available as a contingency, to accept liquid if any overflow occurred from ASTs A and B in the Oil House. Tanks G and H were drained of their contents in 1979 and were reportedly never used again. Tanks D, G, H, and I were reportedly removed in June 1987.

Liquid acid and caustic wastes from a former metal finishing room within Building 1 drained via floor drains into Tank F, a 3,500-gallon UST, located outside the southwestern corner of Building 1. Tank F replaced an older butyl rubber-lined open top steel tank, which was taken out of service in 1981 and

removed from the property in June 1987. No identification number of this open top steel tank is provided, and it appears to be described by multiple names (acid tank and inorganic waste) and varying capacities (ranging 3,000 to 3,800 gallons). Tank F was reported to have been taken out of service before the summer of 1988 and removed in February 1990.

In 2012, AECOM, under direction of the Responsible Party (RP), Lockheed Martin, reviewed a series of historical GE site plans provided by the current property owner. This review uncovered a trichloroethene (TCE) AST (estimated to be approximately 275 gallons in size) that was formerly present in the metals finishing room as part of the GE operations (southwest corner of Building 1). No detailed information or mention of this tank has been found in any historical site documents.

Chemical liquid wastes generated by Hamilton Standard's "Direct Energy Conversion Operation" discharged into a 5,000-gallon UST (Tank J) located east of Building 1A. This tank was reported to have been taken out of service in 1981 and removed in 1987.

Chemical wastes from sinks in the Liquid Crystal Division Laboratory, Materials Destruction Laboratory, and Liquid Crystal Division clean room flowed into Tank E, an underground butyl rubber-lined, open-top steel tank. Tank E was installed in 1981 and was located east of Building 1A, below the ground surface in a concrete secondary containment vault. Tank E was removed in December 1992. Tank E reportedly replaced Tank J.

GE's former sub-lessee, Converse, installed a 5,000-gallon gasoline UST (Tank K) east of Building 2 and a blow-down UST associated with the steam curing of rubber (Tank L) north of Building 2. Converse removed both tanks in 1986 before vacating the property. Converse also reportedly generated waste naphtha, methyl ethyl ketone, and rubber compounds, which were removed from the property and properly disposed.

According to Environmental Database Reports (EDRs) obtained by CDM Smith in 2009, and by AECOM in 2012, there are no USTs currently on site.

2.4 PHYSICAL SETTING

This section summarizes the physical setting of the site including topography, geology, and hydrogeology. The geologic and hydrogeologic descriptions are based on soil borings and monitoring

wells at and in the vicinity of the site, as well as published studies of the area and other investigations of nearby sites (TRC, Sept. 2001b).

2.4.1 Topography

Local topography of the former GE property, at an approximate elevation of 80 feet above mean sea level, gently rises to the west. South of the property, land surface rises gently to Concord Road. Wetlands directly border the northern and eastern property boundaries, and naturally occur throughout the surrounding region. A tributary to the Ipswich River also follows the northeastern property boundary, running from a small unnamed pond approximately 750 feet to the northeast, to within 500 feet east of the property, then moving southeast to the river basin.

2.4.2 Geology

2.4.2.1 Overburden Geology

The surficial geology in the vicinity of the former GE property includes Pleistocene glacial deposits and recent swamp deposits. The former GE property is situated in an upland terrain comprised primarily of glacial till and ice contact deposits (Sammel, et al, 1964). Recent swamp deposits consisting of peat are located in low-lying areas to the east-northeast of the property and to the south along the Ipswich River.

According to past geological studies (Sammel, et al., 1964, Kick, 1990), the Wilmington and North Reading areas of Massachusetts are characterized by glacial deposits in buried valleys that represent the pre-glacial Ipswich River and its tributaries. The main river channel is coincident with the current Ipswich River, with a depth to bedrock of as much as 90 ft below ground surface (bgs) (elevation: -20 feet National Geodetic Vertical Datum 1929 [NGVD29]) directly south of the former GE property. A northwest trending buried valley that appears to be a tributary of the pre-glacial Ipswich River is located to the northeast of the former GE property (Sammel, et al., 1964). This buried tributary valley extends along the axis of the wetland area approximately 1,500 feet east of the property, and is expected to represent a preferential flow pathway for groundwater in the overburden aquifer east of the former GE property.

Based on observations from on-site investigation activities during the 2001 TRC Groundwater Investigation, the former GE property is underlain by fill, very fine to coarse sand and gravel, boulders, glacial till and organic deposits (peat). The overburden deposits range in thickness from 3 feet (in the

Drum Storage area), to over 45 feet in the eastern portion of the former GE property. The wetland area east of the former GE property is also underlain by peat, stratified glacial deposits (fine sands and gravel), and till. These deposits are approximately 70 feet in thickness in the central portion of the wetland area (TRC, Sept. 2001b).

2.4.2.2 Bedrock Geology

The bedrock in the vicinity of the site is comprised of Ordovician and Silurian plutonic rocks of the Nashoba Zone. This Zone is a fault-bounded block of steeply dipping, high-grade meta-sedimentary and meta-volcanic rocks intruded by younger felsic plutonic rocks (Zen et al., 1983). It is generally accepted that the porosity of these types of igneous rocks is very low (Pankow & Cherry, 1996). Furthermore, given the nature of these igneous rocks, and the complex regional history of deformation, intrusions, and faulting, any localized fractures and jointing in the rock will be highly variable. Evidence of high angle joints/faults at various orientations have been observed from rock cores collected at the site, borehole geophysical logging, and pumping test results.

According to the TRC 2001 Groundwater Data Report, bedrock at the site is more highly fractured in the upper zones and becomes more competent with depth. Based on observations made during previous drilling activities, and geophysical logging, the upper 10 to 20 feet of bedrock is more highly fractured and water-bearing. Bedrock becomes more competent with depth, thereby reducing its capacity to transmit water.

2.4.3 Hydrogeology

Groundwater at the property flows through the overburden, ranging in thickness from one to three feet at the former Tank Farm area to 45 feet in the eastern portion of the property, and fractured bedrock. The degree of interconnection between these units is discussed below.

2.4.3.1 Overburden Aquifer

Shallow overburden groundwater flows to the east. As the shallow groundwater flows into the wetlands, it is influenced by groundwater from the north, resulting in a southeast groundwater flow pathway through the wetlands. Water level measurements from the deep overburden groundwater indicate that groundwater flows to the east, both on site and through the wetlands. At the eastern end of the off-site wetland area, the groundwater flow direction has been observed to deflect to the south. This diversion in

flow direction coincides with a bend in the axis of the buried valley described by Sammel, et al. (1964). Therefore, it appears that groundwater flow in the overburden follows the axis of the buried valley at some distance from the property.

Hydraulic conductivity tests of overburden deposits performed by GZA during 1989 Phase II activities indicated the following results: approximately 40 to 600 feet per day in the sand and gravel deposits, approximately 2 to 120 feet per day in the sandy zones, and approximately 0.2 to 7 feet per day in the silty sand zones (GZA, 1990).

2.4.3.2 Bedrock Aquifer

The majority of bedrock wells on and near the property are located within the upper 50 feet of the bedrock aquifer. In general, groundwater has the potential to flow to the east toward and under the wetlands area (see Long-Term Groundwater Monitoring Report, TRC, 2000).

Aquifer tests in bedrock performed by GZA during 1989 Phase II activities indicated that the hydraulic conductivity of the bedrock decreases with depth. The shallow fractured zones of bedrock yielded results ranging from 0.01 to 50 feet per day. At depths of 5 to 20 feet into bedrock, test results indicated ranges of 0 to 0.5 feet per day (GZA, 1990).

TRC conducted groundwater pumping tests in June 2001 in borehole TRC-202R to determine the maximum sustainable yield, transmissivity, and hydraulic conductivity of targeted bedrock intervals (TRC, 2001b). The most conductive zone, based on a sustainable flow rate of approximately 3 gallons per minute (gpm) was the 95-115 ft bgs interval.

2.5 UTILITIES

Underground utility services including gas, electric, and water are present on site. Based on the Existing Conditions Plan EX-2 prepared by RJ O'Connell & Associates (October 2008) for WRT, these services are mainly present under the grassy area between Fordham Road and Buildings 1, 1A, and 2 with feeds coming from Fordham Road. These utilities also run between Buildings 1A and 2 and along the south and east sides of Building 1. Underground electrical service to the Treatment Shed and the EPL lights is from the east side of Building 1.

On-site storm water and sanitary sewage are treated at the Sewage Treatment Plant and Wastewater Treatment Plant located in the northern portion of the property. The associated outfalls for the treated

storm water, Outfall 001 and Outfall 002, are located at the western boundary of the wetlands along the tree line with the EPL. The treated sewage is discharged to leach fields adjacent to the treatment plant.

Telephone and fiber optic services to the property are underground on the west side of Buildings 1 and 1A along Fordham Road.

2.6 REGULATORY AND RESPONSE HISTORY

Contamination of the Stickney Well, a currently inactive public supply well for the town of North Reading, was discovered in the late 1970s. Subsequent investigations of multiple surrounding properties, including the GE property, began in the early 1980s. The property has been involved in remedial investigations and cleanup since 1986. A timeline summary of the regulatory history of the site is provided in **Table 2-1**.

On October 9, 1987, the MassDEP classified the former GE facility as a Priority Disposal Site, prior to the adoption of the MCP in 1988. In 1994, the MassDEP classified the former GE facility as a Tier 1A Transition Site and provided Permit No. 83052 to authorize comprehensive remedial response actions to meet the requirements of the MCP.

2.6.1 Release Tracking Number (RTN) 3-0518

The property has had a history of manufacturing processes performed by a number of firms that have contributed to releases of fuels, oils, solvents, and metals to the environment. RTN 3-0518 incorporates four separate operating units (OU) as summarized in **Table 2-2**. Analytical data have shown that six primary types of organic and inorganic compounds are associated with RTN 3-0518. These include chlorinated volatile organic compounds (CVOCs); total petroleum hydrocarbons (TPH); benzene, toluene, ethyl benzene and xylenes (BTEX) compounds; methyl tertiary butyl ether (MTBE); several metals; and light non-aqueous phase liquid (LNAPL) identified as Stoddard fuel (solvent).

Areas within OU-3 have been resolved and closed under the MCP via a partial RAO (Class A-2) submitted in December 2004. In accordance with the MassDEP Water Quality Certification (WQC), the wetland area was required to undergo a five-year post-restoration monitoring program through the fall of 2009. The work was completed and a final status report was submitted to MassDEP in December 2009. OU-4 has been resolved and closed under the MCP via a partial RAO (Class A-2) dated November 9, 2010. The remaining two areas, OU-1 and OU-2, make up RTN 3-0518. A detailed summary of the

historical remedial response actions is provided in the ROS Status, ROS Termination, and Tier IA Permit Extension Report (AECOM, March 2013).

2.6.2 Tier I Permit

On July 13, 1999, a Tier I Minor Permit Modification was submitted to MassDEP by TRC, on behalf of Lockheed Martin, to document that Lockheed Martin, the current signatory to the Tier IA Permit, had entered into an outsource agreement with TRC for future environmental work at the Former GE Facility; and that there was a change in Licensed Site Professional (LSP)-of-Record for the site. On August 5, 1999, a Tier I Permit Extension application was submitted to the MassDEP by TRC, again on behalf of Lockheed Martin, in anticipation of a change in the party conducting response actions. On October 22, 1999, Lockheed Martin contractually assigned direct responsibility for the MCP actions to TRC. On December 13, 1999, TRC submitted a Tier I Permit Transfer application to transfer the Waste Site Cleanup Permit from Lockheed Martin to TRC. The Permit Extension and Permit Transfer applications were approved simultaneously by MassDEP on December 28, 1999.

With an effective date of January 18, 2000, the Tier IA permit was extended for four years. Due to the need for additional bioremediation studies prior to installation of the proposed groundwater source control remedy, a second extension to the Tier 1A permit was submitted in December 2003 and was subsequently approved (the approval date is unknown) for two additional years. A Remedy Operation Status (ROS) Opinion was filed on April 20, 2006, which effectively suspended Tier IA Permit requirements.

While each of the four Operable Units have proceeded on separate MCP response action courses from 2000 to 2006, an ROS Report was submitted for the entirety of RTN 3-0518 in April 2006. Since that time, semi-annual ROS Reports have been submitted to MassDEP.

Lockheed Martin has reclaimed MCP responsibility for the remaining response actions under OU-1 and OU-2 through the submittal of a Tier 1 Major Permit Modification to MassDEP dated January 6, 2012. On May 30, 2012, a Tier 1 Minor Permit Modification (BWSC 109) was filed to replace the CDM Smith LSP-of-Record with AECOM's LSP, Elissa Brown (LSP #5371). AECOM completed a subsequent Tier 1 Minor Permit Modification (BWSC 109) and uploaded it to MassDEP's eDEP system on March 13, 2013 to replace Elissa Brown, with Daniel Folan, LSP #1736, as LSP-of-Record for the site.

On February 28, 2013, AECOM completed and submitted to Lockheed Martin a comprehensive data evaluation and trend analysis for the monitoring well network to determine the impact of the 2007 EZVI injection and the subsequent 2008 groundwater pump and treatment system shutdown. Based upon this evaluation, AECOM and Lockheed Martin determined that groundwater data trends did not indicate significant reductions in contaminant concentrations on site and additional actions may be necessary to achieve a permanent-solution. Accordingly, Lockheed Martin and AECOM determined on February 28, 2013, that the requirements to maintain ROS are no longer being met, and therefore submitted the required ROS Termination Notice on March 27, 2013. Since additional response actions (exclusive of preliminary response actions) cannot be conducted at the site in the absence of a Tier 1 permit, a Tier I Permit Extension Application was also submitted on March 27, 2013. With the submittal of the ROS Termination and the Tier IA Permit Extension application, the site has now returned to Phase II/Phase III of the MCP. Semi-annual status reports will not be required while in these phases of the MCP.

2.7 PUBLIC INVOLVEMENT PLAN

The site is one of four MCP Tier 1A sites in the Fordham Road and Concord Street portion of the towns of Wilmington and North Reading, Massachusetts. These four sites are part of a single PIP, prepared by MassDEP on November 17, 2000. The three other sites include Roadway Express, MSM Industries, and Sterling Supply. On February 22, 2011, TRC (the previous environmental consultant/LSP) notified the Public Involvement mailing list participants that the PIP was no longer considered active. However, no formal modification or termination notice was submitted to MassDEP regarding the PIP. Lockheed Martin and its contractors intend to continue communications as site activities are developed and implement public involvement activities in accordance with the 2000 PIP (see Section 3.3.3).

3.0 SCOPE OF WORK

This section presents the SOW for the supplemental phase II investigation activities to be conducted in 2013 through 2015. This section also includes a summary of the supplemental investigation activities conducted in 2012 and to date in 2013. Decision-making processes are also presented in this section. The specific methods and procedures to be used in the performance of this SOW are contained in Sections 4 and 5. This SOW has been reviewed by the LSP-of-Record (Daniel W. Folan, LSP# 1736) to ensure compliance with the RAP Standards of the MCP 310 CMR 40.0191.

3.1 2012 ACTIVITIES COMPLETED

The following supplemental investigation activities were conducted in 2012 while under ROS status to support a revised conceptual site model. The results of these activities were presented in the Remedy Operation Status, ROS Termination, and Tier 1 Permit Extension, which documented site activities through December 1, 2012, and was submitted to the MassDEP on March 27, 2013. Refer to **Figure 2-2 Site Plan** for monitoring well locations.

- On May 31, 2012, AECOM performed the ROS groundwater monitoring event at four monitoring wells (EMW-10D, EMW-11D, and GZA-105D in the EPL, PS-1D in the wetland). Samples were analyzed for total and dissolved arsenic via Method 6010, VOCs via Method 8260, and 1,4-dioxane via Method 8270SIM. Samples for VOC analyses were analyzed via both passive diffusion bag (PDB) and low-flow purge and sample procedures for comparison at all wells except PS-1D.
- On May 31, 2012, AECOM gauged four monitoring wells (CW-1, CW-2, PZ-2S, and TRC-101) in the EPL for the presence of LNAPL. Sheen with no detectable LNAPL thickness was present in well CW-2; no other evidence of LNAPL was noted.
- On August 23, 2012, AECOM collected one round of indoor air samples within Building 1 (IA-2, IA-3, IA-4, IA-7, and IA-8 on the first floor, and IA-9 and IA-10 on the second floor) and the Guard Shack (IA-6). The samples were collected during the cooling season with the Building 1 air conditioning (AC) system off. The Guard Shack does not have electrical service, and therefore, no AC. One ambient outdoor air sample was collected. Samples were analyzed for VOCs via Method TO-15.
- On August 28, 2012, AECOM collected one round of indoor air samples within Building 1 (IA-2, IA-3, IA-4, IA-7, and IA-8 on the first floor, and IA-9 and IA-10 on the second floor),

including one ambient outdoor air sample, during the cooling season with Building 1 AC system on. Location IA-6 within the Guard Shack was not sampled. Samples were analyzed for VOCs via Method TO-15.

- On August 29, 2012, AECOM collected one round of sub-slab vapor samples within Building 1 (SG-1, -2, -3, -4, -5, -6, -7, -8, -9, -14, -15, -16, and -17), during the cooling season with Building 1 AC system on. Location SG-13 in the Guard Shack was not sampled. Samples were analyzed for VOCs via Method TO-15.
- In August 2012, AECOM advanced 19 soil borings (AE-4 through AE-22) via hollow-stem auger and drive and wash drilling methods to evaluate the potential presence of LNAPL and petroleum hydrocarbons in soil beneath the EPL down-gradient of the former Tank Farm. Collected soil samples for analyses of VOCs via Method 8260, EPH/VPH via MassDEP Method, and arsenic via Method 6010. Two monitoring wells were installed and developed (AE-3 and AE-4) in the EPL.
- On August 14 and 15, 2012, twelve temporary soil gas points (SG-18 through SG-29) were advanced outside the southwest corner of Building 1 in the vicinity of the former Tank F location and immediately south of the former location of the TCE tank within the southwest corner of Building 1. Soil gas screening samples were collected over a 1-hr period from a depth of approximately two feet above the groundwater table to screen soils to aid in the placement of groundwater monitoring wells AE-1S/I and AE-2I. Samples were analyzed for VOCs via Method TO-15.
- In August 2012, AECOM advanced two soil borings (AE-1 and AE-2) via drive and wash methods to evaluate soil and groundwater conditions in the former Tank F area adjacent to the southwest corner of Building 1. Soil samples were collected for analyses of metals (arsenic, beryllium, chromium, copper, lead, nickel, silver, zinc) via Method 6010, VOCs via Method 8260, cyanide via Method 9012, and for pH and Oxidation Reduction Potential (ORP). Three monitoring wells (AE-1S, AE-1I, and AE-2I) were installed and developed outside the southwest corner of Building 1.
- On September 24, 2012, AECOM collected groundwater samples from two monitoring wells in the EPL and from five monitoring wells in the former Tank F area. Samples were analyzed for VOCs via Method 8260, 1,4-dioxane via Method 8270SIM, petroleum hydrocarbons via MassDEP EPH/VPH Method, total and dissolved arsenic via Method 6010, and quantitative *dehalococcoides* (qDHC). In addition, the samples from the former Tank F area were also

analyzed for additional metals (beryllium, chromium, copper, lead, nickel, silver, zinc) via Method 6010, and cyanide via Method 9012.

- On November 5 – 7, 2012, AECOM performed the ROS groundwater monitoring event at 15 monitoring wells (EMW-10D, EMW-11D, EMW-11R1, EMW-11R2, IP-1R2, GZA-105D, and TRC-401RB in the EPL; AE-1S, AE-1I, AE-2I, GZA-12, and GZA-101R in the former Tank F area; AE-3 and AE-4 in the EPL; and PS-1D in the wetland). Samples were analyzed for VOCs via Method 8260, 1,4-dioxane via Method 8270SIM, total and dissolved arsenic via Method 6010. Samples from select EPL and wetland wells were also analyzed for qDHC, and select wells in the former Tank F area were also analyzed for cyanide via Method 9012. In addition, select EPL and former Tank F area wells were analyzed for petroleum hydrocarbons via the MassDEP EPH/VPH Method.
- On November 5, 2012, AECOM gauged six monitoring wells (pre-existing wells CW-1, CW-2, PZ-2S, TRC-101, new wells AE-3 and AE-4) in the EPL for the presence of LNAPL. The only evidence of LNAPL was 0.01 ft measured in well CW-2.
- Between May 29 and November 5, 2012, AECOM checked and maintained the packer pressure at 200 psi in monitoring well TRC-202R. Troubleshooting, leak testing, and replacement of fittings was performed in both June and July 2012 to repair pressure leaks.
- In May and June 2012, AECOM performed inspection and evaluation of the inactive groundwater treatment system.
- In December 2012, AECOM removed and sealed pre-existing sub-slab vapor points within Building 1 (SG-1, -2, -3, -4, -5, -6, -7, -8, -9, -14, -15, -16, and -17). Removal of these points was required due to cracking and degradation of the concrete beyond repair at a number of locations. The original SG-13 location in the Guard Shack still exists on site as an intact and viable sampling point. The former locations SG-10, SG-11, and SG-12 were destroyed when Building 3 was demolished in 2011.

3.2 2013 ACTIVITIES COMPLETED

The following supplemental investigation activities were conducted in 2013 while under ROS status to support a revised conceptual site model. The results of these activities have not yet been presented to MassDEP, and will be included in the Supplemental Phase II Report in 2015.

- In February 2013, AECOM installed vapor pins SG-1R, -2R, -3R, -4R, -5R, -6R, -7R, -8R, -9R, -14R, -15R, -16R, and -17R were installed as replacements for former sub-slab vapor point locations within Building 1.
- On February 27, 2013, AECOM collected one round of indoor air samples within Building 1 (IA-2, IA-3, IA-4, IA-7, IA-8 on the first floor, and IA-9 and IA-10 on the second floor) and the Guard Shack (IA-6), including one ambient outdoor air sample. These samples were collected during the heating season with the Building 1 heating system on. Samples were analyzed for VOCs via Method TO-15.
- On February 28, 2013, AECOM collected one round of sub-slab vapor samples within Building 1 (SG-1R, -2R, -3R, -4R, -5R, -6R, -7R, -8R, -9R, -14R, -15R, -16R, and -17R). These samples were collected during the heating season with Building 1 heating system on. Location SG-13 in the Guard Shack was not sampled. Samples were analyzed for VOCs via Method TO-15.

The following supplemental investigation activities were conducted in 2013 following termination of ROS status. The results of these activities have not yet been presented to MassDEP, and will be included in the Supplemental Phase II Report in 2015.

- On May 21, 2013, AECOM collected one round of indoor air samples within Building 1 (IA-2, IA-3, IA-4, IA-7, IA-8 on the first floor, and IA-9 and IA-10 on the second floor) and the Guard Shack (IA-6), including one ambient outdoor air sample. These samples were collected with the heating and ventilation system off. Samples were analyzed for VOCs via Method TO-15.
- On May 21, AECOM gauged seven monitoring wells (AE-3, AE-4, CW-1, CW-2, GZA-102S, PZ-2S, and TRC-101) in the EPL for the presence of LNAPL. The only evidence of LNAPL was 0.01 ft measured in wells CW-1 and CW-2.
- On May 22, 2013, AECOM collected groundwater samples at five wells (AE-3, AE-4, GZA-102S, PZ-2S, and TRC-101) in the EPL for analyses of VOCs via Method 8260 and EPH/VPH via MassDEP Method.
- In May and June 2013, AECOM advanced three soil borings and installed and developed two shallow overburden wells AE-23S and AE-24, and one bedrock well AE-23R, beneath the southwestern corner of Building 1. These wells were installed in the vicinity of the highest detected sub-slab vapor and indoor air concentrations. Soil samples were collected for analysis of metals (arsenic, beryllium, chromium, copper, lead, nickel, silver, zinc) via Method 6010, VOCs via Method 8260, and cyanide via Method 9012.

- On July 3, 2013, AECOM collected groundwater samples from wells AE-23S, AE-23R, and AE-24 for analysis of metals (arsenic, beryllium, chromium, copper, lead, nickel, silver, zinc) via Method 6010, VOCs via Method 8260, cyanide via Method 9012, and 1,4-dioxane via Method 8270SIM.
- In May 2013, AECOM performed a site-wide inventory of all groundwater monitoring wells and piezometers, performed trail maintenance, and generated a detailed well inventory and summary of proposed future well rehabilitation and maintenance activities.
- On January 11, April 1, June 28, and August 28, 2013 AECOM checked and maintained the packer pressure in monitoring well TRC-202R. The pressure was maintained between 190 and 200 psi.
- In August and September 2013, AECOM performed an evaluation of a condition of Substantial Release Migration (SRM). This included: communications with the N. Reading Board of Health; review of private well construction details and proximity to the site chlorinated solvent plume; water level measurements to confirm groundwater flow directions; and collection of groundwater samples at four wells (MW-5, PS-8S, PS-8D, and PS-3) in the wooded/wetland area down-gradient of the site for VOC (8260) analyses. The results indicated a lack of impacts in monitoring wells located between the private wells and the CVOC plume. In addition, the private wells are clearly located up-gradient of the CVOC plume. Therefore, it was concluded that a Condition of SRM has never existed and does not currently exist.

3.3 PROPOSED FUTURE SUPPLEMENTAL INVESTIGATION ACTIVITIES 2013 – 2015

The following supplemental investigation activities will be conducted to further delineate impacted soil and groundwater beneath Building 1, and to collect additional overburden and bedrock groundwater data in the EPL and the wooded and wetland areas to refine the site CSM and further support future risk assessments and a Phase III remedial action alternatives evaluation.

3.3.1 Planning, Preparation, and Permits

Based on supplemental borings and wells planned for the on-site wetlands buffer area and off-site wetlands east of the -site, wetland permits will likely be required. Access to and from the wooded and wetland areas is planned to be via the old Stickney Well access road off of Redmond Avenue. The Town of North Reading will be notified in advance, and agreements obtained, if needed.

A Request for Determination of Applicability (RDA) will be submitted to the North Reading Conservation Commission for borings/wells to be placed on site in the EPL. A Notice of Intent Wetlands Permit for the access and installation of borings/wells in the off-site wetlands will also be submitted to the same agency with a dual filing to the State.

Depending on the total disturbed footprint area, a variety of separate permits may be required. The trigger for these permits would be disturbance of 5,000 square feet of wetlands. If triggered, these additional permits include:

- Massachusetts EPA (MEPA) Environmental Notification Form (ENF)
- Massachusetts DEP 401 Clean Water Act Water Quality Certificate
- US Army Corps of Engineers (USACE) Category 2 404b Wetlands Permit

Prior to subsurface drilling or any probing or excavation, the Massachusetts one-call utility clearance (DigSafe) system will be contacted and a permit obtained for the areas in question. A street opening permit may be required from the Town of North Reading for the boring/wells to be advanced adjacent to the STM-8 location along Concord Street. The need for this permit will be dependent on the final selected location of the boring(s), and will be confirmed with local municipal departments and obtained, if needed, prior to commencing intrusive work.

No other approvals will be required for installation and operation of the 2013-2015 site-wide activities on site or within the wooded areas and wetlands.

Site preparation work will be conducted in advance of mobilizing with the drilling subcontractor. Site preparation work may include, but is not limited to, the mobilization and set up of the following: portable facilities, equipment staging areas, and materials storage, decontamination pads, site mark-outs, geophysical utility clearance, fencing, wetlands flagging, vegetation clearing, grubbing, grading, erosion control, swamp mats, or any other requirements as stated in permits or Orders of Conditions obtained.

AECOM's Project Manager (PM) and the subcontracted driller's field supervisor will complete Lockheed Martin's Risk Handling Checklist and the Dig Permit and submit it to the Lockheed Martin Project Lead, who will complete and approve it, and then forward them to the Lockheed Martin Environmental Safety and Health (ESH) Professional and the Managing Contractor for review. It is anticipated that separate checklists and dig permits will be completed for drilling in the Building 1

activities and for the EPL, Concord Street, and wetland activities. Copies of these forms are attached in **Appendix A**.

3.3.2 Access Agreements

Prior to performing field work, AECOM will review the locations of planned activities and access routes and if necessary contact the various property owners to secure formal access permission for the work. A list of properties for which Lockheed Martin has access, and or will likely need to obtain access, is included in **Table 3-1**. If the need for access to additional properties is identified, these will be addressed during execution of this SOW in 2014.

Prior to any intrusive field work or sampling on properties other than those owned by Lockheed Martin, AECOM will prepare the required BWSC 123 form, “Notice of Environmental Sampling,” and submit to the appropriate property owners prior to the work.

3.3.3 Agency Notification and Public Involvement

The former GE facility is subject to both the minimum public involvement requirements of the MCP those required by the joint PIP.

Minimum Public Involvement Requirements of the MCP

All work conducted will conform to the MCP, and other applicable state, federal, and local laws and regulations. Multiple public notifications are necessary to execute this work. This includes the requirements provided in Sections 40.1403 and 40.1406 of the MCP. On the behalf of Lockheed Martin, AECOM will prepare and submit the necessary documents, letters, legal notices, forms and associated supporting materials to the applicable public parties that apply to the SOW described in this proposal.

A summary of the minimum public involvement requirements listed at 310 CMR 40.1400 include the following:

- 1) Written notification of the Chief Municipal Officer (CMO) and Board of Health (BOH) agent for the towns of Reading, North Reading and Wilmington upon availability of Phase II, Phase III Report and RAO Statement submittals to MassDEP. MassDEP is copied on notifications to towns.

- 2) When sampling on off-property locations the MassDEP Form BWSC-123, “Notice of Environmental Sampling,” will be submitted to the property owners in advance of any sampling. Within 30 days of receipt of the analytical data from the laboratory, the form will be re-issued to the property owners with a copy of the analytical data.

Additional minimum public involvement requirements are listed at 310 CMR 40.1406 and include the following:

- 1) Provide written notice to the owners of properties within the boundaries of the disposal site as depicted and described in a Phase II Report and RAO Statement.
- 2) The written notice shall include the following information:
 - a) a copy of the disposal site map showing the boundaries of the disposal site;
 - b) a copy of the Phase II Report or RAO Statement conclusions;
 - c) a statement that Public Involvement Activities are available under 310 CMR 40.1400; d) the name, address and telephone number of a contact person representing the persons conducting response actions who may be contacted for additional information on the disposal site; and
 - e) a copy of all written notices shall be submitted to the MassDEP with the corresponding Phase II Report or RAO Statement.

PIP Requirements

The former GE facility is part of a joint PIP with other Potentially Responsible Parties (PRPs) that was prepared in 2000 by the MassDEP. Being a “PIP” site, there are additional regulatory requirements above and beyond the minimum requirements. These include public notifications including local newspapers, public meetings, draft document public comment periods and responding to public comments on final documents.

- 1) For the following draft documents: Phase II SOW, Phase II Report, Phase III Report, Phase IV Remedy Implementation Plan (if applicable) and RAO Statement, the November 17, 2000 PIP Plan requirements (MassDEP, 2000) that specifically apply to the former GE facility will include the following documents or activities: Provide a copy of the draft document to the designated information repository established in the PIP (Town of North Reading library).

- 2) A written Notice of Availability of the draft document will be sent to parties on the PIP site mailing list.
- 3) A Notice of Public Meeting to present the draft document will be sent to parties on the PIP site mailing list 14 days in advance of the meeting.
- 4) Hold public meeting(s) to discuss the draft document.
- 5) Starting after the public meeting, allow a 20-day public comment period on the draft document. MassDEP will determine if the comment period should be extended based on site complexity. Public comments are to be sent to MassDEP (Northeast Regional Office), AECOM (Chelmsford, MA) and Lockheed Martin concurrently.
- 6) Within 60 days of the close of the comment period, AECOM, on the behalf of Lockheed Martin, will prepare a Response Summary that will include a summary of all comments received on the draft document available for public comment, and the responses to these comments prepared by AECOM and Lockheed Martin. In addition, those comments that are incorporated into the revised document will be identified and an explanation will be provided for each comment that is not incorporated into the revised document.
- 7) A copy of the Response Summary will be sent to all those who submitted comments and will be placed in the information repository.
- 8) A Notice of Availability of the Response Summary will be sent to the PIP mailing list.
- 9) Written Notice of start of field work for Phase II activities will be sent to parties on the PIP site mailing list at least 7 days in advance.

Additional public notification requirements may be required as part of the wetland permitting process.

3.3.4 Well Rehabilitation

A number of monitoring wells on site and off site within the wooded and wetland areas are in need of rehabilitation, mainly as a result of wear and tear and deterioration of road boxes and concrete pads due to age. A drilling subcontractor, New Hampshire Boring (NH Boring) of Londonderry, NH, will conduct this work with AECOM oversight. A summary of the well repairs needed is presented in **Table 3-2**. Prior to conducting this repair work, a one-call system utility coordination mark-out will be conducted. No other utility clearance activity will be required for this task. Additionally, well TRC-301R will be evaluated in the field against the construction log, as preliminary observations indicate there may be an

obstruction down-hole. Depending on the evaluation, this well may also require rehabilitation or replacement.

3.3.5 Vapor Intrusion – Building 1

Two (2) indoor air sampling events will be conducted, one each during the heating seasons of 2014 and 2015 to evaluate potential indoor air risks. These sampling events will be conducted with the heating system operational for a minimum of 48 to 72 hours prior to start of sampling. After notifying the property owner, and prior to commencing sampling, AECOM will conduct an indoor air quality building survey per *WSC#11-435 Interim Final Vapor Intrusion Guidance* (MassDEP, December 2011). This survey will include an inventory questionnaire and photographs of the sampling locations and relevant interior areas of the building. Screening of indoor air with a photoionization detector (PID) will be conducted concurrent with commencement of sampling. Indoor air samples will be collected at 7 locations within Building 1: IA-2, IA-3, IA-4, IA-7, and IA-8 on the first floor, and IA-9 and IA-10 on the second floor. One (1) duplicate sample will be collected for QC and one (1) upwind ambient air sample will be collected outside Building 1 to account for any potential outdoor contaminant sources impacting the indoor air results. The location of the upwind sample will be determined on the day of sampling. Samples will be collected in 6-liter Summa air canisters and the air samples will be analyzed for volatile organic compounds via Method TO-15. Refer to **Figures 3-1 and 3-2** for the indoor air sample locations.

3.3.6 Utility Clearance

Utility mark-out and clearance activities will be performed prior to commencing any phase of subsurface investigation activities. These will include one-call system utility coordination mark-outs, as well as a review of available historical building and site activity sub-surface plans and as-builts. Live utility screening and mark-outs by a geophysical subcontractor and licensed electrician may be conducted if needed in select areas such as in Building 1, the EPL and along Concord Street.

Boring locations within the EPL and along Concord Street will be cleared using soft dig methods (air knife and/or vacuum excavation) to a depth of 5 ft bgs or a reasonable depth to verify that subsurface utilities or obstructions are not present. Utility survey and vacuum excavation will not be required at well locations within the wooded areas or in the wetland.

The site electrician for WRT will perform a live locate and markout of the electrical lines within and below the floors in the proposed work areas of Building 1. In addition, the electrician will de-energize and isolate nearby electrical panels, bus ducts, and transformers, to the extent possible, for the duration of the indoor work.

3.3.7 Mobilization 1 – EPL Soil Boring and Monitoring Well Installation

AECOM will oversee the drilling activities along Transect A (**Figure 3-3**) located on the eastern edge of the EPL. Cascade Drilling, L.P. (Cascade) of Northborough, Massachusetts will perform all drilling activities.

The initial bedrock boring (AE-102R) will be installed upgradient of TRC-202R with a min-sonic drilling rig. Cascade will use an eight-inch core barrel followed by temporary 10-inch sonic casing, to advance a ten-inch borehole through the overburden and up to five feet into the competent bedrock. Overburden soil at all boreholes will be continuously logged from ground surface, screened for VOCs, and sampled following standard protocols. Prior to sealing permanent casing into competent bedrock, the weathered bedrock interval will be cored at each bedrock borehole, screened for VOCs, and sampled following standard protocols.

To seal off the overburden, a 6-inch diameter permanent steel casing will be advanced up to 5 feet into competent rock and tremie-grouted to the surface as the 10-inch casing is withdrawn. The top of the 6-inch casing will be threaded to allow future attachment of a temporary casing extension at the surface, if needed. After a minimum 24-hour curing period, bedrock coring will be performed to 175 ft bgs. Bedrock will be cored using a PQ sized conventional single wall core barrel, or a triple tube core barrel, as needed. The PQ-sized core barrel (4.83 inch diameter) results in a 5-inch open rock borehole. Typically, the triple tube core barrel is used when the rock is highly fractured and numerous loose fragments are anticipated. Rock Quality Designation (RQD) will be calculated for each core run. The core barrel will be either 5- or 10-ft in length. Bedrock core lengths may be adjusted longer or shorter as appropriate based on rock conditions encountered.

Stone Environmental, Inc (Stone) of Montpelier, Vermont will be on site to crush and containerize rock samples at a high frequency from the rock core for VOC analysis. The spacing of the samples will depend on fracture density and spacing. For planning purposes a frequency of one sample per foot was assumed. Cascade will develop the open borehole via air lift methods. After development, Flexible Liner

Underground Technologies, Ltd. Co. (FLUTe) of Velarde, New Mexico will perform the installation of a blank FLUTe liner within the open rock borehole. The purpose of this initial FLUTe visit will be to install and demonstrate the blank liner installation technique to Cascade so the driller can perform future blank liner installations. To complete the liner installation, FLUTe will install a 5-ft long polyvinyl chloride (PVC) casing extension to the top of the well, setup a five (5) foot high scaffolding over the well, and add a combination of heavy drilling mud and water to extend the liner down the hole to the optimal depth. The installation of the blank liners will seal the borehole so that mixing of impacted groundwater from different zones does not occur.

Four nested overburden monitoring well triplets (AE-101S/M/D, AE-102S/M/D, AE-103S/M/D, and AE-104S/M/D) will be installed in a straight line with the initial boring AE-102R, perpendicular with the direction of groundwater flow, with either 5-foot or 10-foot screens in the following anticipated intervals: 10 to 20 ft bgs, 20 to 30 ft bgs, and 30 to 40 ft bgs. Cascade will install these wells with a min-sonic drilling rig which allows for continuous core sampling of the overburden soils. The core sample will be extruded into polyethylene bags and laid out for characterization. For these nested wells, a telescopic casing advancement technique will be used.

A six-inch sonic borehole will be advanced to approximately 40 ft bgs with continuous core recovery. Seven-inch override casing will then be advanced to approximately 30 ft bgs and eight-inch override casing will be advanced to approximately 20 ft bgs. The monitoring wells will be constructed using either 1.5-inch or 2-inch diameter Schedule 40 PVC casing. It is anticipated that 0.10-slot screen size will be used. Screen length and slot size may be adjusted based on field observations. Bentonite chips will be used to separate each interval with a finer-grained “choker” sand used to separate the sandpack from the bentonite chips. Each triplet will be finished with a flush-grade road box. All overburden monitoring wells will be developed by Cascade within 48 hours of installation via bailing, surging, and purging methods.

During borehole advancement, two soil samples will be collected from each well cluster location (AE-101 through AE-104, and at STM-8R1/R2) from just below the water table to the top of bedrock for analysis of VOCs via Method 8260, 1,4-dioxane via Method 8270SIM, and fraction organic carbon (fOC) via Lloyd Khan. The samples for fOC will be collected preferentially at intervals where no evidence of impacts are observed. The objective is to obtain estimates of the amount of naturally-occurring organic carbon in the soil.

In addition, as part of Transect C (**Figure 3-3**), bedrock well STM-8R1/R2 will be drilled and installed adjacent to STM-8 along Concord Street following the same procedure as for AE-102R. Bedrock coring will be performed to 100 ft bgs at this location. The borehole will be advanced five (5) feet into competent bedrock with a sonic drilling rig and a 6-inch diameter permanent steel casing will be grouted inside the borehole to seal off the overburden. Bedrock coring will proceed after a minimum 24-hour cure period. After development of the open borehole by Cascade, the driller will install a blank liner. Based on historical water levels, it is anticipated that a casing extension and scaffolding will be unnecessary at this location to install the liner. However, heavy mud and water will likely be needed.

Refer to **Table 3-3** for a general summary of the rationale for each of the mobilizations. Refer to **Table 3-4** for details pertaining to the Mobilization 1 activities.

3.3.8 Building 1 Soil and Groundwater Investigation

Additional soil and groundwater investigation activities will be performed beneath Building 1 to delineate soil and groundwater impacts encountered at locations AE-23S/R and AE-24 installed in May and June 2013.

3.3.8.1 Soil Boring and MW Installation / Development

Three overburden-bedrock well pairs (AE-25S/R, AE-26S/R, and AE-27S/R) will be installed inside of Building 1 to the northwest, northeast, and east of AE-23S/R and AE-24, respectively. In addition, one bedrock well (AE-2R) will be installed adjacent to overburden well AE-2I outside Building 1 to the south (**Figure 3-3**). Cascade will drill and install these monitoring wells via sonic drilling methods. The overburden wells will be drilled utilizing 6-inch diameter temporary drill casing and will allow installation of two-inch diameter PVC wells. For the well pairs, the bedrock well will be installed adjacent to the overburden well. The bedrock well will be installed utilizing telescopic casing advancement. Overburden soil at all boreholes will be continuously logged from ground surface, screened for VOCs, and sampled following standard protocols.

Using an eight-inch core barrel followed by temporary 10-inch sonic casing, a ten-inch borehole will be advanced through the overburden and up to five feet into the competent bedrock. Prior to sealing permanent casing into competent bedrock, the weathered bedrock interval will be cored at each bedrock borehole, screened for VOCs, and sampled following standard protocols. To seal off the overburden, a 6-inch diameter permanent steel casing will be advanced up to 5 feet into competent rock and tremie-

grouted to the surface as the 10-inch casing is withdrawn. After a minimum 24-hour curing period, bedrock coring will be performed to at least 55 ft bgs. Bedrock will be cored using PQ sized conventional single wall core barrel, or a triple tube core barrel, as needed. RQD will be calculated for each core run. The core barrel will be either 5- or 10-ft in length.

Total depths of the four bedrock monitoring wells (AE-2R, AE-25R, AE-26R, and AE-27R) is anticipated to be approximately 25 feet into competent bedrock, or no deeper than approximately 55 ft below the slab. Monitoring well AE-27R is intended to be drilled at an angle to investigate soil and groundwater quality beneath the portion of southwest corner room of Building 1 east of AE-24 where drill rig access is not possible. Bedrock coring will be performed to the planned total depth after a minimum 24-hour grout curing period. Air lift purging of the open borehole will be performed during drilling to aid in the identification of water bearing bedrock fractures for screen placement. After development of the open borehole by Cascade, a standard construction PVC monitoring well will be installed. It is anticipated that these wells will be 2-inch diameter PVC wells with 5 or 10 foot long, 0.10-slot screens. Well diameter, screen length, and slot size may be adjusted based on field observations.

The three overburden monitoring wells (AE-25S, AE-26S and AE-27S) will be installed through six-inch sonic drill casing as standard construction 2-inch diameter PVC wells with 10 foot long, 0.10-slot screens. The total depth of these wells is estimated to be between 20 - 30 ft bgs with the screen intervals just at/below the water table or above the bedrock surface, depending on subsurface conditions encountered. Well diameter, screen length, and slot size may be adjusted based on field observations. Monitoring well AE-27S will follow the same angle as AE-27R and total depth will be adjusted to reach the desired screen interval and depth beneath the southwest corner room of Building 1.

Three soil samples will be collected from each monitoring well pair location for analysis of VOCs via Method 8260, EPH/VPH via the MassDEP Method, and RCRA Metals via Method 6010. If no impact is observed, the three samples will be collected from below the slab, above the water table, and from just above the bedrock surface.

Refer to **Table 3-5** for more details pertaining to the Building 1 soil and groundwater investigation activities.

3.3.8.2 Building 1 Groundwater Sampling

Prior to commencing groundwater sampling, one round of synoptic water level measurements will be obtained at the 7 newly installed wells within and outside of Building 1 (AE-25S/R, SE26S/R, SE-27S/R, and AE-2R) as well as 9 existing wells (AE-1S/I, AE-2I, AE-23S/R, AE-24R, GZA-12, GZA-101R, and TRC-201R).

One round of groundwater samples will be collected from the seven newly installed wells (AE-2R, AE-25S/R, AE-26S/R, and AE-27S/R) and three pre-existing wells AE-23S/R and AE-24 within and outside of Building 1. Groundwater sampling will be performed using low flow purging and sampling procedures using either peristaltic or bladder pumps. Groundwater samples will be collected for analysis of VOCs via Method 8260 and 1,4-dioxane via Method 8270-SIM.

Following receipt of groundwater analytical results, a pumping test will be conducted in one bedrock monitoring well within Building 1. The pumping well will be selected based on hydraulic conductivity information obtained during well development and on the groundwater VOC analytical results, biasing the well selection towards higher hydraulic conductivity and higher groundwater VOC concentrations.

Water level elevations shall be collected from all wells prior to the pumping test. Pressure transducers shall be installed in each overburden and bedrock well within the Building 1 foot print and in the pumping well. Water levels shall be collected via transducers for a period of 72 hours before to 24 hours after the pumping test. The intended duration of the pumping event is 8 hours. Water levels from wells proximate to Building 1 along Fordham Road and the entrance driveway will be monitored periodically by hand during the pumping test. Grab groundwater samples shall be collected from the pumped well at the beginning, midpoint and conclusion of pumping and analyzed for VOCs via Method 8260. The performance and methods for this pumping test may be modified based on observed field conditions and the well development and analytical results. The use of other NAPL evaluation methods, such as product reactive paste or reactive liners, may also be considered.

Refer to **Table 3-9** for more details pertaining to the Building 1 groundwater investigation activities.

3.3.9 Mobilization 2 – EPL Monitoring Well Completion

Once field and analytical data is obtained and reviewed from the borings/wells performed in the EPL in Mob 1, AECOM will oversee the remaining drilling activities along Transect A which will include the

drilling and installation of four bedrock monitoring wells AE-100R, AE-101R, AE-103R, and AE-104R along the eastern edge of the EPL (see **Figure 3-3**). Cascade will perform all drilling activities.

Bedrock monitoring well installation will consist of drilling through overburden to a depth of 5 feet into competent bedrock with a sonic drilling rig and temporary 10-inch diameter casing. Overburden soil at all boreholes will be continuously logged from ground surface, screened for VOCs, and sampled following standard protocols. A 6-inch diameter permanent steel casing will be grouted inside the borehole to seal off the overburden. After a minimum 24-hour curing period, bedrock coring will be performed to 175 ft bgs using a 5-inch diameter core barrel. Five- to 10-foot long bedrock core samples will be collected continuously to completion depth. Bedrock core lengths may be adjusted longer or shorter as appropriate based on rock conditions encountered. Cascade will develop the open borehole via air lift methods.

After development using air lift pumping, Cascade will install a blank liner within the open borehole. To complete the liner installation, Cascade will install a 5-ft long PVC casing extension to the top of the well, setup a five (5) foot high scaffolding over the well, and add a combination of heavy drilling mud and water to extend the liner down the hole to the optimal depth..

No soil or bedrock samples will be collected for chemical or physical analyses during Mobilization 2.

Refer to **Table 3-6** for details pertaining to the Mobilization 2 activities.

3.3.10 Mobilization 3 – Wetlands Soil Boring and Monitoring Well Installation

3.3.10.1 Site Preparation- Wetland Mats Installation

Following access and permit approvals, access roads within the wetland will be prepared (see **Figure 3-3**). Tree and brush cutting activities will be performed along the designated routes. Following completion of the clearing activities, 14-foot wide wetland mats will be laid down and stacked along the designated paths to allow the drill rig and support equipment to reach to the drilling locations.

Cascade will set up a decontamination pad for drilling tool decontamination and a staging area for drums, rollofs, and frac tanks, will be created at a secure location on site. Other site preparation activities will also be performed such as mobilization of equipment, preparation of a lay-down area, porta-johns, temporary fencing, utility mark-outs, erosion controls, etc.

3.3.10.2 Soil Boring and MW Installation / Development

AECOM will oversee the drilling and well installation activities along Transect B (see **Figure 3-3**) in the wetlands. This will include the installation of three monitoring well clusters (AE-105, AE-106, and AE-107). Cascade will perform all drilling activities.

AE-105 cluster

The AE-105 cluster will include one open rock hole (AE-105R) with a total depth of 175 ft bgs and an overburden triplet (AE-105S, AE-105M, and AE-105D) with either 5-foot or 10-foot screens installed in the following anticipated overburden intervals: 10 to 20 ft bgs, 30 to 40 ft bgs, and 50-60 ft bgs. The well construction details for the open rock hole will be determined after all borehole testing is completed.

AE-106 cluster

The AE-106 cluster will include one open rock hole (AE-106R) with a total depth of 175 ft bgs and an overburden triplet (AE-106S, AE-106M, and AE-106D) with either 5-foot or 10-foot screens installed in the following anticipated overburden screen intervals: 10 to 20 ft bgs, 30 to 40 ft bgs, and 50-60 ft bgs. The well construction details for the open rock hole will be determined after all borehole testing is completed.

AE-107 cluster

The AE-107 cluster will include an overburden triplet (AE-107S, AE-107M, and AE-107D) with either 5-foot or 10-foot screens installed in the following anticipated screen intervals: 10 to 20 ft bgs, 30 to 40 ft bgs, and 50-60 ft bgs.

Bedrock monitoring well installation will consist of drilling through overburden to a depth of 5 feet into competent bedrock with a mini-sonic drilling rig and temporary 10-inch diameter casing. Overburden soil at each borehole will be continuously logged from ground surface, screened for VOCs, and sampled following standard protocols. Prior to sealing permanent casing into competent bedrock, the weathered bedrock interval will be cored at each bedrock borehole, screened for VOCs, and sampled following standard protocols. A 6-inch diameter permanent steel casing will be grouted inside the borehole to seal off the overburden. After a minimum 24-hour curing period, bedrock coring will be performed to 175 ft

bgs using a 5-inch diameter core barrel. Bedrock will be cored using PQ sized conventional single wall core barrel, or a triple tube core barrel, as needed. RQD will be calculated for each core run. The core barrel will be either 5- or 10-ft in length. Bedrock core lengths may be adjusted longer or shorter as appropriate based on rock conditions encountered. Stone will be on site to crush and containerize rock core samples for DFN analysis at either location AE-105R or AE-106R.

Cascade will develop the open boreholes via air lift methods. Existing wetland well TRC-301R, located between the AE-105 and AE-106 clusters, will be redeveloped using air lift methods. After development, Cascade will install blank FLUTe liners within the open rock boreholes, as well as in well TRC-301R. To complete the liner installation, Cascade will install a 5-ft long PVC casing extension to the top of the well, setup a five (5) foot high scaffolding over the well, and add a combination of heavy drilling mud and water to extend the liner down the hole to the optimal depth.

Three nested overburden monitoring well triplets (AE-105S/M/D, AE-106S/M/D, AE-107S/M/D) will be installed in the wetlands with either 5-foot or 10-foot screens in the following anticipated intervals: 10 to 20, 30 to 40, and 50 to 60 ft bgs inside of eight (8) inch diameter, seven (7) inch diameter, and six (6) inch diameter telescoping casings, respectively. Cascade will install these wells with a mini-sonic drilling rig which allows for continuous core sampling of the overburden soils. The core sample will be extruded into polyethylene bags and laid out for characterization. For these nested wells, a telescopic casing advancement technique will be used. A six-inch sonic borehole will be advanced to approximately 60 ft bgs with continuous core recovery. Seven-inch override casing will then be advanced to approximately 40 ft bgs and eight-inch override casing will be advanced to approximately 15 ft bgs.

The monitoring wells will be constructed using either 1.5-inch or 2-inch diameter Schedule 40 PVC casing. It is anticipated that 0.10-slot screen size will be used. Screen length and slot size may be adjusted based on field observations. Bentonite chips will be used to separate each interval with a finer-grained “choker” sand used to separate the sandpack from the bentonite chips. Each triplet will be finished with a locking standpipe. All overburden monitoring wells will be developed by Cascade within 48 hours of installation via surging and purging methods.

During borehole advancement, two soil samples will be collected from each triplet location, at regular intervals where no evidence of impacts are observed from just below the water table to the top of bedrock, with one sample from the peat layer. Soil samples will be analyzed for fOC via Lloyd Khan.

Refer to **Table 3-7** for more details pertaining to the Mobilization 3 activities.

3.3.11 Mobilization 4 – Borehole Geophysics and Transmissivity Profiling

3.3.11.1 Mobilization 4A – Borehole Geophysics and FLUTe Transmissivity Profiling

Borehole geophysical tests and FLUTe transmissivity profiling will be performed at nine (9) bedrock wells locations: AE-100R, AE-101R, AE-102R, AE-103R, AE-104R, AE-105R, AE-106R, STM-8R1/R2, and TRC-301R.

FLUTe will mobilize to the Site to conduct transmissivity profiling and will remove the blank liners in advance of the borehole geophysics contractor. Hager-Richter Geoscience, Inc. (Hager-Richter) of Fords, New Jersey will perform the following geophysical tests on the designated boreholes:

- 1) Fluid temperature
- 2) Fluid resistivity
- 3) Single point resistance
- 4) Spontaneous potential
- 5) Natural gamma
- 6) Electrical formation resistivity
- 7) Acoustic borehole televiewer (data from this log will be used to generate an acoustic caliper log)
- 8) Optical televiewer
- 9) Mechanical caliper (this will be run if the ATV does not produce a usable acoustic caliper)
- 10) Field data analysis to select targets followed by heat pulse flow meter (ambient and pumping)

FLUTe will mobilize to the site to conduct transmissivity profiling. To complete the transmissivity profile, The following sequence will be followed:

1. FLUTe will dismantle the 5-ft extension and temporary scaffolding then remove the blank liner from the first borehole using a linear capstan to help develop the well.
2. Hager-Richter will start borehole geophysics on the first hole the following morning. It is assumed that borehole geophysics will take the entire day to complete.
3. While borehole geophysics is being completed, FLUTe will mobilize to the 2d hole and pull that liner so borehole geophysics can be conducted the following day.

4. Once borehole geophysics is completed on the 1st hole, FLUTe will then conduct a transmissivity profile on the well.
5. Once completed with the transmissivity profile, FLUTe will re-install the blank liner with the 5-ft extension, scaffolding, and recycled heavy mud.
6. Both FLUTe and Hager-Richter will continue this process for all nine bedrock borehole locations until the borehole geophysics and transmissivity profiling is completed in all 9 holes.

Refer to **Table 3-8** for more details pertaining to the Mobilization 4A activities.

3.3.11.2 Mobilization 4B – ALS Temperature Profiling

Waterloo Geophysics, Inc. (WGI) of Waterloo, Ontario will be on site to perform Active Line Source (ALS) temperature logging with a heated source within the following nine (9) FLUTe lined wells: AE-100R, AE-101R, AE-102R, AE-103R, AE-104R, AE-105R, AE-106R, STM-8R, and TRC-301R. The ALS Temperature logging technique is useful for detecting ambient groundwater flow in a fractured bedrock borehole. The method places a borehole into thermal dis-equilibrium, and thereby allows interpretation of groundwater flow through fractures where it may have been previously undetected. The method consists of temperature logging while after a borehole is heated by the cable and during cooling after the heating. With two or more logs collected during cooling, an estimate of thermal conductivity is obtained.

Alternative methods for flow detection, such as flow-meters, require an open borehole and either have poor vertical resolution or require multiple stationary measurements, often with packers to minimize the effects of connecting flow. The ALS technique is a comparatively simple tool, useful in both open and cased or lined boreholes, run continuously down the length of the borehole, with fracture resolution on the order of a few centimeters.

Refer to **Table 3-8** for more details pertaining to the Mobilization 4B activities.

3.3.12 Mobilization 5 – FLUTe Well and STM-8R1/R2 Well Completion

AECOM will oversee the completion of the following bedrock monitoring wells: AE-100R, AE-101R, AE-102R, AE-103R, AE-104R, AE-105R, AE-106R, STM-8R1/R2, and TRC-301R. Standard PVC well construction will be used for STM-8R1 and STM-8R2. All other holes will be fitted with permanent

Water FLUTe systems or equivalent multi-level well completion depending on the results of the borehole geophysical logging.

Permanent Water FLUTe liners will be ordered following a review of available preliminary data and identification of optimal sampling depths. The Water FLUTe liners will have sampling ports installed at the targeted screen intervals. FLUTe will remove existing scaffolding, 5-ft casing extensions and pull the blank liners. FLUTe will install the Water FLUTe permanent sampling liners. Heavy mud will be used, as needed, to install the permanent Water FLUTes manufactured with up to five liner ports within each bedrock monitoring well. The depths of the ports will be based on the borehole geophysics, FLUTe transmissivity, and ALS temperature profiling results at each location.

Cascade will be on site to install monitoring wells STM-8R1 and STM-8R2 within borehole STM-8R1/R2. It is intended that these two wells will be standard construction 1.5-inch diameter PVC casings installed within the 5-inch diameter open-rock borehole. Screen intervals within the bedrock will be selected based on the coring logs, borehole geophysics, FLUTe transmissivity profiling, and ALS temperature logging results.

Wells within the EPL and along Concord Street are anticipated to be completed with flush-mount road boxes with concrete pads, while the wetland wells will be completed with steel protective casings set in concrete casings.

3.3.13 Hydraulic Conductivity Testing

AECOM will complete aquifer testing (slug tests) at all new conventional monitoring wells locations to provide spatial distribution in the overburden across the site, and in bedrock at the Concord Street location. It is anticipated that three or more tests (rising or falling head) will be performed at each well, using different initial displacements (slug sizes). Both rising and falling head tests will be conducted if possible (falling head tests will be not performed in water table wells). A pressure transducer and data-logger will be employed to record the head changes. Data will be evaluated using the approach recommended by Butler 1998. Plots of head displacement versus time and estimates of hydraulic conductivity will be generated.

3.3.14 Rock Core Diffusion Rate Testing

Select rock cores (approximately 5) will be packaged and shipped to Golder Associates Ltd. (Golder) of Mississauga, Ontario to perform rock core diffusion rate testing. The results obtained from this method allow for calculation of an estimate of the diffusion rate of chlorinated solvents in the fractured bedrock matrix. This method uses chloride as a surrogate tracer. The resulting matrix diffusion coefficient for chloride is then divided by the chloride diffusion coefficient in pure water to give a matrix “tortuosity factor”. The resulting tortuosity factor can be used to calculate matrix diffusion coefficients for specific chlorinated solvents. The method also includes analysis for specific gravity, total porosity, dry bulk density, hydraulic conductivity, and water content.

3.3.15 Well Survey

The horizontal coordinates and top of casing vertical elevations will be surveyed of all new monitoring wells installed within Building 1, in the EPL, in the wooded and wetland areas, and along Concord Street. The monitoring wells installed within Building 1 will be located by measuring distances from internal walls. The survey will be accurate to the nearest 0.01 foot for vertical elevations in the North American Vertical Datum 1988 and 0.1 foot for horizontal coordinates in the Massachusetts State Plane Coordinate System relative to the North American Datum 1983. The well survey may be conducted in phases and may also include the resurvey of existing wells, as needed.

3.3.16 Groundwater and Surface Water Sampling in EPL, Wetlands, and Concord Street

Prior to commencing each of three groundwater sampling events, a round of synoptic water level measurements will be obtained. Following installation of the new wells in 2014, water levels will be measured at the 63 newly installed wells/screens, as well as an estimated 20 existing monitoring wells. In October 2014 and October 2015, site-wide synoptic water level measurement rounds will be conducted on all existing monitoring wells.

Three rounds of groundwater sampling will be performed in 2014 and 2015 as detailed in **Table 3-9**. The first round will be performed in 2014 following the installation of the monitoring wells along Transects A, B, and C. It is intended that groundwater sampling at Building 1 will be conducted separately from the initial sampling of the Transect A, B, and C wells. The second round will be conducted in October 2014 with the third round to be conducted in October 2015. The first round is intended as a screening of new wells to identify locations with significant VOC concentrations in

groundwater, and will include approximately 63 screen intervals (21 overburden and 42 bedrock) with analyses for field parameters, VOCs and oxygen, sulfur, and deuterium isotopes in samples from the three sets of overburden monitoring wells completed in the wetlands. The scope of the second and third rounds are detailed in **Table 3-9**, but may change based on the analytical results obtained from the first 2014 sampling event. These events will include newly installed and pre-existing wells.. The second and third rounds will include analyses of VOCs with an expanded list of MNA parameters at select wells.

In addition, to evaluate substantial hazards and potential ecological impacts, four surface water samples from the wetlands and three from the Ipswich River will be sampled. Each of the samples will be analyzed for VOCs, and the wetland samples will also be analyzed for isotopes. The scope of the sampling rounds is presented in **Table 3-9**. All groundwater sampling will be performed using low flow purging and sampling procedures using either peristaltic, bladder, or potentially submersible pumps. All FLUTe sample ports in bedrock will be sampled in accordance with FLUTe sampling procedures. Surface water samples will be collected as grab samples.

3.3.17 Treatment System O&M Activity

AECOM will continue to periodically monitor the packer within the bedrock extraction well TRC-202R in the EPL to ensure the packer pressure is maintained between 180 and 200 psi to prevent communication between the overburden and bedrock groundwater. Packer pressure will be monitored at a minimum during the following months: March, June, September, and December of 2014, and March, June, September of 2015. More frequent checks may be made as personnel are on site performing other work.

In addition, during each system O&M visit, AECOM will gauge six wells (PZ-2S, CW-1, CW-2, TRC-101, AE-3, and AE-4) to monitor for the presence of LNAPL. Water and product levels, if present, will be gauged with an interface probe to the nearest 0.01 foot. Depth to product, depth to groundwater, and product thickness shall be noted in the field records.

3.3.18 Waste Management

Drill cuttings will be containerized in 55-gallon drums and/or rolloff containers, depending on the volume of cuttings and the timing of generation. All containers will be segregated according to point of generation and will be temporarily staged in a secure location on site pending characterization analyses. Laboratory analyses to be determined by the disposal facility will be used for waste characterization and

profiling to determine appropriate off-site management. Other accumulated solid waste such as used gloves, paper towels, and plastic will be bagged and placed in appropriate containers to be managed as standard solid waste.

Well development/purge water and decontamination fluids will be containerized in 55-gallon drums, 275-gallon totes, and/or in frac tanks, depending on the volume of liquids and the timing of generation. All containers will be segregated according to point of generation and will be temporarily staged in a secure area on site pending characterization analyses. Laboratory analyses to be determined by the disposal facility will be used for waste characterization and profiling to determine appropriate off-site management.

3.3.19 MCP Reporting

The following MCP required reports will be prepared and submitted to the MassDEP in accordance with MCP requirements, including public involvement notifications.

- The Supplemental Phase II Comprehensive Site Assessment Report will be prepared in accordance with Section 40.0835 of the MCP and the applicable performance standards (40.0833). This document will summarize the required details pertaining to the disposal site, site history, and hydrogeological characteristics, and will include environmental fate and transport evaluation, nature and extent of contamination, an exposure assessment, risk characterization, and conclusions.
- A Phase III Remedial Action Plan will be prepared and submitted in accordance with Section 40.0850 of the MCP.
- A Response Action Outcome (RAO) Statement will be prepared in accordance with Section 40.1000 of the MCP, specifically 40.1056. The RAO will be submitted to MassDEP on or before May 1, 2015.
- A Post Class C RAO Status and Remedial Monitoring Report (RMR) will be prepared in accordance with Section 40.0898 of the MCP for submittal to MassDEP.

3.3.20 Schedule

The table below outlines the proposed schedule for the Supplemental Phase II activities detailed in this SOW.

	2013				2014				2015			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4
ROS Termination Notice												
Tier 1 Permit Extension Application												
Planning, Permitting, Notifications												
Additional Site Assessment Activities												
Phase II Evaluation												
Site-wide Risk Characterization												
Phase III Evaluation												
RAO Deadline												

4.0 SAMPLING AND ANALYSIS PLAN

This section details the methods and procedures to be used during the performance of the supplemental investigation activities outlined in Section 3. Field work and sampling will be conducted in multiple phases as described in Section 3 to further characterize indoor air, soil, bedrock, and groundwater quality at the site.

4.1 PROJECT OPERATION PROCEDURES

All investigation activities will be conducted in accordance with detailed Project Operation Procedures (POPs). **Table 4-1** provides a summary of the POPs and clarification of site-specific procedures and methods to be followed during the execution of this SOW. Copies of the following POPs are provided in **Appendix B** of this SOW:

POP #	POP name
001	Recording of Field Data
002	Chain of Custody Procedures
003	Packing and Shipment of Environmental Samples
004	Procedures for Passive Sampling of Air Using SUMMA Canisters
005	Monitoring Well Construction and Installation
006	Operation and calibration of a PID
007	Headspace Screening
008	Subsurface Soil Sampling
009	Rock Core Drilling
010	Logging of Rock Cores
011	Decontamination of Field Equipment
012	Monitoring Well Development
013	Water Level Measurements
014	Low Stress Groundwater Sampling Procedures
015	Field Calibration of the YSI Water Quality Meter
016	Hydraulic Conductivity Testing

4.2 SUBCONTRACTOR STANDARD OPERATING PROCEDURES

In addition, the following SOPs provided by the different subcontractors that will likely be involved with the supplemental investigation activities are provided in **Appendices C through G** of this SOW:

<u>Subcontractor</u>	<u>SOP</u>
Stone Environmental	VOCs in Rock Core Samples
FLUTe	Liner Installation Procedure
FLUTe	Groundwater Sampling Procedures
Hager-Richter	Borehole Geophysical Procedures
Waterloo	Active Line Source (ALS) Temperature Profiling
Golder	Rock Core Diffusion Testing Procedure

Copies of example field records to be used to document field activities and data collection are provided in **Appendix H**.

4.3 ANALYTES OF CONCERN

Samples will be analyzed for the constituents listed in **Tables 4-2 through 4-4** for soil, groundwater, surface water, bedrock, air, and IDW. Analyses specific to each sample are presented in the **Section 3 Tables**.

4.4 ANALYTICAL PROCEDURES

Soil, groundwater, and surface water samples will be analyzed for typical analytes by:

Spectrum Analytical, Inc.
11 Almgren Drive
Agawam, MA 01001-3831
(413) 789-9018

Spectrum Analytical, Inc. (Spectrum) will also perform fractional organic carbon analyses on soil samples. The Spectrum facility located at 175 Metro Center Boulevard, Warwick, RI will perform a separate analysis for 1,4-dioxane in order meet sensitivity requirements.

Analysis of groundwater samples for microbial populations and functional genes will be performed by:

Microbial Insights, Inc.
2340 Stock Creek Boulevard
Rockford, TN 37853
(865) 573-8188

Natural isotopic analysis of surface waters and groundwater for oxygen, hydrogen/deuterium, and sulfur will be performed by:

Isotech Laboratories, Inc.
1308 Parkland Court
Champaign, IL 61821
(217) 398-3490

Air samples will be analyzed by:

Alpha Analytical
320 Forbes Boulevard
Mansfield, MA 02048
(508) 844-4156

Compound Specific Isotope Analyses (CSIA) and dissolved gases analyses in groundwater will be performed by:

Microseeps, Inc.
220 William Pitt Way
Pittsburgh, PA
(412) 826-5245

VOC analyses of crushed bedrock will be performed by:

Stone Environmental
535 Stone Cutters Way
Montpelier, VT 05602
(802) 229-4541

Rock core diffusion and physical parameter analyses will be performed by:

Golder Associates Ltd.

6925 Century Ave. Suite 3100

Mississauga, Ontario Canada L5N 7K2

(905) 567-4444

Samples will be analyzed for the constituents listed in **Tables 4-2 through 4-4**. The laboratory analytical methods to be used are summarized in **Table 4-5**.

4.5 SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIME

Sample bottles and chemical preservatives will be provided by the laboratories. The containers will be cleaned by the manufacturer to meet or exceed all analyte specifications established in the latest United States Environmental Protection Agency's (USEPA) Specifications and Guidance for Contaminant-Free Sample Containers. Certificates of analysis will be kept on file at the laboratory providing the containers for each lot of containers and maintained to document conformance to USEPA specifications. In addition, SUMMA® canisters for TO-15 analyses will be batch-certified by the laboratory for samples associated with sub-slab and indoor air sampling. Batch certification will be performed on canisters used for soil gas sampling.

A summary of sample container, preservation, and holding time requirements is presented in **Table 4-6**.

4.6 FIELD QUALITY CONTROL

QC samples for laboratory analyses will include field duplicates, MS/MSDs, equipment blanks, trip blanks, and temperature blanks. These samples will be collected as described below:

Field Duplicates

Field duplicates will be collected at a frequency of one field duplicate per 20 field samples, per matrix, per sampling technique, with certain exceptions. Field duplicates for solid samples will be collected by alternately filling two sets of identical sample containers from the interim container used to homogenize the sample. For soil VOC samples, the field duplicate will be collected using the collection device (e.g., sample coring device) from the same areas as the parent sample (i.e., soil VOC samples are not homogenized). For aqueous samples, the parent sample and field duplicate sample containers will be

filled in an alternating fashion (i.e., one parent sample container filled, one field duplicate container filled). For soil gas samples, a T-connection will be used to fill two canisters simultaneously. All field duplicates will be analyzed for the same parameters as their associated samples.

Matrix Spike/Matrix Spike Duplicate

MS/MSD samples will be collected at a frequency of one for every 20 field samples, per matrix where applicable to the method. For those samples designated as MS/MSDs, sufficient additional volume or mass (based on the laboratory's requirements) will be collected.

Equipment Blanks

Equipment blanks will be collected at a rate of one for every 20 field samples, per matrix, per sampling technique, when possible. Equipment blanks will be collected by pouring laboratory volatile organic analysis (VOA)-free water over the decontaminated sampling equipment, and collecting the rinsate into the appropriate sample containers. Equipment blanks will not be collected when dedicated sampling equipment is used (e.g., peristaltic pump with dedicated tubing) or for air samples.

Trip Blanks

Trip blanks will be included with each shipment of bedrock cores, groundwater and soil samples collected for VOC analyses. Trip blanks associated with groundwater samples will originate in the laboratory and will be prepared by filling two 40-mL VOA vials with laboratory VOA-free water and the chemical preservative, and sealing the vials with septum-lined caps (allowing no headspace). Trip blanks associated with soil VOC samples will consist of one set of VOA vials (i.e., two low level VOA vials and one high level VOA vial) with water, preservative, and a stir bar (no soils). Trip blanks will accompany the sample bottles to the site and will remain (unopened) in the shipping container until the sample bottles are received back at the laboratory.

Temperature Blanks

Temperature blanks will be included in each cooler, allowing the laboratory to determine the temperature of the shipment without disturbing the field samples. Temperature blanks will be prepared by filling a plastic or glass vial with water.

4.7 LABORATORY QUALITY CONTROL

The analytical laboratories have a QC program in place to ensure the reliability and validity of the analysis performed at the laboratory. All analytical procedures are documented in writing as SOPs and each SOP includes the minimum requirements for the procedure. The internal QC checks differ slightly for each individual procedure and are outlined in the SOPs. In general they include:

- Blanks (method, reagent/preparation, instrument)
- MS/MSDs
- Surrogate spikes (organic analyses)
- Laboratory duplicates
- Laboratory control samples (LCSs)
- Internal standard area counts (gas chromatography/mass spectrometry [GC/MS] analyses)
- Calibration check compounds
- Interference checks (ICP analysis)
- Serial dilutions (ICP analysis)
- Individual canister cleaning certification

The control limits for precision and accuracy will be the laboratory limits current at the time of analyses.

The MassDEP's WSC #10-320: Compendium of Quality Control Requirements and Performance Standards for Selected Analytical Protocols, "Compendium of Analytical Methods" (CAM) for each analysis defines the type, frequency, and corrective action for the applicable QC checks. The control limits for precision and accuracy will be the control limits published in the CAM laboratory protocols. For non-CAM analyses, the control limits for precision and accuracy will be the laboratory limits current at the time of analyses.

4.8 REPORTING

Data management and reporting operations include data recording, validation, transformation, transmittal, reduction, analysis, tracking, storage and retrieval. Once the field and laboratory information is reviewed, they are included into various summary reports with conclusions associated to them.

Upon receipt from the laboratory, hard copy data and electronic data deliverables (EDDs) will be checked for completeness. During the data analysis process, a variety of quality checks are performed to ensure data integrity. These checks include

- Audits to ensure that laboratories reported all requested analyses
- Checks that all analytes are consistently and correctly identified
- Reviews to ensure that units of measurement are provided and are consistent
- Reports to review sample definitions (depths, dates, locations)
- Proofing manually entered data against the hard-copy original

Records of the checks are maintained on file.

Once all data quality checks are performed, the data will be exported to a variety of formats to meet project needs. Cross-tab tables showing concentrations by sample location will be prepared.

The project data will be maintained on a secure network drive, which is backed up regularly. Access to the data will be limited to authorized users and will be controlled by password access.

5.0 QUALITY ASSURANCE PROJECT PLAN

The USEPA QAPP policy as presented in USEPA Requirements for QAPP (EPA QA/R-5, March 2001) and the *Massachusetts Contingency Plan (MCP)* [Massachusetts Department of Environmental Protection (MassDEP, June 2009)] were used as guidance in preparing the following QAPP sections. Additional guidance in MassDEP's *WSC #10-320: Compendium of Quality Control Requirements and Performance Standards for Selected Analytical Protocols* (the "CAM") was used as additional guidance.

5.1 QUALITY ASSURANCE OBJECTIVES FOR DATA ASSESSMENT

QA objectives for the data to be collected include quantitative determinations of the data quality indicators or precision, accuracy (bias), representativeness, comparability, and completeness (PARCC) parameters. The objectives for PARCC parameters will vary with the anticipated use of the data. A discussion of how each of these five parameters will be integrated into this project is provided below. Sensitivity, as demonstrated by laboratory reporting limits, is also discussed below.

Precision

Precision is a measure of the degree to which two or more measurements are in agreement. Field precision is assessed through the collection and measurement of field duplicates at a rate of one duplicate per twenty analytical samples, per matrix, per sampling technique.

Precision will be measured through the calculation of relative percent difference (RPD). The objective for field precision RPDs is < 30% RPD for aqueous and soil vapor samples, and < 50% RPD for solid samples, where results reported at greater than 5 times the reporting limit.

Precision in the laboratory is assessed through the calculation of RPD for duplicate samples, either as MS/MSDs or as laboratory duplicates. The precision objectives, as measured by RPDs, will be the control limits generated by the laboratories that are current at the time of analyses.

Accuracy

Accuracy is the degree of agreement between the observed value and an accepted reference or true value. Accuracy in the field is assessed through the use of trip blanks and equipment blanks and through the adherence to all sample handling, preservation, and holding time requirements. The objective for trip

blanks and equipment blanks is that no target compounds are present above the reporting limit. Sampling preservation and holding time requirements are provided in **Table 4-6**.

Laboratory accuracy is assessed through the analysis of laboratory method blanks, and spiked samples such as MS/MSDs, LCSs, and surrogate compounds. Method blanks should not contain any target compounds above the reporting limits (RLs). For spiked samples, the accuracy objectives, as measured by percent recoveries (%Rs) will be the control limits generated by the laboratories that are current at the time of analyses.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition within a defined spatial and/or temporal boundary.

Representativeness is ensured through the design of the sampling program and will be satisfied by ensuring that the SOW is followed and that proper sampling techniques are used. Within the laboratory, representativeness will be ensured by the use of appropriate methods, conformance to the approved analytical procedures, and adherence to sample holding times.

Comparability

Comparability expresses the confidence with which one data set can be compared to another. Comparability is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the protocols described in this QAPP are followed and that proper sampling techniques are used. Planned analytical data will be comparable when similar sampling and analytical methods are used as documented in the SOW.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. "Normal conditions" are defined as the conditions expected if the sampling plan was implemented as planned.

Field completeness is a measure of the amount of valid samples obtained during all sampling for the project. The field completeness objective is greater than 90 percent.

Laboratory completeness is a measure of the amount of valid measurements obtained from all the measurements taken in the project. The laboratory completeness objective is greater than 95 percent.

Sensitivity

Sensitivity of analytical data is demonstrated by laboratory RLs and Method Detection Limits (MDLs). The target RLs for the analytes to be analyzed are presented in **Tables 4-2 through 4-4** for soil groundwater, air and IDW. The RLs for chlorinated VOCs in bedrock will range from 125 to 1250 ug/kg. The RLs for the actual samples may differ due to analytical dilutions, sample volume, or sample matrix. The laboratory will notify AECOM if significant sample dilutions are needed or matrix interferences are encountered during sample analysis that may result in elevated RLs.

Reporting limits were selected in part by consideration of the data quality levels (DQLs) to be achieved and in part by consideration of the actual ability of the laboratory to attain reporting limits at the DQLs. Selected Ion Monitoring (SIM) will be performed for 1,4-dioxane analyses to obtain lower reporting limits. Not all risk based target analyte DQLs are obtainable using the RLs of conventional USEPA or MassDEP methods.

5.2 DATA QUALITY OBJECTIVES

The USEPA data quality objectives (DQO) process is a multi-step, iterative process that ensures that the type, quantity, and quality of environmental data used in decision making is appropriate for its intended application. The DQO process is summarized below.

DQO Step	Description
State the Problem	Releases or spills to the environment have occurred from historical operations.
Identify the Decision	Fill data gaps identified from previous investigations at the site.
Identify Inputs to the Decision	• Water level measurements • Water quality measurements • Drilling of soil borings • Soil gas point installation • Well installation and development • Groundwater samples from monitoring wells • Soil samples • Soil gas, indoor, and ambient air samples • Headspace screening for total VOCs during borehole advancement, soil sampling, and bedrock coring • Analysis of soil, groundwater, and soil vapor/indoor air samples for the parameters listed in Tables 4-2 through 4-5.

DQO Step	Description
Define Study Boundaries	The Disposal Site.
Develop a Decision Rule	The results of the sampling program will be used to meet the objectives stated in Section 5.2.1 of this QAPP
Specify Decision Error Limits	The data will be considered acceptable if they are collected according to this SOW and QAPP and they meet the applicable screening levels and data validation criteria.
Optimize the Study Design	Since a formal statistical design is not being utilized, an iterative process with dynamic work strategies for optimizing the sample design will be used.

5.2.1 Project Objectives

The objectives of this investigation are to:

- Further characterize soil, bedrock, and groundwater conditions and assess contaminant concentrations in support of modifying the conceptual site model to support future risk characterizations and a revised Phase III RAP.
- Collect data to support mass flux calculations of chlorinated solvents in overburden and bedrock groundwater along the down-gradient property boundary and in the off-site wetlands.
- Assess chlorinated solvent impacts in soil and groundwater in both overburden and bedrock beneath Building 1 to determine the nature and extent of this area of concern, and its relationship, if any, to impacts in the vicinity of the former Tank F as well as the former tank farm area on site.
- Collect additional rounds of indoor air data to further assess the indoor air exposure pathway at Building 1.
- Collect additional data to support the site-wide assessment of arsenic and 1,4-dioxane, and monitored natural attenuation evaluation of chlorinated solvents in groundwater.
- Maintain the packer pressure within bedrock extraction well TRC-202R to prevent communication between the overburden and bedrock groundwater.
- Meet the performance standards of the MCP.

5.3 SAMPLING REQUIREMENT

5.3.1 Sample Receipt and Handling

The AECOM Field Team Leader is responsible for all samples collected on site. The AECOM Field Team Leader will designate a sample custodian for each day of the sampling event. The designated sample custodian is responsible for overseeing and supervising the implementation of proper sample custody procedures in the field. The sample custodian is also responsible for ensuring sample custody until the samples have been transferred to the laboratory. Once received by the laboratory, the samples proceed through an orderly processing sequence specifically designed to ensure continuous integrity of both the sample and its documentation. By following these procedures, documents or records needed to ensure a traceable link between the reported measurement results and the represented site conditions will be generated.

5.3.2 Sample Custody

Custody is one of several factors that are necessary for the admissibility of environmental data as evidence in a court of law. Custody procedures help to satisfy the two major requirements for admissibility: relevance and authenticity. Sample custody is addressed in two parts: field sample collection and laboratory analysis.

A sample is considered to be under a person's custody if:

- The item is in the actual possession of a person.
- The item is in the view of the person after being in actual possession of the person.
- The item was in the actual physical possession of the person but is locked up to prevent tampering.
- The item is in a designated and identified secure area.

Field Custody Procedures

The field sampler is personally responsible for the care and custody of the samples until they are transferred or dispatched properly. Field procedures have been designed such that as few people as possible will handle the samples. Field samplers will maintain control of all samples in their possession during field activities. When not in field sampler's direct possession, all samples will be locked in secure

locations, either within field vehicles or the treatment building on site. Samples may also be temporarily secured at the AECOM office in Chelmsford, MA while awaiting pickup by a laboratory courier.

All sample containers will be identified by the use of sample labels with sample numbers, sampling locations, date/time of collection, and type of analysis. Sample labels will be completed for each sample using waterproof ink unless prohibited by weather conditions. For example, a logbook notation would explain that a pencil was used to fill out the sample tag because the pen would not function in freezing weather.

Samples will be accompanied by a properly completed Chain of Custody (COC). The sample numbers and locations will be listed on the COC. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents the transfer of custody of samples from the sampler to another person, to the permanent laboratory, or to/from a secure storage location. An example COC is presented in **Appendix H**. For soil vapor samples collected in SUMMA® canisters, a specialized COC that includes fields for initial and final canister pressure must be used. An example COC to be used for TO-15 (air samples) is presented in **Appendix H**.

All sample shipments will be accompanied by the COC identifying the contents. The original record will accompany the shipment, and the back copy will be retained by the sampler and placed in the project files.

Field samples will be packed and shipped to the laboratory according to Section 4.14.5 of this SOW. With the exception of the SUMMA® canisters, samples will be properly packaged on ice at 4°C for shipment and dispatched to the laboratory for analysis, with a separate signed custody record enclosed in and secured to the inside top of each sample box or cooler. Shipping containers will be sealed and secured with strapping tape and custody seals for shipment to the laboratory. The custody seals will be attached to the front right and back left of the cooler and covered with clear plastic tape after being signed by field personnel. The cooler will be strapped shut with strapping tape in at least two locations. For the SUMMA® canisters, the samples will be shipped in the boxes in which they were received.

If the samples are sent by common carrier, the waybill will be used. Waybills will be retained as part of the permanent documentation. Commercial carriers are not required to sign off on the custody forms since the custody forms will be sealed inside the sample cooler and the custody seals will remain intact.

Laboratory Custody Procedures

Samples will be received and logged in at the laboratory by a designated sample custodian or his/her designee. Upon sample receipt, the sample custodian will

- Examine the shipping containers to verify that the custody tape is intact.
- Examine all sample containers for damage.
- Determine if the temperature required for the requested testing program has been maintained during shipment and document the temperature on the COC or in sample log-in records.
- Compare samples received against those listed on the COC.
- Verify that sample holding times have not been exceeded.
- Examine all shipping records for accuracy and completeness.
- Determine if sample pH is adequate and whether any adjustments were required (if applicable) and record sample receipt form.
- Sign and date the COC immediately (if shipment is accepted) and attach the waybill.
- Note any problems associated with the coolers and/or samples on the cooler receipt form and notify the Laboratory Project Manager (PM), who will be responsible for contacting the client.
- Attach laboratory sample container labels with unique laboratory identification and analyses required.
- Place the samples in the proper laboratory storage.

Following receipt, samples will be logged in according to the following procedure:

- The samples will be entered into the laboratory information management system (LIMS). At a minimum, the following information will be entered: project name or identification, unique sample identification numbers (both client and internal laboratory), type of sample, required analyses, and date and time of laboratory receipt of samples.
- The appropriate laboratory personnel will be notified of sample arrival.
- The completed COC, waybills, and any additional documentation will be placed in the project file.

Specific details of laboratory custody procedures for sample receiving, sample identification, sample control, and record retention are described in the Laboratory QA Manual and laboratory SOPs.

5.3.3 Sample Holding Time Requirements

Holding time requirements for the analyses to be performed on the soil, groundwater, and air samples are presented in **Table 4-6**.

5.4 DATA REDUCTION, REVIEW, AND ASSESSMENT

Field data will be reviewed daily by the AECOM Field Team Leader to ensure that the records are complete, accurate, and legible and to verify that the sampling procedures are in accordance with the protocols specified in the SOW and QAPP.

Laboratory data reduction procedures will be performed according to the following protocol.

- All information related to analysis will be documented in controlled laboratory logbooks, instrument printouts, or other approved forms.
- All entries that are not generated by an automated data system will be made neatly and legibly in permanent, waterproof ink.
- Information will not be erased or obliterated. Corrections will be made by drawing a single line through the error and entering the correct information adjacent to the cross-out. All changes will be initialed, dated, and, if appropriate, accompanied by a brief explanation.
- Unused pages or portions of pages will be crossed out to prevent future data entry.
- Analytical laboratory records will be reviewed by the supervisory personnel on a regular basis, and by the Laboratory QA Coordinator periodically, to verify adherence to documentation requirements.

Prior to the release of any data from the laboratory, the data will be reviewed and approved by laboratory personnel. The review will consist of a tiered approach that will include reviews by the person performing the work, by a qualified peer, and by supervisory and/or QA personnel.

Corrective Action during Data Review and Data Assessment

The need for corrective action may be identified during either data review or data assessment. Potential types of corrective action may include re-sampling by the field team or rejection/re-analysis of samples by the laboratory. These actions are dependent upon the ability to mobilize the field team and whether the data to be collected is necessary to meet the required QA objectives. If the AECOM data reviewer or data assessor identifies a corrective action situation, the AECOM PM, who in consultation with the LSP-of-Record, will be responsible for informing the appropriate personnel.

5.5 LABORATORY OPERATION DOCUMENTATION

5.5.1 Laboratory Reports

The standard laboratory turnaround time will be ten business days for all parameters. At certain points in the program, in order to accommodate the timing of dynamic work strategies, preliminary (unvalidated by lab) data may be needed for some analyses prior to the ten day period.

The laboratory will provide a hard copy report as a PDF file and an EDD. The EDD will be provided as text files in AECOM-specific EQUIS® format. The hardcopy data report will conform to the specifications found in the applicable CAM protocols for those analyses. For non-CAM analyses, the hard copy data report will contain QC results provided on summary forms.

5.5.2 Data Assessment or Validation Reports

A limited qualitative validation of the data deliverables will be performed. All QC results specified as a laboratory report deliverable in the CAM protocols will be reviewed by AECOM's data validation staff. These method-specific QC results typically include method blanks, LCS, matrix spikes, matrix duplicates, and/or surrogates, and are summarized on QC forms. In addition, the CAM protocols require that the laboratory include a narrative in the report that details all QC non-conformances that may have occurred during sample shipping, receipt, processing, and analysis. This information will also be reviewed by AECOM's data validation staff and will be evaluated with regard to any potential impacts to the sample data. The QC criteria specified in the CAM protocols will be used to evaluate the QC information (summarized on forms and detailed in the narrative) during data validation.

Validation of the data will be performed using actions in described in U.S. USEPA Region I, USEPA-NE Data Validation Functional Guidelines for Evaluation of Environmental Analyses (USEPA, 1996)

and USEPA Region I Inorganic Data Validation Functional Guidelines (USEPA, 2008), modified for non-Contract Laboratory Program (CLP) methods.

Upon completion of the validation, a Validation Summary Report will be prepared. This report will summarize the samples reviewed, elements reviewed, any non-conformances with the established criteria, and validation actions (including application of data qualifiers). Data qualifiers will be consistent with the USEPA guidelines. In addition, a Data Usability Report will be prepared in conformance with the Data Usability Guidelines of MassDEP Policy BWSC 07-350 “MCP Data Usability Assessment”.

5.6 CORRECTIVE ACTION MEASURES

Corrective action is the process of identifying, recommending, approving, and implementing measures to counter unacceptable procedures or out-of-limit QC performance that can affect data quality. Corrective action can occur during field activities, laboratory analyses, and data assessment. All corrective action proposed and implemented should be documented in the QA reports to management (see Section 5.6.3 below). Corrective action should only be implemented after approval by the AECOM PM and LSP-of-Record, or their designee.

The Lockheed Martin PM will be notified of significant issues that potentially impact the achievement of the project objectives.

5.6.1 Field Activities

Corrective action in the field may be needed when the sample network is changed (i.e., more/less samples, sampling locations other than those specified in the QAPP, etc.), or when sampling procedures and/or field analytical procedures require modification, etc. due to unexpected conditions. The field team may identify the need for corrective action. The AECOM Field Team Leader, if they concur, will notify the AECOM PM. The AECOM PM, in consultation with the AECOM Laboratory Task Manager and LSP-of-Record, will approve the corrective measure. The AECOM Field Team Leader will ensure that the corrective measure is implemented by the field team.

Corrective action resulting from internal field audits will be implemented immediately if data may be adversely affected due to unapproved or improper use of approved methods. The AECOM Laboratory Task Manager, Field Task Manager, and LSP-of-Record will identify deficiencies and recommend

corrective action to the AECOM PM and LSP-of-Record. Implementation of corrective actions will be performed by the AECOM Field Team Leader and field team. Corrective action will be documented in QA reports to the project management team (see Section 5.6.3 below).

Corrective actions will be implemented and documented in the field record book. Documentation will include:

- A description of the circumstances that initiated the corrective action
- The action taken in response
- The final resolution
- Any necessary approvals

No staff member will initiate corrective action without prior communication of findings through the proper channels.

5.6.2 Laboratory

Corrective action in the laboratory may occur prior to, during, and after initial analyses. A number of conditions such as broken sample containers, multiple phases, low/high pH readings, and potentially high concentration samples may be identified during sample log-in or analysis. Following consultation with laboratory analysts and supervisory personnel, it may be necessary for the Laboratory QA Coordinator to approve the implementation of corrective action. The AECOM PM and LSP-of-Record will be notified if the non-conforming condition causes the project objectives to be missed.

These corrective actions are performed prior to release of the data from the laboratory. The corrective action will be documented in both the laboratory's corrective action files, and in the narrative data report sent from the laboratory to the AECOM PM. If the corrective action does not rectify the situation, the laboratory will contact the AECOM PM, who after consultation with the LSP-of-Record, will determine the action to be taken and inform the appropriate personnel.

5.6.3 Implementation and Reporting

QA reports will be submitted to the AECOM PM and LSP-of-Record to ensure that any problems identified during the SAP programs are investigated and the proper corrective measures taken in response. The QA reports will include (where applicable):

- All results of field and laboratory audits
- A summary of revisions to the QAPP
- Results of any performance evaluation (PE) or split samples
- Problems noted during data validation and assessment
- Significant QA/QC problems, recommended corrective actions, and the outcome of corrective actions

QA reports will be prepared by the AECOM Laboratory Task Manager and submitted on an as-needed basis.

5.7 DOCUMENTATION

Documentation for this project will include a variety of field and office reports to log or record information for further evaluation and review. These include:

- Field log books
- Soil boring logs
- Well construction logs
- Field data sheets
- Well development and sampling logs
- Equipment calibration forms
- Indoor air building survey form
- Field summary report
- Semi-annual ROS Report

6.0 WASTE MANAGEMENT PLAN

This section describes the functional details that comprise the project's WMP. This WMP has been prepared in accordance with Lockheed Martin EROP-03: EESH Remediation Waste Management procedure. In summary, this WMP satisfies the preparation of a waste sampling, testing and hazardous waste determination plan for approval prior to remediation-derived waste generation. The purpose of the plan is to ensure that all wastes are properly characterized prior to disposal. Copies of Lockheed Martin waste management procedures and forms are included in **Appendix I**.

6.1 INVESTIGATION DERIVED WASTE STREAMS

IDW anticipated to be generated during site activities will include:

- drill cuttings and soil cores from soil borings and monitoring well installation activities
- groundwater from development and purging of monitoring wells
- decontamination fluids
- absorbent wicks saturated with NAPL for Stoddard Fuel (only if deployed)
- soiled personal protective equipment (PPE) and sampling supplies

As a sustainability measure, attempts will be made to minimize the volume of IDW generated by returning these materials to their point of origin, to the extent practical. All waste soils and rock pieces not sampled will be contained for profiling and disposal. Where possible, purged groundwater will be discharged back to the point of withdrawal, as per 310 CMR 40.0045, providing there is no silt or NAPL evident. Other criteria that will be used as triggers for potentially impacted IDW are visual or olfactory evidence of contamination, and/or photoionization detector (PID) screening vapors of 5 ppm_v above background. Used but not soiled PPE and sampling supplies will be segregated from soiled materials and disposed as general trash. Attempts will also be made to reduce usage of materials through the dedication of sampling equipment at individual locations, where possible without compromising data quality.

IDW to be managed will be containerized in 55-gallon steel drums while on or off site, or in containers of appropriate size and material for that particular IDW (i.e., rolloff containers, 275-gallon totes, or frac tanks). The material will be temporarily stored in a secure area on and off site pending analytical

characterization. For drilling and testing/sampling of monitoring wells, it is anticipated that temporary secured IDW storage areas will be constructed both on site and along the access path leading from the Stickney Well Road to proposed wells AE-105 series. Each container will be labeled with the following information:

- Container contents (type of IDW)
- Location(s) from which the IDW was generated (SB, MW identification) including approximate depths
- Date(s) of generation
- AECOM contact information:

Scott Olson

250 Apollo Drive Chelmsford, MA 01824

978.905.2100

All containers and associated information will be tracked on an IDW log (excel spreadsheet – example included in **Appendix H**) to facilitate management of the IDW and the characterization, profiling, and disposal process.

6.2 WASTE PROFILES

For soil cuttings generated during drilling, chemical analysis of the soil samples will be used to profile soil IDW. Similarly, water samples collected from wells will be used to profile IDW liquids generated during development, purging and sampling. These total chemical concentrations along with generator knowledge can be sufficient for the waste contractor to generate a profile for transport and disposal of material categorized as non-hazardous. If additional analyses are required, a grab sample will be obtained for VOC analysis, and a composite sample will be obtained for submittal to the laboratory for other parameters. If the total concentration data yields concentrations that are borderline hazardous (generally using the 20 times rule) then Toxicity Characteristic Leaching Program (TCLP) extraction analyses and possible additional waste characterization analyses will be performed. A composite liquid sample may be collected to profile liquid IDW generated during drilling, decontamination, and/or well development activities.

The following are typical waste characterization analyses, some or all of which may be conducted as required, either based on the materials encountered on site (grossly impacted materials, material generated from a new investigation area, discovery of a new condition, etc.) or based on requirements of the disposal facility:

- total (RCRA 8) metals by USEPA Method 6010B
- total VOCs by USEPA Method 8260B
- total semi-volatile organic compounds (SVOCs) by USEPA Method 8270C
- TPH by USEPA Method 8015 Modified
- total PCBs by USEPA Method 8082
- TCLP (metals, VOCs, SVOCs)
- RCRA Characteristics (ignitability, corrosivity, reactivity)

6.3 WASTE CLASSIFICATION DETERMINATION

Concentrations obtained from the waste characterization analyses will be used to determine waste classification during waste profile preparation, based on the Maximum Concentration of Contaminants for the Toxicity Characteristic listed in 40 CFR § 261.24.

AECOM personnel managing Lockheed Martin wastes will complete one Waste Listing Assessment Form per media per area of concern (anticipated to be soils, liquids, and solids such as spent absorbent wicks with NAPL, possible PPE, supplies, etc.) based on the anticipated nature of the materials to be generated. The LSP-of-Record will review and approve the form(s) and forward to the AECOM PM who will submit them to the Lockheed Martin Project Lead for approval of the determinations made. Finalization of the waste classification will be made upon receipt of the analytical profiling results which will be provided to the Lockheed Martin Project Lead in an updated Waste Listing Assessment form for approval.

IDW generated for disposal from the site is not anticipated to be characterized as hazardous material. If any IDW is characterized as hazardous, AECOM personnel have the requisite training to satisfy Element B of the EROP-03: EESH Remediation Waste Management procedure. In addition, the requirements of

Element C of the EROP-03: EESH Remediation Waste Management procedure will be addressed in the Waste Listing Assessment Form.

6.4 WASTE HANDLING, TRANSPORTATION, DISPOSAL, AND DOCUMENTATION

Based on the waste classification determination made, a Waste Management Vendor will be selected from Lockheed Martin's approved vendor list. AECOM intends to subcontract Clean Harbors, a Lockheed Martin approved hazardous waste vendor. Although not required for transport and disposal of non-hazardous materials, AECOM selected Clean Harbors to allow for flexibility with one vendor in case any IDW from site activities is characterized as a hazardous material. Clean Harbors will arrange for transportation and disposal of IDW from the site. Recommendations to use a non-Lockheed Martin approved vendor require prior written approval by the Lockheed Martin Project Lead.

Manifests shall be signed by a Lockheed Martin employee or an AECOM employee as designated agent by Lockheed Martin and then only after a Lockheed Martin authorization form is completed and approved by the Lockheed Martin Project Lead.

Typically, manifests are provided by the waste hauler in advance of shipment. Manifests are preprinted with waste names, codes, and generator information. AECOM will review the manifests for accuracy and completeness, and forward them to the Lockheed Martin Project Lead for signature, after which AECOM will hold in preparation for the shipment of waste. This "pre-signing" may occur weeks in advance. When a manifest is to be used, the actual waste quantity, hauler's name, and signature are added to the form. This completes the manifest for purposes of waste transport. AECOM tracks the unique identifying numbers of pre-signed and used manifests for the purpose of manifest inventory control. The maximum time-frame for waste storage on site prior to removal, based on the date of generation, will be as follows: 90 days for hazardous wastes, 120 days for non-hazardous wastes.

Soils and liquids will be transported off site in sealed drums in a box truck. One signed manifest is required per batch of drums shipped. To save on costs, batching waste shipments to maximize loads are the best approach.

Upon shipment off site, a copy of each manifest is given to AECOM. AECOM will provide one copy to the Lockheed Martin Project Lead and retain one copy in the project file.

The “Designated Facility to Generator” manifest copy should be sent directly to Lockheed Martin from the disposal facility within 30 days after waste receipt.

6.5 TRAINING REQUIREMENTS

All AECOM personnel working at the former GE site in Wilmington, MA will be trained in OSHA hazardous waste operations (HAZWOPER) with current annual refreshers as specified in 29 CFR §1910.120.

In addition, AECOM employees who may be involved with the signing of manifests at the Wilmington site will have the required Department of Transportation (DOT) Basic Hazmat Employee training, HM-181 per 49 CFR §172.704 (Subpart H)).

Federal training requirements do not apply to remediation projects that generate less than 100 kilograms per month (kg/month) of hazardous waste. AECOM personnel (either project team members or select personnel in our Chelmsford, MA office) are familiar with hazardous waste handling and emergency procedures, in the event that any IDW at the site is characterized as hazardous material.

6.6 EXPECTED WASTE SCHEDULE

Waste characterization determinations will be re-evaluated, at a minimum, whenever any of the following circumstances occur:

- A change occurs in the process that produces the waste (e.g. – a new chemical constituent is discovered, the treatment process is changed).
- A change in the treatment media is made (e.g. – a new media vendor or type is used).
- A waste was tainted by inadvertent mixing of the waste with another waste.
- A change occurred in the hazardous waste regulations that apply to the waste.

Wastes generated as a result of ongoing remediation or treatment operations shall be profiled once per year unless a more frequent profile is dictated by one of the circumstances defined above. For the scope of the 2013-2015 site-wide activities at the Wilmington site, it is anticipated that the waste characterization determinations will be made once for each waste media for each area of concern (solids, liquids, wicks, etc.).

6.7 SUBMITTALS

AECOM will submit the Waste Listing Assessment Form (**Appendix I**) to the Lockheed Martin Project Lead for approval prior to disposal of wastes generated as a result of AECOM's work performed on site. This form will be updated upon receipt of the analytical results and resubmitted for approval by the Lockheed Martin Project Lead.

Waste characterization analytical results, the generator copy of the waste manifest, COC, transportation, and destruction records (including certificates of destruction) shall be scanned and electronically submitted to Lockheed Martin for records retention within 30 days of record finalization for any wastes transported and disposed of as a result of AECOM performed work.

7.0 REFERENCES

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TRC (TRC Environmental Corporation). 2000. Long Term Groundwater Monitoring Report, Former GE Facility, RTN 3-0518, Wilmington, Massachusetts.

TRC. 2001a. Phase IV As-Built Construction and Final Inspection Report, Eastern Parking Lot Area, Former GE Facility, RTN#3-0518, Wilmington, Massachusetts. January 2001.

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USEPA Region 1. 2008. Inorganic Data Validation Functional Guidelines, Modified for Non-CLP Methods.

Zen, E., et al. 1983. Bedrock Geologic Map of Massachusetts: scale 1:250000. U.S. Geological Survey.

Tables

Table 2-1
Site Characterization History and Regulatory Timeline
Former GE Facility, 50 Fordham Road, Wilmington, MA

1968 - 70	Development of 50 Fordham Road property
1970	GE's Aerospace Instruments Control Systems enters facility
Dec-78	Town of North Reading tests the Stickney Well; Well is shut down
1986	Tank K removed
Jun-86	DEP (DEQE) issues GE a Notice of Responsibility (NOR)
Sep-86	Phase I study
Jun-87	Tanks D, G, H, I, J and a small tank adjacent to Tank F are removed.
Jun-87	Interim Phase II Site Investigation Report
Oct-87	DEP (DEQE) classifies the GE site as a Priority Disposal Site
Feb-90	Tank F removed
Apr-90	Phase II investigation Report
Oct-91	MassDEP approves Tank Farm Area Interim Measure
Oct-91	Tank Farm Pump-and-Treat System Installed (TF-1) (operated ~1993 - 2002)
Nov-91	Phase II Supplemental Investigation Report
Dec-91	MassDEP approves Eastern Parking Lot Interim Measure
Dec-91	Public Health and Ecological Risk Characterization Report
1992	Interim Measure Remediation System Installed at the Tank Farm and Eastern Parking Lot - Groundwater treatment and product recovery (RW-1 and RW-2) (operated ~1992 - 1994)
Dec-92	Second Phase II Supplemental Investigation Report
Apr-93	Martin Marietta acquires GE Aerospace
Oct-93	Phase III Remedial Action Plan (RAP)
1994	Completion of product recovery operations in Eastern Parking Lot (no product in wells RW-1 & RW-2)
Oct. 28, 1994	MassDEP classifies the site as Transition Tier IA site - Issues Permit #83052
Mar-95	Lockheed and Martin Marietta merge to form Lockheed Martin
Nov-95	MassDEP conditionally approves RAP soil and sediment remediation activities
Oct-96	MassDEP conditionally approves on-site groundwater remediation activities
Mar-97	MassDEP approves RAP modification to eliminate soil vapor extraction and treatment in Tank Farm Area
Jul-97	Conditional approval from MassDEP to proceed with a modified long term groundwater monitoring program
Jan-98	Wilmington Sediment Evaluation letter report
Feb-98	Letter Report presenting proposed change to the Phase III RAP
Mar-98	Request to change Tank K selected remedy from SVE to <i>in situ</i> chemical oxidation
Apr-98	Phase IV Remedy Implementation Plan (RIP) - Eastern Parking Lot and Tank K areas
Jun-98	MassDEP approves request for temporary solution based on technical impracticability and natural attenuation study
Aug-98	MassDEP approves change in selected remedy for Tank K Area pending pilot test results
Sep-98	Eastern Parking Lot Supplemental Investigation Report - Additional groundwater data for RIP
Feb-99	Groundwater Sampling Summary and Evaluation of Natural Attenuation Report
May-99	Tank K Chemical Oxidation Pilot Test letter report - Technology not able to achieve cleanup standards
Aug-99	Tier I Permit Extension Application Submittal 8/6/99
Oct-99	LMC contractually assigns environmental liability and MCP response action responsibility to TRC
Nov-99	MassDEP approves Supplemental Biosparging/SVE Pilot Test for Tank K Area
Nov-99	MassDEP approves Supplemental Soil Sampling in Eastern Parking Lot
Nov-99	MassDEP receives a petition to designate the site as a PIP site
Jan-00	MassDEP grants the Tier I permit Extension and Transfer Application
Jan-00	Tank K Phase III Addendum Report - Biosparging/SVE Pilot Test Results
Feb-00	MassDEP comment letter regarding 1998-1999 reports on groundwater remediation
Jan. 24, 2000	Phase III RAP Addendum for Tank K Area
Mar. 16, 2000	Phase III RAP Addendum for Eastern Parking Lot
Jun. 9, 2000	Conditional approval from MassDEP of Phase III RAP for Eastern Parking Lot
Jun. 9, 2000	Conditional approval from MassDEP of Phase III RAP for Tank K Area
Jul. 7, 2000	Phase IV RIP for Eastern Parking Lot / Drum Storage Area
Jul. 25, 2000	Phase IV RIP for Tank K Area
Aug. 31, 2000	Conditional approval from MassDEP of Phase IV RIP for Eastern Parking Lot Area
Oct. 31, 2000	Conditional approval from MassDEP of Phase IV RIP for Tank K Area
Nov. 7, 2000	Complete Eastern Parking Lot area soil excavation and disposal
Nov. 17, 2000	Public Involvement Plan issued by MADEP
Jan. 19, 2001	Phase IV As-Built and Final Inspection Report for Eastern Parking Lot / Drum Storage Area
Jan. 22, 2001	Eastern Parking Lot Interim Measure Completion Report
Feb. 2001	Tank K Biosparge/SVE System Startup
Mar. 20, 2001	Phase IV As-Built and Final Inspection Report for Tank K
Mar. 29, 2001	Conditional approval from MassDEP of Phase IV As-Built Final Inspection Report for Eastern Parking Lot
Mar. 29, 2001	Conditional approval from MassDEP of proposed work plan addendum for groundwater investigation
Mar.-Aug. 2001	Supplemental Groundwater Investigation
Jun. 11, 2001	Conditional approval from MassDEP of Phase IV As-Built Final Inspection Report for Tank K Area

Table 2-1
Site Characterization History and Regulatory Timeline
Former GE Facility, 50 Fordham Road, Wilmington, MA

Oct. 30, 2001	MassDEP approval of Comprehensive Review of Groundwater Data Report
Jan-02	Scope of Work - Stage II Environmental Risk Characterization for Outfalls 001 and 002
Feb. 2002	Tank Farm Pump-and-Treat System Decommissioned
Mar. 22, 2002	Phase III Remedial Action Plan Addendum for Groundwater
Jul-02	Tank Farm Interim Measure Completion Report
Jul. 12, 2002	Conditional approval from MassDEP of Phase III RAP Addendum for Groundwater
Aug. 16, 2002	Conditional approval from MassDEP of Stage II Environmental Risk Characterization Scope of Work
Nov-02	Phase IV Remedy Implementation Plan for Groundwater
Nov-02	Eastern Parking Lot Area Phase V Operations and Maintenance Report
Nov-02	Tank Farm Phase V Operations and Maintenance Report
Mar. 12, 2003	Conditional approval from MassDEP of Phase IV RIP for Groundwater
Mar. - Aug. 2003	Groundwater Pump-and-Treat System Installed - Start up in August 2003
Aug. 11, 2003	Revisions to the MCP; direct oversight no longer provided by MassDEP
Sept. 11, 2003	Phase IV As-Built and Final Inspection Report for Groundwater
Jan. 21, 2004	Part I - Stage II Environmental Risk Characterization and Part II - Phase IV RIP, Outfalls 001 and 002
Aug - Oct 2004	Remediation of Wetlands (Outfalls 001 and 002) August - September and Restoration in October 2004
Dec. 13, 2004	Phase IV As-Built Construction & Final Inspection Report & Partial (A-2) RAO for Outfalls 001 and 002
5-May-05	Release Abatement Measure (RAM) Plan - New Sewer Line System
Mar. 6, 2005	RAM Completion Report - New Sewer Line System
Apr. 20, 2006	Remedy Operation Status Opinion
Sep. & Nov. 2006	EZVI Injected into Open Boreholes at Tank Farm Area
Sep-07	Phase III RAP Addendum II for Groundwater
Sep-07	Modified Phase IV RIP for Groundwater
Sep-07	Phase IV As-Built Construction and Final Inspection Report for Groundwater
Oct-07	TRC Work Plan Evaluation of Emerging Chemicals and TICs in Groundwater
May-08	Work Plan - Vapor Intrusion Study
Jun-08	Groundwater Pump-and-Treat System Shutdown
Jun. 30, 2008	Tank K biosparge/SVE System Shutdown
Sep-08	TRC Work Plan Evaluation of Emerging Chemicals and TICs in Groundwater Addendum A
Jan.8, 2009	Notification to MassDEP of 120-day Reporting Condition for arsenic in groundwater above RCGW-1
Feb. 26, 2009	MassDEP issued Notice of Responsibility to Lockheed Martin and issued RTN 3-28282
Jul-09	Work Plan - Vapor Intrusion Study Addendum A
Oct. 28, 2009	Vapor Intrusion Sampling Report
Dec-09	Final Status Report for Outfalls 001 and 002 W.Q. Cert. (5-Year Post-Restoration Monitoring)
Jan. 8, 2010	Phase I Site Assessment Rpt, Completion Statement & Tier 1C Permit Application RTN 3-28282
Jul. 29, 2010	Vapor Intrusion Sampling Report
Nov. 9, 2010	Partial (A-2) RAO for the Tank K Area
Jun-11	RAM Plan for Building 3 and Oil House Demolition and B3 Soil Excavation/Disposal
Aug-11	RAM Plan Addendum Building 3 and Oil House Demolition and B3 Soil Excavation/Disposal
Oct-11	RAM Status Report Building 3 and Oil House Demolition and B3 Soil Excavation/Disposal
Jan. 6, 2012	Tier 1 Permit Mod. Transferring Environmental Liability from TRC to Lockheed Martin
Jan. 7, 2012	Interim Phase II Comprehensive Site Assessment for RTN3-28282
Mar-12	RAM Completion Report Building 3 and Oil House Demolition and B3 Soil Excavation/Disposal
Mar. 30, 2012	RTN 3-28282 Linked to RTN 3-0518
Sep-12	ROS Status Report
Mar. 13, 2013	T1 Minor Permit Modification - Change LSP of Record

Source:

Information listed 1968 through February 2000 taken from the Public Involvement Plan (PIP) (MassDEP 11/17/00). Subsequent information compiled from site historical files provided by CDM, TRC, and the MassDEP website. While this project timeline summary is detailed, it is not considered to be comprehensive.

Table 2-2
Operable Unit Summary
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Operable Unit	Description	Affected Media	Compounds of Concern	Regulatory Status
OU-1	Former Tank Farm source area and adjacent EPL	Vadose zone soils and shallow groundwater	Stoddard solvent LNAPL in groundwater and extractable petroleum hydrocarbons (EPH)-volatile petroleum hydrocarbons (VPH) in both soils and groundwater; associated arsenic	Open
OU-2	Former Tank Farm source area and down-gradient plume on- and off-property	Groundwater	CVOCs and 1,4-dioxane	Open
OU-3	Stormwater/Wastewater Outfalls 001 and 002	Sediment	Metals and petroleum hydrocarbons	Closed, Partial Class A-2 Response Action Outcome (RAO) (Submitted December 2004)
OU-4	Former Tank K source area and immediately down-gradient plume	Vadose zone soils and shallow groundwater	Gasoline related petroleum hydrocarbons Volatile Organic Compounds (VOCs)	Closed, Partial Class A-2RAO (Submitted November 9, 2010)

Table 3-1
Property Access Requirements
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Property/Owner	Owner	Activities
99 Concord Street, N. Reading, MA	International Family Church	Access needed for well rehabilitation activities, groundwater sampling, and walking access to the other properties and well locations in the wooded/wetland areas.
Stickney Well Road, N. Reading, MA	Town of N. Reading, MA	Access via the paved Stickney Well Road for AECOM and subcontractor equipment to the other properties in the wooded/wetland areas.
0 Furbish Pond Lane, N. Reading, MA	Town of N. Reading, MA	Access needed for well rehabilitation activities, groundwater sampling, and walking access to the other properties and well locations in the wooded/wetland areas. In addition, access via a pre-existing road on this property needed for AECOM and subcontractor equipment to the other properties in the wooded/wetland areas. The pre-existing road still exists and will require minor clearing to make it usable again.
#91 Concord Street, N. Reading, MA	Federal Express (formerly Coles Express property)	Possible access needed from this property to the wetlands for AECOM and subcontractor equipment to install and sample proposed AECOM well cluster AE-106
#71 Concord Street, N. Reading, MA (Assessor shows as #65)	Concord Street Realty Trust (DL Maher property)	Access needed to the grass area along Concord Street to install and sample proposed bedrock nested well pair STM8-R1/R2.
#87 Concord Street, N. Reading, MA	Howland Development (formerly Bard Med Systems)	Access needed to the wetland areas to the north and northwest of this property to install and sample proposed bedrock clusters AE-106 and AE-107.

Notes:

If the need for access to additional properties is identified, this will be addressed during execution of the Scope of Work in 2014.

Table 3-2
Monitoring Well Rehabilitation Summary
2013-2014 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Road, Wilmington, MA

Well	Location	Condition/Notes
BRW-1	Edge of EPL and Wetlands	9" Roadbox broken on side; has 7" steel casing inside box; three 2" PVC risers inside box that all feel loose (can move side to side freely); no bolts or bolt holes. Recommend replacing road box and installing large concrete pad.
BRW-1R1		
BRW-1R2		
BRW-1R3		
BRW-1R4		
EMW-10D (WE-10D)	EPL at edge of Wetlands	Soft bottom could be ~2.4 feet of silt in well (expected total depth 29 ft) - does not impact well screen for sampling but could redevelop to remove silt. Bolts do not tightly seal roadbox, may be able to retap threads; PVC casing is jagged but expansion plug provides a seal; Recommend attempt to retap bolt threads and seal lid; else recommend to replace roadbox and to cut PVC flat and resurvey TOC elevation; Redevelop to remove silt.
EMW-10R (WE-10R)		6" Roadbox; bolt holes are stripped and concrete pad has plants growing through. Needs gasket. Recommend to replace roadbox.
EMW-10S (WE-10S)		6" Roadbox; bolt holes are broken and concrete pad has plants growing through. Recommend to replace roadbox.
EMW-11D (WE-11D)		Roadbox not water tight as it is missing one bolt (broken dog ear) and one bolt is stripped; PVC casing is at an angle but expansion plug does provide a seal. Recommend to attempt repair/replace bolts; else replace roadbox and cut PVC flat and resurvey TOC elevation;
EMW-11R1 (WE-11R1)	EPL at edge of Wetlands	8" roadbox; has three 1" PVC risers inside each with PVC cap; has gasket; needs 3 new bolts; Recommend to attempt to replace bolts and secure the lid; if not possible then recommend to replace roadbox.
EMW-11R2 (WE-11R2)		
EMW-11R3 (WE-11R3)		8" Roadbox; 2" PVC riser; one of the three bolt hole ears is broken off; concrete pad has weeds growing through; Recommend to replace roadbox.
EMW-11S (WE-11S)		
GZA-103R1	Tank Farm	8" Roadbox is a water cleanout style fitting. Flush mount, located in grass. 3" steel casing with 2 - 0.5" PVC risers inside. PVC risers feel solid in position. Recommend to gauge wells to confirm depths, and if accurate, to replace roadbox with standard monitoring well roadbox. Consider redevelopment of the wells.
GZA-103R2		
GZA-105D	EPL	Bottom felt firm, but is shy of expected total depth of 26 ft bgs. Could be compacted silt or an inaccurate installation record. Road box in good condition; PVC casing cut at steep angle and is cracked. Roadbox is water tight so repair not required. Recommend to cut PVC down below crack to allow adding an expansion plug, and resurvey TOC elevation.
GZA-105R	EPL	8" Roadbox; 0.5" ID PVC riser; has two 0.5" plastic tubing inside of roadbox; has bolts, but bolt holes are stripped. Recommend to attempt retap threads to secure lid; if no luck then recommend to replace roadbox.
GZA-105S	EPL	7" Roadbox; 2" PVC riser cut at 45 degree angle; no expansion cap, but roadbox is water tight; Recommend to cut PVC flat and add an expansion plug, and resurvey of TOC elevation.
GZA-12	Tank F	Road box in good condition with expansion plug; Rehab not critical but could cut PVC down to install an expansion plug; Would require resurvey of TOC.
IP-13	Tank Farm	12" Roadbox in a 34" x 34" concrete pad; pad slightly cracked. Has one bolt; good condition. 8" steel casing inside; casing feels solid in position. Replace bolt to secure lid.
IP-14	Tank Farm	12" Roadbox in a 34" x 34" concrete pad; pad slightly cracked. Has no bolts; good condition. 8" steel casing inside; casing feels solid in position. Replace bolts to secure lid.
MW-5	Wetlands	3' tall steel guard pipe located in wetland in ~1-2' standing water. Marked with pink flagging. Has lock. Bottom of guard pipe corroded and able to lift off of well. 1.5" PVC riser. Recommend to replace outer casing; will need to install within outer surface casing or tube with standing water removed to allow for pouring concrete to hold locking casing in place.
PS-3	Wetlands	1' tall Skinny stickup casing located in wetland in less than 0.5' standing water. Has lock, but clasp is broken; fabricate/install locking cover.
PS-3S	Wetlands	6" tall Skinny stickup casing located in wetland in less than 0.5' standing water. Obstruction at 0.4 ft inside; attempt to remove obstruction; if unsuccessful - abandon point; if successful, fabricate/install a locking cover.
PS-8S	Wetlands	Skinny stickup located in wooded area. No standing water. Does not have a cover; fabricate/install locking cover.

Table 3-2
Monitoring Well Rehabilitation Summary
2013-2014 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Road, Wilmington, MA

Well	Location	Condition/Notes
PS-8M	Wetlands	Skinny stickup located in wooded area. No standing water. Does not have a cover; fabricate/install locking cover.
PS-8D	Wetlands	Skinny stickup located in wooded area. No standing water. Does not have a cover; fabricate/install locking cover.
PZ-2S	EPL - Tank Farm	LNAPL gauging well. 4-inch dia. PVC. Road box in good condition but no bolts. Well sealed with expansion plug. Recommend attempt to replace bolts to secure lid; if no luck then recommend to replace roadbox.
PZ-9D	Wetland north of Bldg 2	3' tall steel guard pipe with broken cap and no lock. Three 1" PVC risers inside of pipe, only 1 has a PVC cap. Poison ivy around well. Recommend to replace cap and lock, and install PVC caps/expansion plugs.
PZ-9R		
PZ-9S		
STM-8D	Concord Rd	8" Roadbox located in grass 20' east of fire hydrant. Good condition, but bolts rusted, should be replaced. No concrete pad. Four 1" PVC risers within a 4" steel casing. One of the risers does not have a cap or label. STM-8M has a 1" riser that is outside of the 4" steel casing, but within the roadbox. Recommend to attempt to retap or replace bolts; else replace road box and install concrete pad.
STM-8M		
STM-8R		
STM-8S		
STM-10R1	Concord Rd	7" Roadbox; fair condition, no bolts or concrete pad. Three 1" PVC risers within roadbox. All have expansion plugs. Recommend to replace roadbox.
STM-10R2		
STM-10S		
TRC-101	EPL	6" Roadbox; has 1" PVC riser; no bolts; has one broken bolt ear and concrete pad is cracked to the subsurface. Recommend to replace roadbox.
TRC-102	EPL	6" Roadbox; has 1" PVC riser; no bolts; has one broken bolt ear and concrete pad is cracked to the subsurface. Recommend to replace roadbox.
TRC-103	EPL	6" Roadbox; has 1" PVC riser; roadbox cover is broken; no bolts and concrete pad is cracked to the subsurface. Recommend to replace roadbox.
TRC-401R-B	EPL	8" roadbox; has gasket and bolts; one bolt hole stripped 3/8"; has 4" steel casing with expansion plug that provides seal on the well; Recommend try to retap threads, else replace roadbox.
<u>Notes:</u> Evaluate each MW roadbox prior to commencing removal. Permanent well casings and grout around PVC may impact ability to remove roadbox without damaging PVC. Re-evaluate if significant damage to PVC well could occur. Concrete pads to be 2' x 2' x minimum 6" thick; wire mesh bar to be set in prior to pouring concrete for reinforcement. Pads are to be poured in such a manner to minimize potential plow damage, while not allowing for puddling over the pad. Pads set in grass or dirt areas will be set with a 2' x 2' wood form (with cut 2x4s)		

Table 3-3
Rationale of Proposed 2013-2015 Investigation Activities
2013-2014 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Location ID	Activities	Objective/Rationale
General Mobilization	Site Preparation - Will consist of grubbing and grading access pathways through the wooded area up to the entry points to the wetlands. - Access roads through the wetlands will be installed by laying down and stacking swamp mats. - Setup of facilities; including decontamination area, portable restroom, storage area for drums, core boxes, FLUTE reels, etc.	Prepare site for proposed work scope.
Building 1 Mobilization	Building 1 Drilling and Well Installation - Conduct electric utility and geophysics scans beneath the floor for utility clearance prior to drilling. - Conduct pumping test at AE-23R. Stress well by pumping and screen purge water for possible evidence of DNAPL using dye or other methods. - Install one bedrock well to a depth of approximately 55 feet, outside and to the South of Building 1. This well will be paired with the overburden well AE-21. - Install one bedrock (55 feet deep) and one overburden well (30 feet deep) pair in the high bay room to the North of AE-23R/S. - Install one bedrock (55 feet deep) and one overburden well (30 feet deep) pair in Building 1 between AE-23R/S and the Tank Farm. - Install two angled borings from the high bay room to reach soil beneath the southwest corner room. Complete one boring as an overburden well (30 feet deep) and one boring as a bedrock well (55 feet deep). - Cascade will use a compressor to perform well development for the open bedrock boreholes using the air-lift method. Cascade will use a surge block and pump to develop overburden wells. - Cascade will perform well development on each overburden well after the PVC has been installed and well materials have had time to settle (minimum of 24-48 hours).	Evaluate nature and extent of CVOC impacts within overburden and bedrock groundwater beneath Building 1. Secondary objective is to evaluate whether a source of CVOCs exists beneath the Building.
Mobilization 1	Initial Boring and Well Installation - Drilling activities will be completed along Transect A, located on the eastern edge of the Eastern Parking Lot. The initial boring will consist of drilling through overburden to the bedrock surface and then coring into bedrock to 175 feet below surface grade. - Rock core samples will be collected at high frequency for discrete fracture network (DFN) analysis. - Stone Environmental on-site to crush and containerize rock samples. - A bedrock boring will be installed along Transect C, located on Concord Street in the vicinity of existing well STM-8. This boring will consist of two nested PVC wells installed to a maximum depth of 100 feet below surface grade. - Cascade will use a compressor to perform well development for the open bedrock boreholes using the air-lift method. Cascade will use a surge block and pump to develop overburden wells. - A blank FLUTE liner will be installed in the open boreholes following drilling and development. A FLUTE technician will be on-site to instruct Cascade how to install a liner in the initial well. Temporary scaffolding, a 5-foot long PVC extension and heavy drilling mud will be used for each bedrock well to install the FLUTE liner. - Four nested overburden wells will be installed in the vicinity of the initial boring. Each nested well will have three separate PVC wells installed at three depths to a maximum depth of 40 feet below surface grade. - Cascade will perform well development on each well after the PVC has been installed and well materials have had time to settle (minimum of 24-48 hours).	Evaluate extent of CVOC impacts within bedrock fractures immediately downgradient of Tank Farm source area; including evaluation of vertical "zone of irrelevance". Results from this rock core DFN hole will be used to evaluate whether the proposed maximum drilling depth of 175 ft bgs is adequate, or if this hole and other proposed bedrock holes in later mobilizations need to be drilled deeper. Install overburden wells to complete the shallow portion of the monitoring well "fence" (Transect A). Also, the bedrock boring near STM-8 along Concord Street will be used to complete a monitoring well "fence" (Transect C). Each "fence" will be used for future mass flux/mass discharge evaluations.
Mobilization 2	Eastern Parking Lot Bedrock Wells - Drilling activities along Transect A will be completed with the installation of four bedrock wells. - The drilling depth will be determined using information gained from the initial well installation and testing. - Cascade will use a compressor to perform well development for the open bedrock boreholes using the air-lift method. - Cascade will install a blank FLUTE liner in each borehole following well development. Temporary scaffolding, a 5-foot long PVC extension and heavy drilling mud will be used for each bedrock well to install the FLUTE liner.	Once the maximum drilling depth has been confirmed, based on results from Mobilization #1, install additional bedrock wells to complete the bedrock portion of the monitoring well "fence" (Transect A). The "fence" will be used for future mass flux and mass discharge evaluations.
Mobilization 3	Wetland Wells - Two nested overburden wells will be installed along Transect B, located in the vicinity of existing well TRC-301R. Each nested well will have three separate PVC wells installed at three depths to a maximum depth of 40 feet below surface grade. - Two bedrock wells will be cored adjacent to the two overburden wells. Rock samples will be collected from one for DFN analysis. - One nested overburden well will be installed East of Transect B. The well will be constructed with three separate PVC wells, installed at three depths to a maximum of 40 feet below surface grade. - Cascade will use a compressor to perform well development for the open bedrock boreholes using the air-lift method. Cascade will use a surge block and pump to develop overburden wells. - Cascade will perform well development on each overburden well after the PVC has been installed and the well materials have had time to settle (minimum of 24-48 hours). - Cascade will install a blank FLUTE liner in each bedrock borehole following well development. Temporary scaffolding and a 10 foot long PVC extension will be used for each bedrock well to install the FLUTE liner.	Install "fence" (Transect B) of overburden and bedrock monitoring wells in wetlands near existing well TRC-301R to be used for future mass flux and mass discharge evaluations. Install additional overburden well cluster in wetlands along the mid-point of the plume. Objective of this additional well cluster is to better define this portion of the plume along the southern side.
Mobilization 4A	Borehole Testing - FLUTE will remove the blank liner from the first borehole in the morning. - Hager-Richter will perform borehole geophysics on the first hole in the afternoon. - In the same afternoon, FLUTE will mobilize to next hole, pull the liner and perform a transmissivity profile on the second hole. - Both FLUTE and Hager-Richter will continue this process for all eight new bedrock borehole locations in addition to TRC-301R.	Conduct testing to identify and evaluate transmissive bedrock fractures that may represent contaminant migration pathways. Also, collect data on hydraulic properties of these fractures to assist with the future mass flux and mass discharge evaluations.
Mobilization 4B	Borehole Testing Waterloo Geophysics will perform ALS temperature profiling on all eight new bedrock borehole locations in addition to TRC-301R. This testing will be completed with the 5-ft extension, 5-ft scaffolding and blank FLUTE liners installed (with heavy mud at the bottom).	
Mobilization 5	Bedrock Well Completion Cascade and FLUTE will complete all bedrock wells by installing either PVC nested wells or FLUTE wells at each location.	Once all preliminary data collected is evaluated, determine the optimal locations to screen bedrock boreholes for future groundwater sampling and head measurements.

Table 3-4
Mobilization 1 - Transect A (EPL) and Transect C (Concord St) Investigation Summary
2013-2015 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Location ID	Completion Depth*	Media	Sample Depth	No. of Samples	Analyses	Procedures
General Preparation Work:						
Cascade to set up decontamination pad for drilling tool decon. Setup drum staging area.						
AE-102R (MW-Bedrock) Eastern Parking Lot	Estimated 175 feet, leave as open borehole sealed by FLUTE liner.	Bedrock	Samples will be collected at high frequency from bedrock surface to completion depth. Expected interval from 40-175 ft.	135	Discrete fracture network (DFN); physical parameter analysis (dry bulk density, sepecific gravity, total porosity, TOC, hydraulic conductivity) to be conducted on an estimated 4 samples, or at a representative spacing based on fracture conditions encountered.	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to will advance a 10 inch borehole 5 feet into competant bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Stone Environmental on-site to crush and containerize rock samples for analysis. • Cascade to develop open boreholes using air lift methods. • FLUTE on-site to instruct Cascade how to install blank liners in open borehole. Liners installed after development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTE liner.
AE-101S AE-101M AE-101D (MW - Overburden Nested Triplet) Eastern Parking Lot	Estimated 40 feet, 5-ft or 10-ft screen intervals estimated from 10-20 ft, 20-30 ft, and 30-40 ft	Soil	Two overburden soil samples to be collected per location; if no contamination evident, first sample from just above water table, and second just above bedrock	2	VOCs, EPH/VPH, RCRA Metals	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-102S AE-102M AE-102D (MW - Overburden Nested Triplet) Eastern Parking Lot	Estimated 40 feet, 5-ft or 10-ft screen intervals estimated from 10-20 ft, 20-30 ft, and 30-40 ft	Soil	Two overburden soil samples to be collected per location; if no contamination evident, first sample from just above water table, and second just above bedrock	2	VOCs, EPH/VPH, RCRA Metals	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-103S AE-103M AE-103D (MW - Overburden Nested Triplet) Eastern Parking Lot	Estimated 40 feet, 5-ft or 10-ft screen intervals estimated from 10-20 ft, 20-30 ft, and 30-40 ft	Soil	Two overburden soil samples to be collected per location; if no contamination evident, first sample from just above water table, and second just above bedrock	2	VOCs, EPH/VPH, RCRA Metals	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-104S AE-104M AE-104D (MW - Overburden Nested Triplet) Eastern Parking Lot	Estimated 40 feet, 5-ft or 10-ft screen intervals estimated from 10-20 ft, 20-30 ft, and 30-40 ft	Soil	Two overburden soil samples to be collected per location; if no contamination evident, first sample from just above water table, and second just above bedrock	2	VOCs, EPH/VPH, RCRA Metals	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
STM-8 (MW - Bedrock Nested Couplet) Concord St	Estimated 100 feet, leave as open borehole sealed by FLUTE liner.	Bedrock	Two overburden soil samples to be collected per location; if no contamination evident, first sample from just above water table, and second just above bedrock	2	VOCs, EPH/VPH, RCRA Metals	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to will advance a 10 inch borehole 5 feet into competant bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using air lift methods. • Cascade to install blank FLUTE liner following development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTE liner.
Notes: ID - identification NA - Not applicable No. of samples listed does not include QA/QC samples MW - Monitoring Well Soil sample intervals for laboratory analyses may be adjusted based on observed field conditions * - Depths may be adjusted based on depth to water and depth to bedrock						

Table 3-5
Building 1 Investigation Summary
2013-2014 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Location ID	Completion Depth*	Media	Sample Depth	No. of Samples	Analyses	Procedures
General Preparation Work:						
Geophysics scan for sub-floor indoor utilities. Electric utility clearance. Cascade to setup exhaust fan to ventilate work area from drill rig exhaust fumes.						
AE-2R (MW-Bedrock) South of Building 1	Estimated 45-55 feet, may leave as 10-ft open borehole or install 2-inch PVC well.	Soil / Bedrock	Three overburden soil samples; if no impacts evident: 1) first sample from boring 2) above WT and 3) from shallowest non-impacted depth	3	VOCs (EPA method 8260B); MassDEP EPH/VPH; RCRA Metals	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump.
AE-25R (MW - Bedrock) Building 1 High Bay	Estimated 45-55 feet, may leave as 10-ft open borehole or install 2-inch PVC well.	Soil / Bedrock	Three overburden soil samples; if no impacts evident: 1) first sample from boring 2) above WT and 3) from shallowest non-impacted depth	0	VOCs (EPA method 8260B); MassDEP EPH/VPH; RCRA Metals	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump.
AE-25S (MW - Overburden) Building 1 High Bay	Estimated 30 feet, screen interval estimated from 20-30 ft	Soil	Soil samples to be collected from the bedrock well at each well pair.	3	NA	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-26R (MW - Bedrock) Building 1	Estimated 45-55 feet, may leave as 10-ft open borehole or install 2-inch PVC well.	Soil / Bedrock	Three overburden soil samples; if no impacts evident: 1) first sample from boring 2) above WT and 3) from shallowest non-impacted depth	0	VOCs (EPA method 8260B); MassDEP EPH/VPH; RCRA Metals	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump.
AE-26S (MW - Overburden) Building 1	Estimated 30 feet, screen interval estimated from 20-30 ft	Soil	Soil samples to be collected from the bedrock well at each well pair.	3	NA	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-27R (angled MW - Bedrock) Building 1	Estimated 45-55 feet, may leave as 10-ft open borehole or install 2-inch PVC well.	Soil / Bedrock	Three overburden soil samples; if no impacts evident: 1) first sample from boring 2) above WT and 3) from shallowest non-impacted depth	0	VOCs (EPA method 8260B); MassDEP EPH/VPH; RCRA Metals	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump.
AE-27S (angled MW - Overburden) Building 1	Estimated 30 feet, screen interval estimated from 20-30 ft	Soil	Soil samples to be collected from the bedrock well at each well pair.	3	NA	• Soft dig to 3-5 feet below grade for utility clearance. • Cascade to develop overburden wells a minimum of 24-48 hours after installation.
Notes ID - identification NA - Not applicable No. of samples listed does not include QA/QC samples MW - Monitoring Well * - Depths may be adjusted based on depth to water and depth to bedrock						

Table 3-6
Mobilization 2 - Transect A Well Completion Summary
2013-2015 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Location ID	Completion Depth*	Media	Sample Depth	No. of Samples	Analyses	Procedures
General Preparation Work:	Cascade to set up decontamination pad for drilling tool decon. Setup drum staging area.					
AE-100R (MW-Bedrock) Eastern Parking Lot	Estimated 175 feet, leave as open borehole sealed by FLUTe liner.	Bedrock	No sampling expected	0	NA	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump. • Cascade to install blank FLUTe liner following development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTe liner.
AE-101R (MW - Bedrock) Eastern Parking Lot	Estimated 175 feet, leave as open borehole sealed by FLUTe liner.	Bedrock	No sampling expected	0	NA	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump. • Cascade to install blank FLUTe liner following development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTe liner.
AE-103R (MW - Bedrock) Eastern Parking Lot	Estimated 175 feet, leave as open borehole sealed by FLUTe liner.	Bedrock	No sampling expected	0	NA	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump. • Cascade to install blank FLUTe liner following development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTe liner.
AE-104R (MW - Bedrock) Eastern Parking Lot	Estimated 175 feet, leave as open borehole sealed by FLUTe liner.	Bedrock	No sampling expected	0	NA	• Soft dig to 5 feet below grade for utility clearance using vacuum excavator. • Cascade to will advance a 10 inch borehole 5 feet into competent bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using hoist and submersible pump. • Cascade to install blank FLUTe liner following development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTe liner.
Notes ID - Identification NA - Not applicable No. of samples listed does not include QA/QC samples MW - Monitoring Well * - Depths may be adjusted based on depth to water and depth to bedrock						

Table 3-7
Mobilization 3 - Transect 3 (Wetlands) Investigation Summary
2013-2015 Supplemental Investigation
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Location ID	Completion Depth*	Media	Sample Depth	No. of Samples	Analyses	Procedures
General Preparation Work:	Access roads constructed using swamp matts. Cascade to set up decontamination pad for drilling tool decon. Setup drum staging area.					
TRC-301R (Existing Bedrock MW - Wetlands)	open borehole is grouted up to approximately 105 feet; to seal with FLUTE liner	NA	NA	NA	NA	• Cascade to re-develop open borehole well using air lift methods and/or submersible pump. • Cascade to install blank liner in open borehole after development.
AE-105R (MW-Bedrock) Wetlands	Estimated 175 feet, leave as open borehole sealed by FLUTE liner.	Bedrock	Samples to be collected at high frequency from bedrock surface to completion depth. Expected interval from 60-175 ft.	115	Discrete fracture network (DFN); physical parameter analysis (dry bulk density, sepecific gravity, total porosity, TOC, hydraulic conductivity) to be conducted on an estimated 4 samples, or at a representative spacing based on fracture conditions encountered.	• Following coring and screening of the weathered bedrock zone, Cascade to will advance a 10 inch borehole 5 feet into competant bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Stone Environmental on-site to crush and containerize rock samples for analysis. • Cascade to develop open boreholes using air lift methods and/or submersible pump. • Cascade to install blank liners in open borehole after development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTE liner.
AE-105S AE-105M AE-105D (MW - Overburden Nested Triplet) Wetlands	Estimated 60 feet, screen intervals estimated from 10-15 ft, 35-40 ft, and 55-60 ft	Soil	Two samples from below water table to top of bedrock. Collected in regular intervals. One sample within PEAT layer. Samples not collected in soil with evidence of impact.	3	total organic carbon (TOC)	• Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-106R (MW-Bedrock) Wetlands	Estimated 175 feet, leave as open borehole sealed by FLUTE liner.	Bedrock	No sampling expected	-----	-----	• Following coring and screening of the weathered bedrock zone, Cascade to will advance a 10 inch borehole 5 feet into competant bedrock, allowing for a 6 inch permanent steel casing to be grouted inside the borehole to seal off the overburden. Grout will cure for 24 hours prior to coring. • Cascade will core into bedrock using a 4.83 inch inside diameter core barrel. • Cascade to develop open boreholes using air lift methods and/or submersible pump. • Cascade to install blank liners in open borehole after development. • 5 foot high scaffolding and 5 foot long PVC extension added to bedrock wells in order to install FLUTE liner.
AE-106S AE-106M AE-106D (MW - Overburden Nested Triplet) Wetlands	Estimated 60 feet, screen intervals estimated from 10-15 ft, 35-40 ft, and 55-60 ft	Soil	Two samples from below water table to top of bedrock. Collected in regular intervals. One sample within PEAT layer. Samples not collected in soil with evidence of impact.	3	fraction organic carbon (fOC)	• Cascade to develop overburden wells a minimum of 24-48 hours after installation.
AE-107S AE-107M AE-107D (MW - Overburden Nested Triplet) Wetlands	Estimated 60 feet, screen intervals estimated from 10-15 ft, 35-40 ft, and 55-60 ft	Soil	Two samples from below water table to top of bedrock. Collected in regular intervals. One sample within PEAT layer. Samples not collected in soil with evidence of impact.	3	fraction organic carbon (fOC)	• Cascade to develop overburden wells a minimum of 24-48 hours after installation.
Notes ID - identification NA - Not applicable No. of samples listed does not include QA/QC samples MW - Monitoring Well * - Depths may be adjusted based on depth to water and depth to bedrock						

Table 3-8

Mobilizations 4A and 4B - Borehole Geophysics, FLUTE Transmissivity Profiling, and ALS Temperature Profiling Summary
2013-2015 Supplemental Investigation Activities
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Activity	Location ID	Procedure
General Preparation Work:	Cascade will construct temporary scaffolding 10 feet high at each borehole location. Each borehole will have a blank FLUTE liner in place prior to testing.	
Mobilization 4A		
Borehole Geophysics	AE-100R, AE-101R, AE-102R, AE-103R, AE-104R, AE-105R, AE-106R, STM-8R1/R2, and TRC-301R	• FLUTE will remove the blank liner from two boreholes to allow work on two at one time. • Hagar Richter will perform the following borehole geophysical test: (1) acoustic caliper (2) fluid temperature (3) fluid resistivity (4) single point resistance (5) spontaneous potential (6) natural gamma (7) acoustic borehole televiewer (8) optical televiewer (9) heat pulse flow meter [ambient and low flow pumping]
FLUTE Transmissivity Profiling	AE-100R, AE-101R, AE-102R, AE-103R, AE-104R, AE-105R, AE-106R, STM-8R1/R2, and TRC-301R	• FLUTE will perform FLUTE transmissivity profiling on the second borehole that has had the blank liner removed. This will be done while Hagar Richter is working on the first borehole. After testing, the two companies will swap locations. Leap-frogging will continue until all borehole testing is complete. • FLUTE will re-install the blank liner following all down-hole testing.
Mobilization 4B		
ALS Temperature Profiling	AE-100R, AE-101R, AE-102R, AE-103R, AE-104R, AE-105R, AE-106R, STM-8R1/R2, and TRC-301R	• Waterloo Geophysics will perform ALS temperature profiling. This test will be completed with the blank FLUTE liner in place.
Notes ID - identification NA - Not applicable No. of samples listed does not include QA/QC samples MW - Monitoring Well * - Depths may be adjusted based on depth to water and depth to bedrock		

Table 3-9a
Groundwater Sampling Summary - Initial 2014 Round
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/U SEPA Method 8260C)	1,4-dioxane (SW846/USEPA Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	Isotopic Analysis: O ¹⁶ /O ¹⁸ , H ¹ /H ² and S ³⁴ /S ³⁶
Building 1	AE-01I	N	Overburden	2	WG				
Building 1	AE-01S	N	Overburden	2	WG				
Building 1	AE-02I	N	Overburden	2	WG				
Building 1	AE-02R	Y	Bedrock	2	WG	1	1	1	
Building 1	AE-23R	N	Bedrock	2	WG	1	1	1	
Building 1	AE-23S	N	Overburden	2	WG	1	1	1	
Building 1	AE-24	N	Overburden	2	WG	1	1	1	
Building 1	AE-25R	Y	Bedrock	2	WG	1	1	1	
Building 1	AE-25S	Y	Overburden	2	WG	1	1	1	
Building 1	AE-26R	Y	Bedrock	2	WG	1	1	1	
Building 1	AE-26S	Y	Overburden	2	WG	1	1	1	
Building 1	AE-27R	Y	Bedrock, Angled	2	WG	1	1	1	
Building 1	AE-27S	Y	Overburden, Angled	2	WG	1	1	1	
Building 1	GZA-101R	N	Bedrock	0.5	WG				
Building 1	GZA-12	N	Overburden	2	WG				
Building 1	Pumped Well	N	Bedrock	2 (or open)	WG	3		1	
Concord Street	STM-8D	N	Overburden	0.75	WG				
Concord Street	STM-8M	N	Overburden	0.75	WG				
Concord Street	STM-8R	N	Bedrock	1.5	WG	1		1	
Concord Street	STM-8R1	Y	Bedrock	1.5	WG	1		1	
Concord Street	STM-8R2	Y	Bedrock	1.5	WG	1		1	
Concord Street	STM-8S	N	Overburden	0.75	WG				
EPL Area	AE-03	N	Overburden	2	WG				
EPL Area	AE-04	N	Overburden	2	WG				
EPL Area	GZA-105D	N	Overburden	1.5	WG				
EPL Area	GZA-105S	N	Overburden	1.5	WG				
EPL Area	TRC-102	N	Overburden	1.25	WG				
LTGMP	EMW-10D	N	Overburden	2	WG				
LTGMP	EMW-10R	N	Bedrock	2	WG				
LTGMP	EMW-11D	N	Overburden	2	WG				
LTGMP	EMW-11R1	N	Bedrock	0.75	WG				
LTGMP	EMW-11R2	N	Bedrock	0.75	WG				
LTGMP	EMW-11R3	N	Bedrock	0.75	WG				
LTGMP	TRC-402	existing?	Overburden	2	WG				
LTGMP	TRC-403	existing?	Overburden	2	WG				
Source Control - Downgradient Wetland Wells	GZA-14	N	Overburden	2	WG				
Source Control - Downgradient Wetland Wells	GZA-14A	N	Overburden	2	WG				
Source Control - Downgradient Wetland Wells	MW-4	N	Overburden	1.5	WG				
Source Control - Downgradient Wetland Wells	MW-4A	N	Overburden	1.5	WG				
Source Control - Downgradient Wetland Wells	MW-5	N	Overburden	1.5	WG				
Source Control - Downgradient Wetland Wells	MW-7	N	Overburden	1.5	WG				
Source Control - Downgradient Wetland Wells	PS-1D	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-1M	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-1S	N	Overburden	0.62	WG				

Table 3-9a
Groundwater Sampling Summary - Initial 2014 Round
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/U SEPA Method 8260C)	1,4-dioxane (SW846/USEPA Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	Isotopic Analysis: O ¹⁶ /O ¹⁸ , H ¹ /H ² and S ³⁴ /S ³⁶
Source Control - Downgradient Wetland Wells	PS-2D	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-2M	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-2S	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-3	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-4	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-5D	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-5S	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-8D	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-8M	N	Overburden	0.62	WG				
Source Control - Downgradient Wetland Wells	PS-8S	N	Overburden	0.62	WG				
Source Control - Onsite	IP-1R2	N	Bedrock	2	WG				
Source Control - Onsite	TRC-401R	N	Bedrock	2	WG				
Transect A	AE-100R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-100R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-100R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-100R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-100R-E	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-101D	Y	Overburden	1.5	WG	1		1	
Transect A	AE-101M	Y	Overburden	1.5	WG	1		1	
Transect A	AE-101R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-101R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-101R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-101R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-101R-E	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-101S	Y	Overburden	1.5	WG	1		1	
Transect A	AE-102D	Y	Overburden	1.5	WG	1		1	1
Transect A	AE-102M	Y	Overburden	1.5	WG	1		1	
Transect A	AE-102R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-102R-B	Y	Bedrock	FLUTE	WG	1		1	1
Transect A	AE-102R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-102R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-102R-E	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-102S	Y	Overburden	1.5	WG	1		1	1
Transect A	AE-103D	Y	Overburden	1.5	WG	1		1	
Transect A	AE-103M	Y	Overburden	1.5	WG	1		1	
Transect A	AE-103R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-103R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-103R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-103R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-103R-E	Y	Bedrock	FLUTE	WG	1		1	

Table 3-9a
Groundwater Sampling Summary - Initial 2014 Round
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/U SEPA Method 8260C)	1,4-dioxane (SW846/USEPA Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	Isotopic Analysis: O ¹⁶ /O ¹⁸ , H ¹ /H ² and S ³⁴ /S ³⁶
Transect A	AE-103S	Y	Overburden	1.5	WG	1		1	
Transect A	AE-104D	Y	Overburden	1.5	WG	1		1	
Transect A	AE-104M	Y	Overburden	1.5	WG	1		1	
Transect A	AE-104R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-104R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-104R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-104R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-104R-E	Y	Bedrock	FLUTE	WG	1		1	
Transect A	AE-104S	Y	Overburden	1.5	WG	1		1	
Transect B	AE-105D	Y	Overburden	1.5	WG	1		1	1
Transect B	AE-105M	Y	Overburden	1.5	WG	1		1	1
Transect B	AE-105R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-105R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-105R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-105R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-105R-E	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-105S	Y	Overburden	1.5	WG	1		1	1
Transect B	AE-106D	Y	Overburden	1.5	WG	1		1	1
Transect B	AE-106M	Y	Overburden	1.5	WG	1		1	1
Transect B	AE-106R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-106R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-106R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-106R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-106R-E	Y	Bedrock	FLUTE	WG	1		1	
Transect B	AE-106S	Y	Overburden	1.5	WG	1		1	1
Transect B	AE-107D	Y	Overburden	1.5	WG	1		1	
Transect B	AE-107M	Y	Overburden	1.5	WG	1		1	
Transect B	AE-107S	Y	Overburden	1.5	WG	1		1	
Transect B	TRC-301R-A	Y	Bedrock	FLUTE	WG	1		1	
Transect B	TRC-301R-B	Y	Bedrock	FLUTE	WG	1		1	
Transect B	TRC-301R-C	Y	Bedrock	FLUTE	WG	1		1	
Transect B	TRC-301R-D	Y	Bedrock	FLUTE	WG	1		1	
Transect B	TRC-301R-E	Y	Bedrock	FLUTE	WG	1		1	
EPL, Concord St, Wetlands:						64	10	64	9
Bldg 1:						10	10	10	0
Pumped Well						3	0	1	0
Totals:						77	20	75	9

Notes:

Table 3-9b
Groundwater and Surface Water Sampling Summary - October 2014
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/U SEPA Method 8260C)	1,4-dioxane (SW846/USEPA Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	CSIA: 13C/12C ratio for PCE, TCE, Cis-1,2-DCE, VC	Isotopic Analysis: O ¹⁶ /O ¹⁸ H ¹ /H ² and S ³⁴ /S ³⁶	VPH (MassDEP-VPH-04-1.1 Revision 1)	EPH and polycyclic aromatic hydrocarbons (PAH) (MassDEP-EPH-04-1.1 Revision 1) (on-site wells only)	Total As, Fe, Mn (SW846/USEPA Method 6010C)	Dissolved As, Fe, Mn (field filtered) (SW846/USEPA Method 6010C)	Chloride (USEPA 300.0)	Nitrite	Nitrate (USEPA 300.0)	Sulfate (USEPA 300.0)	Sulfide	Total organic carbon (SW-846 9060A)	Methane/ethane/ethene (Microseeps AM20Gax)	Dissolved hydrogen	Ferrous iron and manganese field test kits	Microbial Analysis: Quantaray (Microbial Insights)
Concord Street	STM-8D	N	Overburden	0.75	WG	1	1	1		1														
Concord Street	STM-8M	N	Overburden	0.75	WG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Concord Street	STM-8R	N	Bedrock	1.5	WG	1	1	1																
Concord Street	STM-8R1	Y	Bedrock	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Concord Street	STM-8R2	Y	Bedrock	1.5	WG	1	1	1																
Concord Street	STM-8S	N	Overburden	0.75	WG	1	1	1	1	1														
EPL Area	AE-03	N	Overburden	2	WG	1		1			1	1	1	1	1	1	1	1	1	1	1	1	1	1
EPL Area	AE-04	N	Overburden	2	WG	1		1			1	1	1	1	1									
EPL Area	GZA-105D	N	Overburden	1.5	WG	1		1			1	1	1	1										
EPL Area	GZA-105S	N	Overburden	1.5	WG	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
EPL Area	TRC-102	N	Overburden	1.25	WG	1		1			1	1	1	1	1									
LTGMP	EMW-10D	N	Overburden	2	WG	1		1																
LTGMP	EMW-10R	N	Bedrock	2	WG	1		1																
LTGMP	EMW-11D	N	Overburden	2	WG	1		1																
LTGMP	EMW-11R1	N	Bedrock	0.75	WG	1		1																
LTGMP	EMW-11R2	N	Bedrock	0.75	WG	1		1																
LTGMP	EMW-11R3	N	Bedrock	0.75	WG	1		1																
LTGMP	TRC-402	existing?	Overburden	2	WG	1		1																
LTGMP	TRC-403	existing?	Overburden	2	WG	1		1																
Source Control - Downgradient Wetland Wells	GZA-14	N	Overburden	2	WG	1		1			1	1	1	1										
Source Control - Downgradient Wetland Wells	GZA-14A	N	Overburden	2	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-4	N	Overburden	1.5	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-4A	N	Overburden	1.5	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-5	N	Overburden	1.5	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-7	N	Overburden	1.5	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-1D	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-1M	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-1S	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-2D	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-2M	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-2S	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-3	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-4	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-5D	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-5S	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-8D	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-8M	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-8S	N	Overburden	0.62	WG	1		1																
Source Control - Onsite	IP-1R2	N	Bedrock	2	WG	1		1																
Source Control - Onsite	TRC-401R	N	Bedrock	2	WG	1		1																
Surface Water	Ipswich River (at expected discharge pt.)	NA	NA	--	WS	1		1																
Surface Water	Ipswich River (downstream of discharge pt.)	NA	NA	--	WS	1		1																
Surface Water	Ipswich River (upstream of discharge pt.)	NA	NA	--	WS	1		1																
Surface Water	Wetlands near AE-102	NA	NA	--	WS	1		1		1														
Surface Water	Wetlands near AE-105	NA	NA	--	WS	1		1		1														
Surface Water	Wetlands near AE-106	NA	NA	--	WS	1		1		1														
Surface Water	Wetlands near AE-107	NA	NA	--	WS	1		1																
Transect A	AE-100R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-100R-B	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-100R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-100R-D	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-100R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101D	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-101M	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-101R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101R-B	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101R-D	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101S	Y	Overburden	1.5	WG	1	1	1																

Table 3-9b
Groundwater and Surface Water Sampling Summary - October 2014
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/U SEPA Method 8260C)	1,4-dioxne (SW846/USEP A Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	CSIA: 13C/12C ratio for PCE, TCE, Cis-1,2-DCE, VC	Isotopic Analysis: O ¹⁶ /O ¹⁸ H ¹ /H ² and S ³⁴ /S ³⁶	VPH (MassDEP-VPH-04-1.1 Revision 1)	EPH and polycyclic aromatic hydrocarbons (PAH) (MassDEP-EPH-04-1.1 Revision 1) (on-site wells only)	Total As, Fe, Mn (SW846/USEPA Method 6010C)	Dissolved As, Fe, Mn (field filtered) (SW846/USE PA Method 6010C)	Chloride (USEPA 300.0)	Nitrite	Nitrate (USEPA 300.0)	Sulfate (USEPA 300.0)	Sulfide	Total organic carbon (SW-846 9060A)	Methane/ethane/ethene (Microseeps AM20Gax)	Dissolved hydrogen	Ferrous iron and manganese field test kits	Microbial Analysis: Quantaray (Microbial Insights)
Transect A	AE-102D	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-102M	Y	Overburden	1.5	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect A	AE-102R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102R-B	Y	Bedrock	FLUTE	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect A	AE-102R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102R-D	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102S	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-103D	Y	Overburden	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect A	AE-103M	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-103R-A	Y	Bedrock	FLUTE	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect A	AE-103R-B	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-103R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-103R-D	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-103R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-103S	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-104D	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-104M	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-104R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104R-B	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104R-D	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104S	Y	Overburden	1.5	WG	1	1	1																
Transect B	AE-105D	Y	Overburden	1.5	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	AE-105M	Y	Overburden	1.5	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	AE-105R-A	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-105R-B	Y	Bedrock	FLUTE	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	AE-105R-C	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-105R-D	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-105R-E	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-105S	Y	Overburden	1.5	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	AE-106D	Y	Overburden	1.5	WG	1		1																
Transect B	AE-106M	Y	Overburden	1.5	WG	1		1																
Transect B	AE-106R-A	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-106R-B	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-106R-C	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-106R-D	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-106R-E	Y	Bedrock	FLUTE	WG	1		1																
Transect B	AE-106S	Y	Overburden	1.5	WG	1		1																
Transect B	AE-107D	Y	Overburden	1.5	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	AE-107M	Y	Overburden	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	AE-107S	Y	Overburden	1.5	WG	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transect B	TRC-301R-A	Y	Bedrock	FLUTE	WG																			
Transect B	TRC-301R-B	Y	Bedrock	FLUTE	WG																			
Transect B	TRC-301R-C	Y	Bedrock	FLUTE	WG																			
Transect B	TRC-301R-D	Y	Bedrock	FLUTE	WG																			
Transect B	TRC-301R-E	Y	Bedrock	FLUTE	WG																			
Notes:						EPL, Concord St, Wetlands:	96	50	96	11	4	19	19	19	19	15	15	15	15	15	15	15	15	11
						Surface Water	7	0	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
						Totals:	103	50	103	11	7	19	19	19	19	15	15	15	15	15	15	15	15	11

Table 3-9c
Groundwater Sampling Summary - October 2015
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/USEPA Method 8260C)	1,4-dioxane (SW846/USEPA Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	CSIA: 13C/12C ratio for PCE, TCE, Cis-1,2-DCE, VC	Isotopic Analysis: O ¹⁶ /O ¹⁸ H ¹ /H ² and S ³⁴ /S ³⁶	VPH (MassDEP-VPH-04-1.1 Revision 1)	EPH and polycyclic aromatic hydrocarbons (PAH) (MassDEP-EPH-04-1.1 Revision 1) (on-site wells only)	Total As, Fe, Mn (SW846/USEPA Method 6010C)	Dissolved As, Fe, Mn (field filtered) (SW846/USEPA Method 6010C)	Chloride (USEPA 300.0)	Nitrite	Nitrate (USEPA 300.0)	Sulfate (USEPA 300.0)	Sulfide	Total organic carbon (SW-846 9060A)	Methane/ethane/ethene (Microseeps AM20Gax)	Dissolved hydrogen	Ferrous iron and manganese field test kits	Microbial Analysis: Quantaray (Microbial Insights)
Concord Street	STM-8D	N	Overburden	0.75	WG																			
Concord Street	STM-8M	N	Overburden	0.75	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Concord Street	STM-8R	N	Bedrock	1.5	WG																			
Concord Street	STM-8R1	Y	Bedrock	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Concord Street	STM-8R2	Y	Bedrock	1.5	WG																			
Concord Street	STM-8S	N	Overburden	0.75	WG																			
EPL Area	AE-03	N	Overburden	2	WG	1		1			1	1	1	1	1	1	1	1	1	1	1	1	1	
EPL Area	AE-04	N	Overburden	2	WG																			
EPL Area	GZA-105D	N	Overburden	1.5	WG																			
EPL Area	GZA-105S	N	Overburden	1.5	WG	1		1			1	1	1	1	1	1	1	1	1	1	1	1	1	
EPL Area	TRC-102	N	Overburden	1.25	WG																			
LTGMP	EMW-10D	N	Overburden	2	WG	1		1																
LTGMP	EMW-10R	N	Bedrock	2	WG	1		1																
LTGMP	EMW-11D	N	Overburden	2	WG																			
LTGMP	EMW-11R1	N	Bedrock	0.75	WG																			
LTGMP	EMW-11R2	N	Bedrock	0.75	WG																			
LTGMP	EMW-11R3	N	Bedrock	0.75	WG																			
LTGMP	TRC-402	existing?	Overburden	2	WG																			
LTGMP	TRC-403	existing?	Overburden	2	WG																			
Source Control - Downgradient Wetland Wells	GZA-14	N	Overburden	2	WG																			
Source Control - Downgradient Wetland Wells	GZA-14A	N	Overburden	2	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-4	N	Overburden	1.5	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-4A	N	Overburden	1.5	WG																			
Source Control - Downgradient Wetland Wells	MW-5	N	Overburden	1.5	WG	1		1																
Source Control - Downgradient Wetland Wells	MW-7	N	Overburden	1.5	WG																			
Source Control - Downgradient Wetland Wells	PS-1D	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-1M	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-1S	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-2D	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-2M	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-2S	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-3	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-4	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-5D	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-5S	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-8D	N	Overburden	0.62	WG																			
Source Control - Downgradient Wetland Wells	PS-8M	N	Overburden	0.62	WG	1		1																
Source Control - Downgradient Wetland Wells	PS-8S	N	Overburden	0.62	WG																			
Source Control - Onsite	IP-1R2	N	Bedrock	2	WG	1		1																
Source Control - Onsite	TRC-401R	N	Bedrock	2	WG																			
Transect A	AE-100R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-100R-B	Y	Bedrock	FLUTE	WG																			
Transect A	AE-100R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-100R-D	Y	Bedrock	FLUTE	WG																			
Transect A	AE-100R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101D	Y	Overburden	1.5	WG																			
Transect A	AE-101M	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-101R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101R-B	Y	Bedrock	FLUTE	WG																			
Transect A	AE-101R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101R-D	Y	Bedrock	FLUTE	WG																			
Transect A	AE-101R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-101S	Y	Overburden	1.5	WG																			
Transect A	AE-102D	Y	Overburden	1.5	WG																			
Transect A	AE-102M	Y	Overburden	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect A	AE-102R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102R-B	Y	Bedrock	FLUTE	WG						1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect A	AE-102R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102R-D	Y	Bedrock	FLUTE	WG																			
Transect A	AE-102R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-102S	Y	Overburden	1.5	WG																			
Transect A	AE-103D	Y	Overburden	1.5	WG						1	1	1	1	1	1	1	1	1	1	1	1	1	

Table 3-9c
Groundwater Sampling Summary - October 2015
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Area	Location	New Well?	Strata	Well Diameter (inches)	Matrix	VOCs (SW846/USEPA Method 8260C)	1,4-dioxane (SW846/USEPA Method 8270D SIM)	Field Parameters: pH, temperature, conductivity, ORP, DO, and/or turbidity	CSIA: 13C/12C ratio for PCE, TCE, Cis-1,2-DCE, VC	Isotopic Analysis: O ¹⁶ /O ¹⁸ H ¹ /H ² and S ³⁴ /S ³⁶	VPH (MassDEP-VPH-04-1.1 Revision 1)	EPH and polycyclic aromatic hydrocarbons (PAH) (MassDEP-EPH-04-1.1 Revision 1) (on-site wells only)	Total As, Fe, Mn (SW846/USEPA Method 6010C)	Dissolved As, Fe, Mn (field filtered) (SW846/USEPA Method 6010C)	Chloride (USEPA 300.0)	Nitrite	Nitrate (USEPA 300.0)	Sulfate (USEPA 300.0)	Sulfide	Total organic carbon (SW-846 9060A)	Methane/ethane/ethene (Microseeps AM20Gax)	Dissolved hydrogen	Ferrous iron and manganese field test kits	Microbial Analysis: Quantaray (Microbial Insights)
Transect A	AE-103M	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-103R-A	Y	Bedrock	FLUTE	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect A	AE-103R-B	Y	Bedrock	FLUTE	WG																			
Transect A	AE-103R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-103R-D	Y	Bedrock	FLUTE	WG																			
Transect A	AE-103R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-103S	Y	Overburden	1.5	WG																			
Transect A	AE-104D	Y	Overburden	1.5	WG																			
Transect A	AE-104M	Y	Overburden	1.5	WG	1	1	1																
Transect A	AE-104R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104R-B	Y	Bedrock	FLUTE	WG																			
Transect A	AE-104R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104R-D	Y	Bedrock	FLUTE	WG																			
Transect A	AE-104R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect A	AE-104S	Y	Overburden	1.5	WG																			
Transect B	AE-105D	Y	Overburden	1.5	WG																			
Transect B	AE-105M	Y	Overburden	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect B	AE-105R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect B	AE-105R-B	Y	Bedrock	FLUTE	WG						1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect B	AE-105R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect B	AE-105R-D	Y	Bedrock	FLUTE	WG																			
Transect B	AE-105R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect B	AE-105S	Y	Overburden	1.5	WG																			
Transect B	AE-106D	Y	Overburden	1.5	WG																			
Transect B	AE-106M	Y	Overburden	1.5	WG	1		1																
Transect B	AE-106R-A	Y	Bedrock	FLUTE	WG	1	1	1																
Transect B	AE-106R-B	Y	Bedrock	FLUTE	WG																			
Transect B	AE-106R-C	Y	Bedrock	FLUTE	WG	1	1	1																
Transect B	AE-106R-D	Y	Bedrock	FLUTE	WG																			
Transect B	AE-106R-E	Y	Bedrock	FLUTE	WG	1	1	1																
Transect B	AE-106S	Y	Overburden	1.5	WG																			
Transect B	AE-107D	Y	Overburden	1.5	WG																			
Transect B	AE-107M	Y	Overburden	1.5	WG	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	
Transect B	AE-107S	Y	Overburden	1.5	WG																			
Notes:			EPL, Concord St, Wetlands:			43	29	43	0	0	11	11	11	11	11	11	11	11	11	11	11	11	11	0
			Surface Water			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Totals:			43	29	43	0	0	11	11	11	11	11	11	11	11	11	11	11	11	11	0

Table 4-1
Project Operation Plan (POP) Summary
Former GE Facility, 50 Fordham Rd, Wilmington, MA

POP # or Reference	Title, Revision, Date	Originating Organization	POP option or Equipment Type (if POP provides different options)	Comments
POP-001	Recording of Field Investigation Revision 0, September 2013	AECOM	--	--
POP-002	Chain of Custody; Revision 0, September 2013	AECOM	Sample labeling procedure: (1) Two digits to represent the year, followed by a letter (beginning with A) to indicate the first, second, etc. sampling round of the year (e.g., 12A). (2) The sample IDs will then contain the following location and/or matrix identifier: • Groundwater – Well ID (PDB samples for VOCs will include “PDB” after the well ID) • Soil – Boring ID followed by the depth interval (e.g. SB12 -2-4) • Soil gas (outside) – Soil gas point (e.g., SGxx) • Sub slab (inside) – Sub-slab point (e.g., SSxx) • Ambient air – (e.g., AAXx) • Indoor air – (e.g., IAXx) • Rock cores – (e.g., RCxx) (3) The last character of the sample identifications will represent the sample type: -1 - field sample -2 - duplicate sample Equipment blanks and trip blanks will be labeled as follows: • Equipment blank – “EB” followed by date (e.g., EB-063012). • Trip blank – “TB” followed by date (e.g., TB-063012). Example sample ID: 12A-GZA-105D-2 represents a field duplicate sample collected at well GZA-105D during the first sampling event of 2012. Samples being designated for MS/MSD analysis will not include an identifier as part of the sample code, but will be identified as such on the COCs.	--
POP-003	Packing and Shipment of Environmental Samples; Revision 0, September 2013	AECOM	--	--
POP-004	Procedures for Passive Sampling of Air Using SUMMA Canisters; Revision 0, September 2013	AECOM	• Use 6-liter SUMMA canisters • Batch Certified canisters acceptable for routine monitoring. Individually Certified canisters are recommended if data to be used for risk assessment. • Flow controllers to be set by laboratory for 8-hour sample duration. • Shut canister off after 8-hr sample duration or when a vacuum of 5 in. Hg remains. • If canister fills slowly, fill until at least 15 in. Hg to obtain sufficient sample volume. • No field blanks to be collected. • Collect one 8-hr ambient outdoor air sample with each round of indoor air samples. From an upwind location, if possible to determine on sampling day, else check with Field Team Leader or PM for location to sample.	Sampling events scheduled during the heating season in February of 2014 and 2015. Need to verify that the Building 1 heating system is operational for a minimum of 48 to 72 hours prior to and during these sampling events. The building is now occupied so this should not be a problem.

Table 4-1
Project Operation Plan (POP) Summary
Former GE Facility, 50 Fordham Rd, Wilmington, MA

POP # or Reference	Title, Revision, Date	Originating Organization	POP option or Equipment Type (if POP provides different options)	Comments
POP-005	Monitoring Well Construction and Installation; Revision 0, September 2013	AECOM	- Overburden wells will be either 1.5-inch or 2-inch diameter PVC - Slot size, screen length and placement to be finalized based on field observations - Inspect well materials and, if needed, have driller steam clean, prior to installation - Surge well screen following installation of sand filter pack prior to installing bentonite seal - For bedrock wells within/near Building 1, purge borehole to confirm water bearing fractures prior to installing well (ideal is ≥ 0.5 gpm). Screen and FLUTE liner port placement will be determined at other locations via analytical, geophysical, and profiling results.	All soil borings and monitoring wells will be located a minimum of five feet from any utilities identified during the utility clearance and geophysical survey. In the event that a location cannot be moved five feet from a utility, the drillers will carefully hand-dig (or vac-ex) to the equivalent depth of the utility to ensure that the utility is not present at the intended location and that installation may proceed. A minimum lateral clearance of 24 inches will be maintained from all utilities.
POP-006	Operation and Calibration of a PID; Revision 0, September 2013	AECOM	- Use a PID with a 10.6 eV lamp - Ambient air will be acceptable for zeroing the PID prior to calibration - Use 100 ppm isobutylene calibration gas	--
POP-007	Headspace Screening; Revision 0, September 2013	AECOM	- Use a PID with a 10.6 eV lamp - Use top-sealing "Zip-Loc" type plastic bags as preferred method - Headspace development time should be the same for all samples. - If ambient temperature is below 32F, headspace development should be within a heated environment (building or vehicle) - Bump test equipment regularly (increase the frequency if moisture is present in sampling bag or ambient air). - If bump test result changed more than 20% than target, recalibrate PID.	PID logbook notes include: - PID calibration and bump test details - Periodic background/ambient concentrations in work zone PID notes on boring logs and field records include: - Sample location (borehole/well id) - Depth interval of sample measured - Soil description - Reading time - PID reading and units of measure
POP-008	Subsurface Soil Sampling; Revision 0, September 2013	AECOM	- Continuous soil sampling to be performed via rotosonic drilling - Soil cores to be collected in sonic core liners for logging and collection of soil samples. - Use unique boring log for each borehole	--
POP-009	Rock Core Drilling; Revision 0, September 2013	AECOM	Use PQ sized triple tube core barrel (4.83" OD) with speed increaser	All bedrock boreholes will be cored; RQDs will be calculated for all core runs.
POP-010	Logging of Rock Cores; Revision 0, September 2013	AECOM	- Use unique boring log for each borehole - Photographic record of cores from each borehole	--
POP-011	Decontamination of Field Equipment; Revision 0, September 2013	AECOM	(1) Rinse with tap water to remove gross contamination (2) Wash with detergent or soap solution (Alconox or Liquinox) (3) Rinse with distilled water	Down-hole drilling equipment: hot water pressure wash between investigation locations and place on polyethylene plastic sheets to dry.
POP-012	Monitoring Well Development; Revision 0, September 2013	AECOM	(1) Air lift development method, or (2) Surge block and submersible pumps, or (3) Surge block and bailer	For bedrock borehole development, air lift will be the primary and preferred method. For overburden monitoring wells, the preferential method will be surge block and submersible pumps. A water quality meter will be used to monitor pH, temp, and conductivity, and a nephelometer will be used to monitor turbidity, during development. Wells will be developed until water is visibly free of silt, turbidity is <50 NTU, and/or field parameters are stable.
POP-013	Water Level Measurements; Revision 0, September 2013	AECOM	Use electronic water-level meter capable reading in 0.01 ft increments.	--

Table 4-1
Project Operation Plan (POP) Summary
Former GE Facility, 50 Fordham Rd, Wilmington, MA

POP # or Reference	Title, Revision, Date	Originating Organization	POP option or Equipment Type (if POP provides different options)	Comments
POP-014	Low Stress Groundwater Purging and Sampling Procedure; Revision 0, September 2013	AECOM	- Refer to FLUTE procedures for sampling of bedrock wells with FLUTE liners installed. - Overburden and bedrock wells deeper than approximately 30 feet will be purged and sampled via non-dedicated bladder pumps. - Wells that are too skinny for the use of a bladder pump (even a skinny diameter pump) will be purged and sampled via peristaltic pump. This includes a number of 0.5" - 0.6" diameter wells deeper than 30 ft that have sufficient head of water column for use of a peristaltic pump.	Monitoring wells with low recharge which cannot sustain a purging rate of 100 ml/min will not be purged dry and sampled upon recharge. A limited purge (removal of one sampling system volume) at the lowest possible flow rate, approximately 50 - 100 ml/min will be conducted and the samples immediately collected at the same low flow rate.
POP-015	Field Calibration of YSI Water Quality Meter; Revision 0, September 2013	AECOM	- Calibrate water quality meter instrument in AM - Recheck calibration during the day when erratic readings or significant drift is observed; recalibrate as needed - End-of-day check (read-only) in PM	Calibration solutions: - Use 3 point calibration for pH (4, 7, and 10) - Use conductivity standard (1,000 $\mu\text{S}/\text{cm}$) - Use ORP calibration standard (mV) - Use air saturation for DO calibration; a zero DO solution may be used as a check or a zero calibration, but is not required.
POP-016	Slug Testing; Revision 0, September 2013	AECOM	- Use solid slug method for wells screened across water table - Falling Head Test - Rising Head Test - Use pneumatic slug method for wells in high K formations not screened across water table - Pressurize system - Release pressure and record system recovery	Perform three or more tests (rising or falling head) at each well. Use at least two different initial displacements that vary by a factor of 2 or more. Conduct both rising and falling head tests if possible (falling head tests will be not performed in water table wells). Run each test to near completion. Follow the data analysis approach recommended in Butler 1998.

Table 4-2
Analytes and Reporting Limits for Soil and Groundwater
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Project Action Limit ¹		Laboratory Reporting Limit ²	
	Groundwater (ug/L)	Soil (mg/kg)	Groundwater (ug/L)	Soil (mg/kg)
VOCs by SW-846 8260B				
				Low Level^{3,4}
Acetone	6300	6	10	0.05
Amyl Methyl Ether (TAME), <i>tert</i> -	NE	NE	1	0.005
Benzene	5	2	1	0.005
Bromobenzene	1000*	100*	1	0.005
Bromochloromethane	832	162	1	0.005
Bromodichloromethane	3	0.1	0.5	0.005
Bromoform	4	0.1	1	0.005
Bromomethane	10	0.5	2	0.01
Butylbenzene, <i>sec</i> -	NE	NE	1	0.005
Butylbenzene, <i>n</i> -	7802	39002	1	0.005
Butylbenzene, <i>tert</i> -	1000*	100*	1	0.005
Carbon Disulfide	7202	100*	2	0.01
Carbon Tetrachloride	5	10	1	0.005
Chlorobenzene	100	1	1	0.005
Chlorodibromomethane	2	0.005	0.5	0.005
Chloroethane	1000*	100*	2	0.01
Chloroform	70	0.4	1	0.005
Chloromethane	1902	100*	2	0.01
Chlorotoluene, 2-	1902	100*	1	0.005
Chlorotoluene, 4-	1902	16002	1	0.005
1,2-Dibromo-3-chloropropane	100*	10*	2	0.01
Dibromoethane, 1,2- (EDB)	0.02	0.1	0.5	0.005
Dibromomethane	5000*	500	1	0.005
Dichlorobenzene, 1,3- (<i>m</i> -DCB)	40	1	1	0.005
Dichlorobenzene, 1,2- (<i>o</i> -DCB)	600	9	1	0.005
Dichlorobenzene, 1,4- (<i>p</i> -DCB)	5	0.7	1	0.005
Dichlorodifluoromethane (Freon 12)	1400**	942	2	0.01
Dichloroethane, 1,1-	70	0.4	1	0.005
Dichloroethane, 1,2-	5	0.1	1	0.005
Dichloroethylene, 1,1-	7	3	1	0.005
Dichloroethylene, <i>cis</i> -1,2	70	0.3	1	0.005
Dichloroethylene, <i>trans</i> -1,2	100	1	1	0.005
Dichloropropane, 1,2-	5	0.1	1	0.005
Dichloropropane, 1,3-	2902	16002	1	0.005
Dichloropropane, 2,2-	NE	NE	1	0.005
Dichloropropene, 1,1-	NE	NE	1	0.005
Dichloropropene, <i>cis</i> -1,3-	0.4**	0.01	0.5	0.005
Dichloropropene, <i>trans</i> -1,3-	0.4**	0.01	0.5	0.005
Diethyl Ether	1000*	100	1	0.005
Diisopropyl Ether (DIPE)	1000*	100	1	0.005
Dioxane, 1,4- (and see SVOC below)	0.3**	0.2	20	0.1
Ethyl Tertiary Butyl Ether (ETBE)	NE	NE	1	0.005
Ethylbenzene	700	40	1	0.005
Hexachlorobutadiene	0.6	6	0.5	0.005
Hexanone (MBK), 2-	342	100*	10	0.05

Table 4-2
Analytes and Reporting Limits for Soil and Groundwater
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Project Action Limit ¹		Laboratory Reporting Limit ²	
	Groundwater (ug/L)	Soil (mg/kg)	Groundwater (ug/L)	Soil (mg/kg)
Isopropylbenzene (Cumene)	3902	1000*	1	0.005
Isopropyltoluene, p-	NE	NE	1	0.005
Methyl Ethyl Ketone (MEK)	4000	4	10	0.05
Methyl Isobutyl Ketone (MIBK)	350	0.4	10	0.05
Methyl Tertiary Butyl Ether (MTBE)	70	0.1	1	0.005
Methylene Chloride	5	0.1	2	0.01
Naphthalene	140	4	1	0.005
Propylbenzene, n-	5302	34002	1	0.005
Styrene	100	3	1	0.005
Tetrachloroethane, 1,1,1,2-	5	0.1	1	0.005
Tetrachloroethane, 1,1,2,2-	2	0.005	0.5	0.005
Tetrachloroethylene	5	1	1	0.005
Tetrahydrofuran (THF)	1.3**	500*	2	0.01
Toluene	1000	30	1	0.005
Trichlorobenzene, 1,2,4-	70	2	1	0.005
Trichlorobenzene, 1,2,3-	NE	NE	1	0.005
Trichloroethane, 1,1,1-	200	30	1	0.005
Trichloroethane, 1,1,2-	5	0.1	1	0.005
Trichloroethylene (TCE)	5	0.3	1	0.005
Trichlorofluoromethane (Freon 11)	11002	1000*	1	0.005
Trichloropropane, 1,2,3-	1000*	100*	1	0.005
Trimethylbenzene, 1,2,4-	152	622	1	0.005
Trimethylbenzene, 1,3,5-	872	10*	1	0.005
Vinyl Chloride	2	0.6	1	0.005
Xylene, o-	10,000	400	1	0.005
Xylene, m-	10,000	400	2 (reported as m&p-Xylene)	0.010 (reported as m&p-Xylene)
Xylene, p-	10,000	400	2 (reported as m&p-Xylene)	0.010 (reported as m&p-Xylene)
SVOC by SW-846 8270C with SIM				
1,4-Dioxane	0.3**	0.2	0.1	N/A
VPH by MADEP –VPH-04-1.1				
C ₅ -C ₈ Aliphatic Hydrocarbons	300	100	75	0.75
C ₉ -C ₁₂ Aliphatic Hydrocarbons	700	1000	25	0.25
C ₉ -C ₁₀ Aromatic Hydrocarbons	200	1000	25	0.25
Benzene	5	2	5	0.05
Ethylbenzene	700	40	5	0.05
Methyl-tert-butyl ether	70	0.1	5	0.05
Naphthalene	140	4	5	0.05
Toluene	1000	30	5	0.05
o-Xylene	10000	400	5	0.05
m & p -Xylene	10000	400	10	0.1

Table 4-2
Analytes and Reporting Limits for Soil and Groundwater
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Project Action Limit ¹		Laboratory Reporting Limit ²	
	Groundwater (ug/L)	Soil (mg/kg)	Groundwater (ug/L)	Soil (mg/kg)
EPH by MADEP –EPH-04-1.1				
C ₉ -C ₁₈ Aliphatic Hydrocarbons	700	1000	100	10 m
C ₁₉ -C ₃₆ Aliphatic Hydrocarbons	14000	3000	100	10
C ₁₁ -C ₂₂ Aromatic Hydrocarbons	200	1000	100	10
Naphthalene	140	4	5	0.333
2-Methylnaphthalene	10	0.7	5	0.333
Phenanthrene	40	10	5	0.333
Acenaphthene	20	4	5	0.333
Fluorene	30	1000	5	0.333
Acenaphthylene	30	1	5	0.333
Anthracene	60	1000	5	0.333
Fluoranthene	90	1000	5	0.333
Pyrene	80	1000	5	0.333
Benzo(a)anthracene	1	7	5	0.333
Chrysene	2	70	5	0.333
Benzo(b)fluoranthene	1	7	5	0.333
Benzo(k)fluoranthene	1	70	5	0.333
Benzo(a)pyrene	0.2	2	5	0.333
Indeno(1,2,3-cd)pyrene	0.5	7	5	0.333
Dibenz(a,h)anthracene	0.5	0.7	5	0.333
Benzo(g,h,i)perylene	50	1000	5	0.333
Dissolved Gases by AM20GAX				
Ethene	NE	NA	0.025	NA
Ethane	NE	NA	0.025	NA
Methane	NE	NA	0.1	NA
Acetylene	NE	NA	0.5	NA
Carbon dioxide	NE	NA	5	NA
Hydrogen	NE	NA	0.0012	NA
Compound Specific Isotope Analyses				
Tetrachloroethene	NE	NA	0.005	NA
Trichloroethene	NE	NA	0.005	NA
Dichloroethene, cis-1,2	NE	NA	0.005	NA
Vinyl chloride	NE	NA	0.005	NA
Stable Isotopes of Water (S, O, H)	NE	NA	NA	NA
Metals by SW-846 6010C or 7196A				
Arsenic	10	20	4	1.5
Beryllium	4	100	2	0.5
Chromium	100	30	5	1
Hexavalent Chromium	100	30	5	4
Copper	10	1000	5	1
Lead	15	300	7.5	1.5
Nickel	100	20	5	1
Silver	100	100	5	1.5
Zinc	200	2500	5	1
Iron	NA	NA	30	NA
Manganese	NA	NA	2	NA

Table 4-2
Analytes and Reporting Limits for Soil and Groundwater
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Project Action Limit ¹		Laboratory Reporting Limit ²	
	Groundwater (ug/L)	Soil (mg/kg)	Groundwater (ug/L)	Soil (mg/kg)
General Chemistry Parameters				
Cyanide, total	5000	100	5	0.5
Sulfite	NE	NA	2 mg/l	NA
Sulfate	NE	NA	1 mg/l	NA
Nitrate	NE	NA	0.1 mg/l	NA
Nitrite	NE	NA	0.1 mg/l	NA
Chloride	NE	NA	1 mg/l	NA
Total organic carbon	NE	NA	1 mg/l	NA
Dissolved organic carbon	NE	NA	1 mg/l	NA
Fractional organic carbon	NE	NA	NA	0.0001*
Sulfide	NE	NA	0.1 mg/l	NA
Microbial Populations (Quantarray Method)	NE	NA	500 – 3000 cells/sample	NA
Functional genes (<i>bvcA</i>, <i>tceA</i>, <i>vcrA</i>)	NE	NA	500 cells/sample	NA
Notes: ¹ Massachusetts Contingency Plan Method 1 Standards and Reportable Concentrations (RCs). Method 1 GW-1 standards used for groundwater and Method 1 S-1/GW-1 standards used for soil. RCGW-1 RC (*) used for groundwater if Method 1 GW-1 standard or Office of Research and Standard Guideline (ORSG) not established. ORSG for drinking water (**) (May 2011) used if Method 1 GW-1 standard not established. RCS-1 RC (*) used for soil if Method 1 S-1/GW-1 standard not established. ² Project Action Limits from USEPA Regional Screening Levels (RSLs) for tapwater. April 2012 [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm]. 3 Water preserved sample 4 Laboratory Reporting Limits are approximately 50x higher for methanol preserved sample SIM - Selected Ion Monitoring NA - Not applicable NE - Not established DHC - Dehalococcoides DSM - Desulfuromonas DHB - Dehalobacter DSB - Desulfitobacterium Laboratory Reporting Limits that exceed the Project Action Limit are in bold type * No units used for this analysis. It is a mathematical expression of the TOC soil result divided by 1 million.				

Table 4-3
Analytes and Reporting Limits for Investigation Derived Waste
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Laboratory Reporting Limit		
Analyte	Aqueous (ug/L)	Soil (mg/kg)
VOCs		
TPH	0.2 mg/l	26.6
Corrosivity	NA	NA
Ignitability	NA	NA
Reactive Cyanide	1 mg/l	25
Reactive Sulfide	4 mg/l	50
TCLP VOCs	See Table 4-2 water reporting limits, multiplied by 5	
TCLP Metals		
Arsenic	0.008 mg/l	
Barium	0.01 mg/l	
Cadmium	0.005 mg/l	
Chromium	0.01 mg/l	
Lead	0.015 mg/l	
Selenium	0.03 mg/l	
Silver	0.01 mg/l	
Mercury	0.0002 mg/l	
PCBs		
Aroclor -1016	0.2	0.02
Aroclor -1221	0.2	0.02
Aroclor -1232	0.2	0.02
Aroclor -1242	0.2	0.02
Aroclor -1248	0.2	0.02
Aroclor -1254	0.2	0.02
Aroclor -1260	0.2	0.02
Aroclor -1262	0.2	0.02
Aroclor -1268	0.2	0.02
SVOCs		
Acenaphthene	5	0.165
Acenaphthylene	5	0.165
Acetophenone	See below	See below
Aniline	5	0.33
Anthracene	5	0.165
Azobenzene	5	0.33
Benzo(a)anthracene	5	0.165
Benzo(a)pyrene	5	0.165
Benzo(b)fluoranthene	5	0.165
Benzo(k)fluoranthene	5	0.165
Benzo(g,h,i)perylene	5	0.165
Bromophenyl phenyl ether , 4-	5	0.33
Butyl benzyl phthalate	5	0.33
Butyl phthalate, Di-n-	5	0.33
Chloroaniline, 4-	5	0.165
bis (2-Chloroethoxy)methane	5	0.33
bis (2- Chloroethyl)ether	5	0.165
bis (2-Chloroisopropyl) ether	5	0.165
Chloronaphthalene, 2-	5	0.33
Chlorophenol, 2-	5	0.165
Chrysene	5	0.165
Dibenz(a,h)anthracene	5	0.165
Dibenzofuran	5	0.165

Table 4-3
Analytes and Reporting Limits for Investigation Derived Waste
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Analyte	Laboratory Reporting Limit	
	Aqueous (ug/L)	Soil (mg/kg)
Dichlorobenzene, 1,2-	5	0.33
Dichlorobenzene, 1,3-	5	0.33
Dichlorobenzene, 1,4-	5	0.33
Dichlorobenzidine, 3,3'-	5	0.33
Dichlorophenol, 2,4-	5	0.165
Diethyl phthalate	5	0.33
Dimethyl phthalate	5	0.33
Dimethylphenol, 2,4-	5	0.33
Dinitrophenol, 2,4-	5	0.33
Dinitrotoluene, 2,4-	5	0.165
Dinitrotoluene, 2,6-	5	0.165
Dioxane, 1,4-	NA	NA
bis (2-Ethylhexyl) phthalate	5	0.165
Fluoranthene	5	0.165
Fluorene	5	0.165
Hexachlorobenzene	5	0.165
Hexachlorobutadiene	5	0.165
Hexachloroethane	5	0.165
Indeno (1,2,3-cd) pyrene	5	0.165
Isophorone	5	0.165
Methylnaphthalene, 2-	5	0.165
Methylphenol, 2 -	5	0.33
Methylphenol, 3-	Reported as 3,4-Methylphenol at 10	Reported as 3,4-Methylphenol at 0.330
Methylphenol, 4-	Reported as 3,4-Methylphenol at 10	Reported as 3,4-Methylphenol at 0.330
Naphthalene	5	0.165
Nitrobenzene	5	0.165
Nitrophenol, 2-	5	0.165
Nitrophenol, 4-	20	1.32
Octyl phthalate, di-n-	5	0.33
Pentachlorophenol	20	0.33
Phenanthrene	5	0.165
Phenol	5	0.33
Pyrene	5	0.165
Trichlorobenzene, 1,2,4-	5	0.33
Trichlorophenol, 2,4,5-	5	0.33
Trichlorophenol, 2,4,6-	5	0.165

Notes:

Acetophenone will be analyzed as a tentatively identified compound (TIC).

NA Not applicable

Table 4-4
Analytes and Reporting Limits for Indoor and Ambient Air
Former GE Facility, 50 Fordham Road, Wilmington, MA

	Project Action Limit1		Laboratory Reporting Limit	
	(ug/m3)	(ppbv)	(ug/m3)	(ppbv)
VOCs by MassDEP TO-15 SIM 2010				
Acetone	91	NE	4.7	2
Benzene	2.3	NE	0.319	0.1
Bromodichloromethane	0.14	NE	0.134	0.02
Bromoform	2.2	NE	0.207	0.02
Bromomethane	0.6	NE	0.078	0.02
Chlorobenzene	2.3	NE	0.092	0.02
Chloroform	1.9	NE	0.098	0.02
Carbon tetrachloride	0.54	NE	0.126	0.02
1,1-Dichloroethane	0.8	NE	0.081	0.02
1,1-Dichloroethylene	0.8	NE	0.079	0.02
1,2-Dibromoethane	0.011	NE	0.154	0.02
1,2-Dichloroethane	0.09	NE	0.081	0.02
1,2-Dichloropropane	0.13	NE	0.092	0.02
Dibromochloromethane	0.1	NE	0.17	0.02
trans-1,2-Dichloroethylene	0.8	NE	0.091	0.02
cis-1,2-Dichloroethylene	0.8	NE	0.079	0.02
cis-1,3-Dichloropropene	0.6	NE	0.091	0.02
m-Dichlorobenzene	0.6	NE	0.12	0.02
o-Dichlorobenzene	0.72	NE	0.12	0.02
p-Dichlorobenzene	0.5	NE	0.12	0.02
trans-1,3-Dichloropropene	0.6	NE	0.091	0.02
1,4-Dioxane	0.59	NE	0.36	0.1
Ethylbenzene	7.4	NE	0.087	0.02
Hexachlorobutadiene	4.6	NE	0.533	0.05
Methylene chloride	5	NE	3.46	1
Methyl ethyl ketone	12	NE	1.48	0.5
Methyl Isobutyl Ketone	2.2	NE	2.05	0.5
Methyl Tert Butyl Ether	39	NE	0.072	0.02
Naphthalene	0.61	NE	0.262	0.05
Styrene	1.4	NE	0.085	0.02
1,1,1-Trichloroethane	3	NE	0.109	0.02
1,1,2,2-Tetrachloroethane	0.04	NE	0.137	0.02
1,1,2-Trichloroethane	0.15	NE	0.109	0.02
1,2,4-Trichlorobenzene	3.4	NE	0.371	0.05
Tetrachloroethylene	1.4	NE	0.136	0.02
Toluene	54	NE	0.188	0.05
Trichloroethylene	0.8	NE	0.107	0.02
Vinyl chloride	0.27	NE	0.051	0.02
m,p-Xylenes	20	NE	0.174	0.02
o-Xylene	20	NE	0.087	0.02
Chloroethane	100,002	NE	0.053	0.02
Carbon disulfide	7302	NE	0.62	0.2
Methyl acetate	NE	NE	See below	See below
Freon 113	310,002	NE	0.383	0.05
Dichlorodifluoromethane	1002	NE	0.247	0.05
Chloromethane	942	NE	1.03	0.5

Notes:

1. Project Action Limits from Massachusetts Department of Environmental Protection's *Interim Final Vapor Intrusion Guidance, December 2011, WSC#-11-435*. Residential Threshold Values in Table I.1 were used.
2. Project Action Limits from USEPA Regional Screening Levels (RSLs) for Residential Air. April 2012 [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm].

NE - Not Established

Methyl acetate will be analyzed for as a Tentatively Identified Compound (TIC)

Actual Reporting limits may be higher depending on the dilution factor and/or sample matrix effects.

Laboratory Reporting Limits that exceed the Project Action Limit are in **bold** type

Table 4-5
Analytical Methods
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Methodology
VOCs (excluding 1,4-dioxane)	SW-846 8260C (CAM)
1,4-Dioxane	SW-846 8270D SIM (CAM)
Metals, total and/or dissolved	SW-846 6010C (CAM)
Cyanide, total	SW-846 9012B (CAM) /EPA 335.4
pH	SW-846 9045D
ORP	Spectrum Analytical SOP
Hexavalent Chromium	SW-846 3060A/7196A
Microbial populations and functional genes	Polymerase Chain Reaction
EPH	MADEP-EPH-04-1.1 Revision 1 (CAM)
VPH	MADEP-VPH-04-1.1 Revision 1.1 (CAM)
Sulfite	SM4500-SO3-B
Sulfide	SM4500-S D
Sulfate	EPA 300.0
Nitrate	EPA 300.0
Nitrite	EPA 300.0
Chloride	EPA 300.0
Total organic carbon	SW-846-9060A
Dissolved organic carbon	SW-846-9060A
Fractional organic carbon	Lloyd Kahn
Ethane/ethane/methane/carbon dioxide/acetylene	Microseeps SOP AM20GAx
Dissolved hydrogen	Microseeps SOP AM20GAx (bubble strip)
Compound specific isotope analyses	Microseeps SOP AM24
Stable isotopes of water (S, O, H)	Isotech methods using CRDS and EA-IRMS
SVOCs	SW-846 8270D (CAM)
PCBs	SW-846 8082A (CAM)
TPH	SW-846 8015C
VOCs in air	EPA TO-15 (CAM)
VOCs in bedrock (performed by Stone Environmental, Inc.)	SW-846 8260C with microwave assisted extraction
Porosity	International Society for Rock Mechanics method
Ignitability	SW-846 1030
Corrosivity	SM2330B
Reactivity	SW-846 Ch. 7.3
TCLP Metals	SW-846 1311, SW-846 6010C/7470A (CAM)
TCLP VOCs	SW-846 1311, SW-846 8260C (CAM)
Rock core diffusion analyses	Refer to Golder Associates SOP in Appendix F

Notes:

CRDS Cavity Ring-Down Spectroscopy

EA-IRMS Elemental Analyzer-Isotope Ratio Mass Spectrometer

Table 4-6
Sample Containers, Preservations, and Holding Times
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Container ¹	Preservation	Holding Time ²
Aqueous Samples			
VOCs (excluding 1,4-dioxane)	3 x 40 mL vials	HCl to pH <2; Ice, 4°C.	14 days
1,4-Dioxane	1 L amber glass	Ice, 4°C.	7 days to extraction; 40 days from extraction to analysis
Metals, total and dissolved (excluding mercury)	500 mL plastic	HNO ₃ to pH <2. Ice, 4°C. (field filter first for dissolved metals)	6 months
Cyanide, total	500 mL plastic	NaOH to pH ≥ 12.0; Ice, 4°C.	14 days to distillation; analyze distillates within 24 hours of distillation
Microbial populations and functional genes	Filter 2 L groundwater, ship filter	Ice, 4°C.	24 - 48 hours
EPH	1 L amber glass	HCl to pH <2; Ice, 4°C	14 days to extraction; 40 days from extraction to analysis
VPH	3 x 40 mL vials	HCl to pH <2; Ice, 4°C.	14 days
Sulfite	250mL plastic	Ice, 4°C.	Analyze immediately
Sulfide	500 mL plastic	Zinc acetate, NaOH to pH >9; cool 4°C	7 days
Sulfate	500 mL plastic	Ice, 4°C.	28 days
Nitrate	250 mL plastic	Ice, 4°C.	2 days
Nitrite	250 mL plastic	Ice, 4°C.	2 days
Chloride	250 mL plastic	Ice, 4°C.	28 days
Total organic carbon	2 x 40 mL vials	H ₃ PO ₄ pH <2. Ice, 4°C.	28 days
Dissolved organic carbon	2 x 40 mL vials	Ice, 4°C.	28 days
Ethene/ethane/methane/carbon dioxide/acetylene	2 x 40 mL vials with butyl rubber septa	Benzalkonium chloride; cool 4°C	14 days
Dissolved hydrogen	1 – 22cc Headspace vial, set to atmospheric pressure w/UHP nitrogen and a stopper type septum	Ice, 4	14 days
Compound specific isotope analyses	9 x 40 mL vials	HCl to pH <2; Ice, 4°C.	14 days
SVOCs	1 L amber glass	Ice, 4°C	7 days to extraction; 40 days from extraction to analysis
PCBs	1 L amber glass	Ice, 4°C	7 days to extraction; 40 days from extraction to analysis
TPH	1 L amber glass	HCl to pH <2; Ice, 4°C	7 days to extraction; 40 days from extraction to analysis

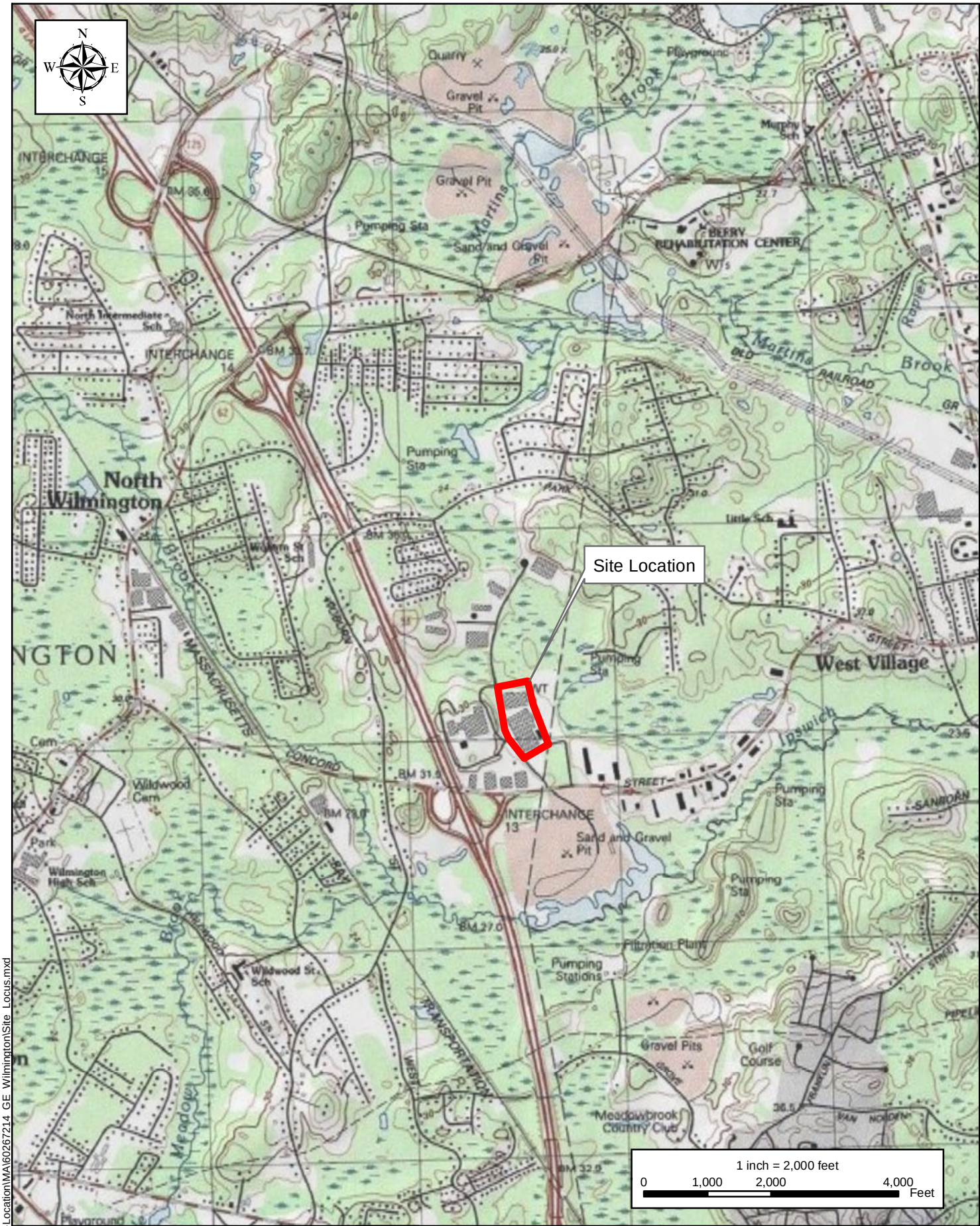
Table 4-6
Sample Containers, Preservations, and Holding Times
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Container ¹	Preservation	Holding Time ²
TCLP metals	500 mL plastic	Ice, 4°C.	28 days to leaching for mercury;180 days to leaching for other metals. 28 days from leaching to analysis for mercury;180 days from leaching to analysis for other metals
TCLP VOCs	4 x 40 mL vials	Ice, 4°C.	TCLP extraction within 14 days of collection, analysis within 14 days from TCLP extraction
Flashpoint	100 ml plastic or glass	Ice, 4°C.	ASAP
Reactivity	100 ml plastic or glass	Ice, 4°C.	7 days
Corrosivity/ pH	100 ml plastic or glass	None Required	Analyze immediately
Stable isotopes of water (S, O, H)	1 L plastic or glass	Ice, 4°C.	None established; 1 month advisory
Soil Samples			
VOCs	High level analysis: 1 40-mL vial filled with 15 mL methanol (15 g soil to 15 mL methanol) Low level analysis: 2 40-mL vials with teflon stir bar and filled with 5 mL deionized water (5 g soil to 5 mL deionized water) % solids: 1 60-mL plastic	Ice, 4°C, in field; Freeze at end of day.	48 hours to freezing for water preserved samples; 14 days from collection to analysis for methanol and water preserved samples
Metals (excluding mercury)	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	6 months
Cyanide, total	4 oz amber glass with Teflon-lined cap	Ice, 4°C.	14 days to distillation; analyze distillates within 24 hours of distillation
pH	4 oz jar with Teflon lined cap and no headspace	Ice, 4°C	24 hours
Oxidation Reduction Potential (ORP)	4 oz jar with Teflon lined cap and no headspace	Ice, 4°C.	24 hours
Hexavalent Chromium	4 oz jar with Teflon lined cap and no headspace	Ice, 4°C	30 days
EPH	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	14 days to extraction; 40 days from extraction to analysis
VPH	40 mL vial filled with 15 mL methanol (15g soil in 15 mL methanol)	Ice, 4°C.	28 days
SVOCs	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	14 days to extraction; 40 days from extraction to analysis
PCBs	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	1 year to extraction; 40 days from extraction to analysis
TPH	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	14 days to extraction; 40 days from extraction to analysis

Table 4-6
Sample Containers, Preservations, and Holding Times
Former GE Facility, 50 Fordham Rd, Wilmington, MA

Parameter	Container ¹	Preservation	Holding Time ²
TCLP metals	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	28 days to leaching for mercury;180 days to leaching for other metals. 28 days from leaching to analysis for mercury;180 days from leaching to analysis for other metals
TCLP VOCs	4 oz glass jar with no headspace	Cool to 4°C. Keep from light.	TCLP extraction within 14 days of collection, analysis within 14 days from TCLP extraction
Ignitability	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	ASAP
Reactivity	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	7 days
Corrosivity/pH	8 oz amber glass with Teflon-lined cap	Ice, 4°C.	ASAP
Fractional organic carbon	It is a mathematical expression of the TOC soil result divided by 1 million.	It is a mathematical expression of the TOC soil result divided by 1 million.	14 days
Bedrock Samples			
VOCs	250-mL wide mouth jar with Teflon-lined cap containing 100 mL methanol	Cool to 4°C. Keep from light.	14 day extraction period in methanol, 14 days from extraction to analysis
VOCs (analysis performed by Stone Environmental, Inc.	1 40-mL vial filled with 15 mL methanol (10 – 15 g crushed rock)	Cool to 4°C from field to laboratory. Freeze at laboratory.	30 days for frozen samples
Porosity	1 HDPE jar, size dependent on rock core size	None	None
Rock core diffusion analyses	Wrapped with plastic wrap and sealed (dipped) in paraffin wax	None	None
Air Samples			
VOCs (TO-15)	6 L SUMMA® canister	None Required	30 days
Notes:			
¹ Laboratory may provide alternate containers as long as the containers meet the requirements of the method and allow the collection of sufficient volume to perform the analyses and any reanalyses required by the method.			
² Holding time begins from date of sample collection.			

Figures



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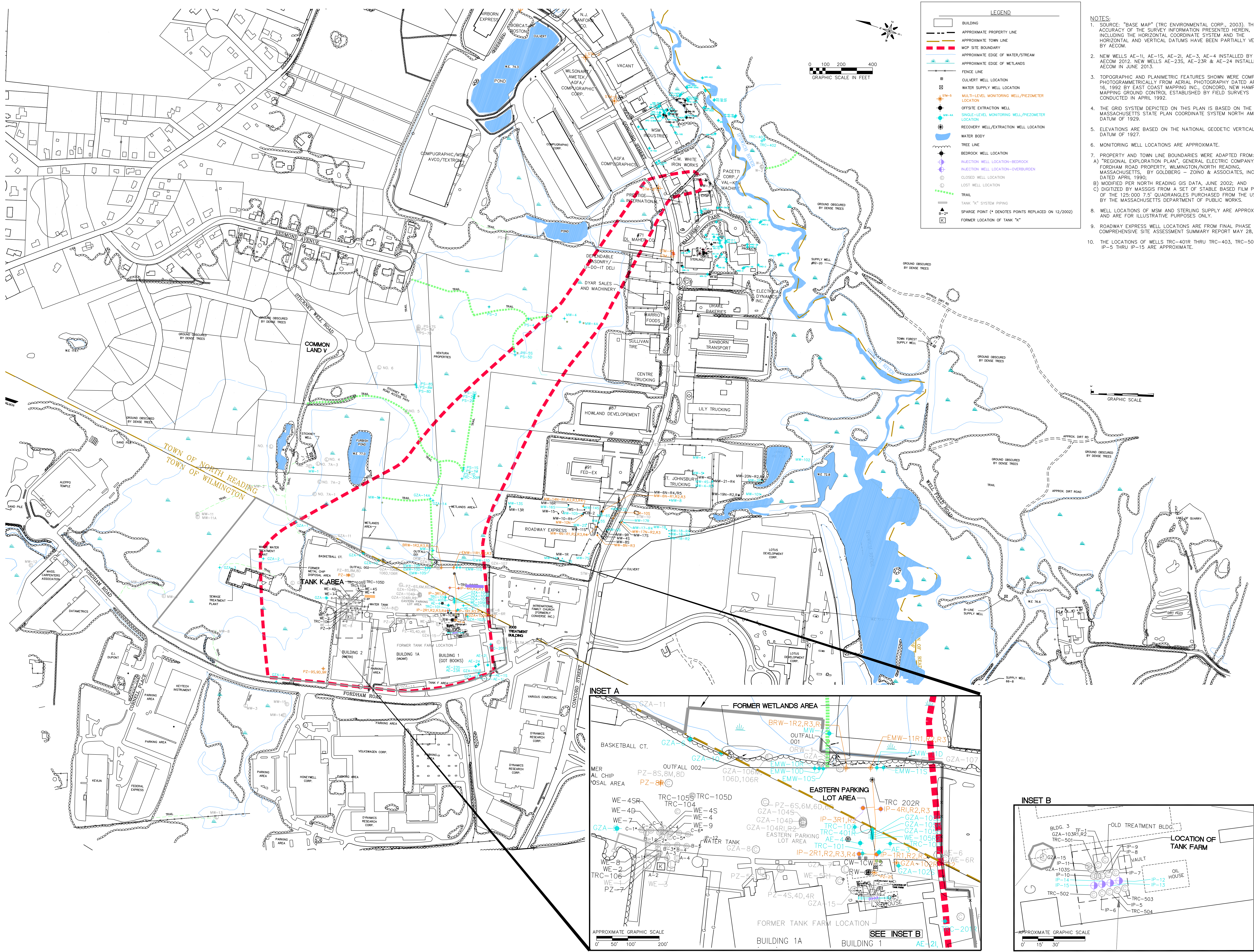
Former GE Facility
50 Fordham Road
Wilmington, MA

Site Location Map

DATE: 10/2013

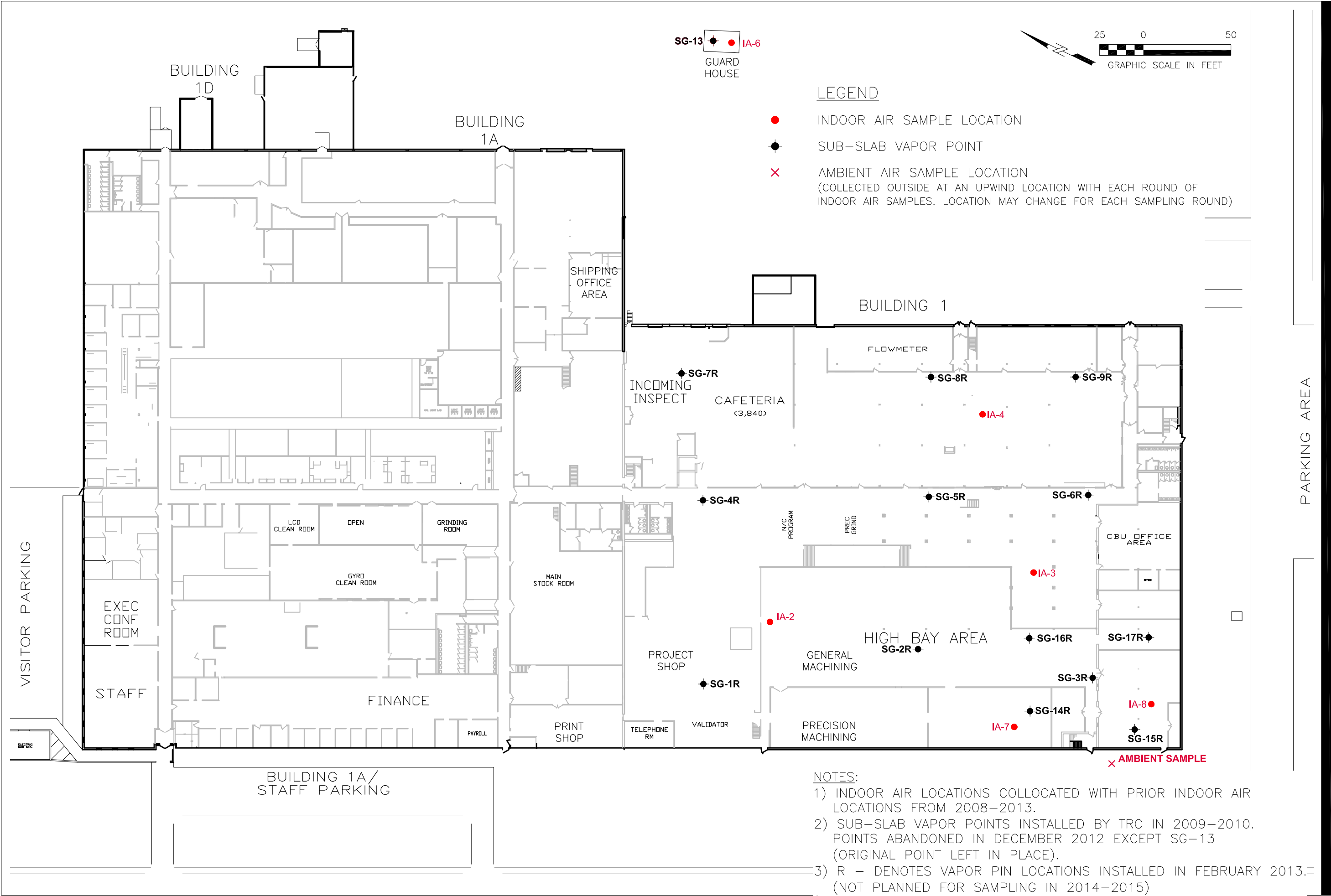
PROJECT 60283655.07.03

FIGURE: 2-1



**Former GE Facility
50 Fordham Road
Wilmington, MA**

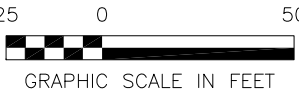
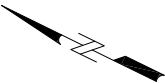
SITE PLAN



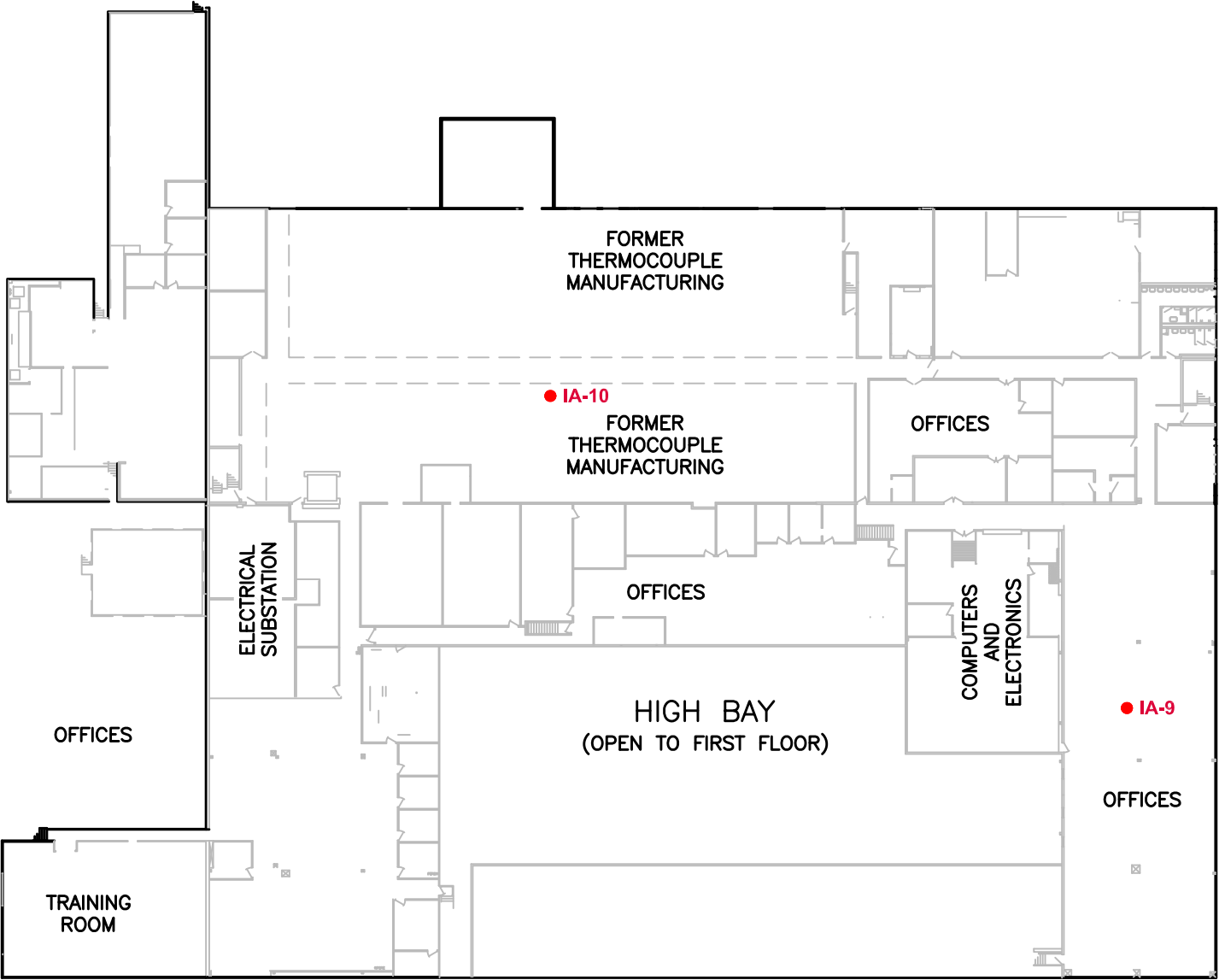
LEGEND

● INDOOR AIR SAMPLE LOCATION

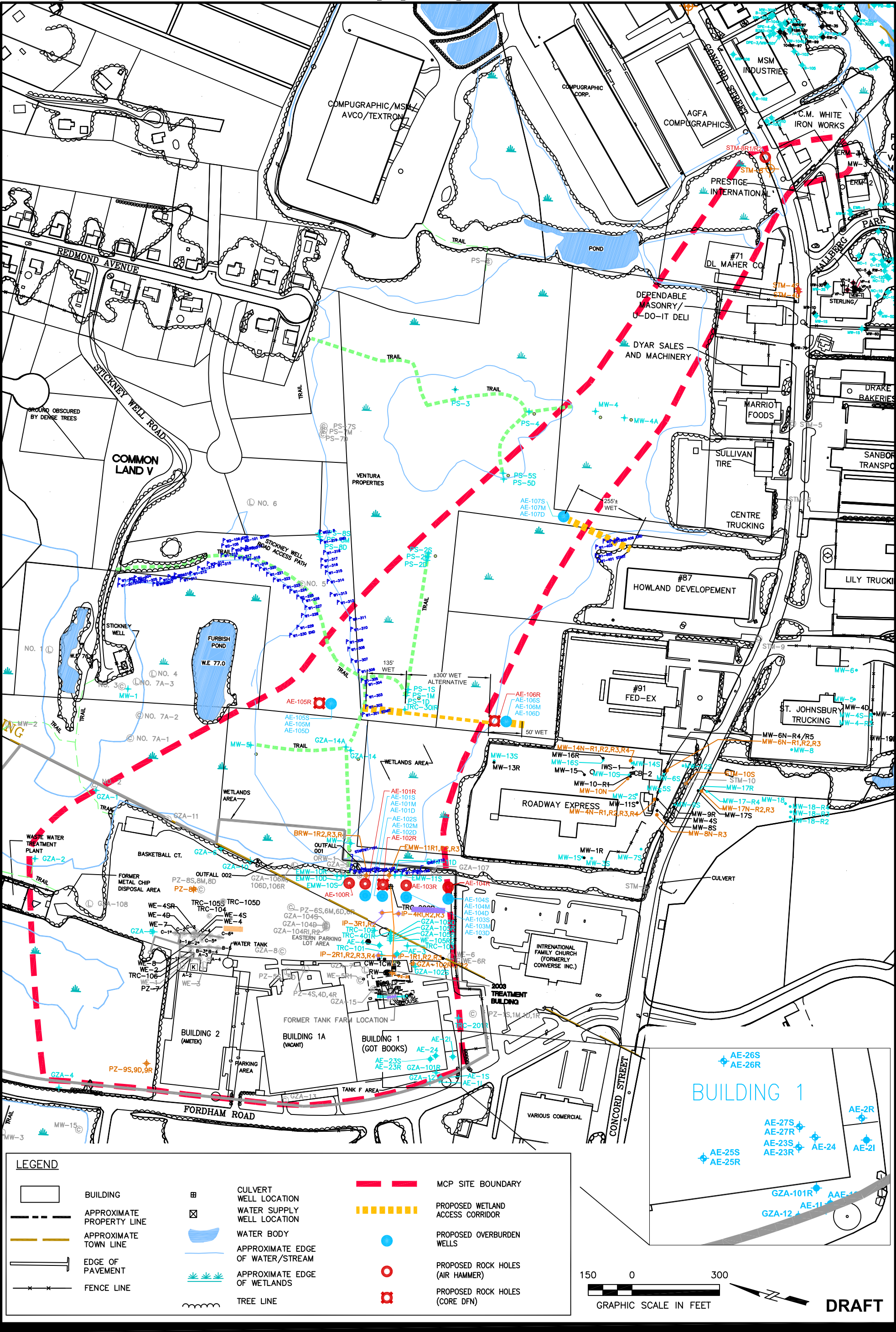
NOTES:
1.) INDOOR AIR LOCATIONS IA-9 AND IA-10 WERE ADDED IN AUGUST 2012 ON SECOND FLOOR OF BUILDING 1.



BUILDING 1A



BUILDING 1



Appendix A

Lockheed Martin Minimum Requirements for Intrusive Field Work

Lockheed Martin Minimum Requirements for Intrusive Fieldwork Work Plans

PURPOSE

The purpose of this requirements document is to prevent damage to subsurface and overhead utilities and structures and unexpected chemical releases during ground disturbance activities such as drilling, augering, direct-push technologies, excavation, trenching, chemical injection, grading or other similar operations.

SCOPE

This document provides minimum requirements for subsurface clearance activities, which must be followed prior to and during ground disturbance activities at any Lockheed Martin remediation project sites. Even after completing the subsurface clearance activities identified in this procedure, all ground disturbance activities shall proceed with caution.

This document also provides requirements on implementing in situ chemical injection programs, on managing significant field changes in field work plans and worksite housekeeping.

The Lockheed Martin Project Lead (PL), the managing contractor, and the performing contractor will be responsible for fulfilling the objectives of this document by ensuring that these requirements are carried out by the performing contractor's employees, sub-contractors and their employees and any other persons involved in the intrusive activity. The work requirements outlined below shall be incorporated into the work plan.

WORK REQUIREMENTS

General

The performing contractor's project manager and the supervisor of the intrusive field work subcontractor must review and sign the Risk Handling Checklist and complete Dig Permit found within the [Corporate Staff Procedure EO-28](#), Digging Projects. Requirements and questions within the Risk Handling Checklist including identification of potential failure modes and hazards, traffic control, and excavation requirements shall be addressed in the work plan. In addition to the provisions of CS-28, relevant state, local and facility requirements must be identified in the work plan and in place before initiating any work. CS-28, the Risk Handling Checklist and the Dig Permit are included in Appendix A of this document.

The permit and the checklist shall be completed and approved by the PL before initiating any ground disturbance activities. The PL shall forward these items to the Environment, Safety and Health (ESH) professional, the performing contractor responsible for oversight, and the facility manager, as necessary, for their review.

Utility and Underground Structure Clearance

A utility and underground structure location survey which includes, but is not limited to records research, consultation with site facilities personnel, site inspection to locate physical evidence of underground or overhead utilities or structures and geophysical or other appropriate remote sensing techniques must be performed by a qualified utility location firm at least two weeks prior to initiating any intrusive activities. The survey shall include the appropriate equipment necessary to detect buried foundations and slabs, piping, direct-bury cables and other buried conduits and structures using the technologies appropriate to the anticipated utilities such as electromagnetic detector; ground penetrating radar; acoustic plastic pipe locator; probe, beacon, or trace wire; or cesium magnetometer. A table summarizing applicability of technologies for detecting various utilities is presented in Appendix B.

Because undocumented or inactive utilities can result in problems as severe as or more severe than documented utilities, utility location work must include, at minimum, ground penetrating radar as a screening tool to identify objects that may not be documented on utility record plans and other records.

The utility location/survey firm operators shall have at least 2 years of experience on industrial sites and preferably direct experience on the site under review. The utility survey firm shall be approved by the Lockheed Martin PL.

In addition to the utility survey, the state or other legally-mandated utility clearing organization (“Dig Safe,” “U-Dig” or other such organization) having jurisdiction over the region in which the work is to occur, shall be notified within the time period required by that organization, state and local regulations. Even if all of the work is conducted entirely on Lockheed Martin or other private property, the utility clearing organization shall be contacted.

All aboveground indicators of subsurface and overhead utilities/services that may be leading to or from buildings and structures within the planned intrusive work area must be located and marked out in the field. Locations of utilities and structures detected by remote sensing equipment shall also be marked out in the field. Public utility mark-outs by for all exterior locations must be identified within required time period. Physical evidence of underground or overhead utilities may include, but is not limited to lights, signs, telephone systems, drains, electrical junction boxes, manhole covers, valve boxes, hand holes, pavement patching or other evidence of prior excavations, and natural gas meters.

The contractor shall make all efforts to avoid known or observed utilities in planning the work. If, however, subsurface structures are known or observed by geophysical survey within five feet of the work area and the work area cannot be moved, the performing contractor and/or its subcontractor shall carefully excavate to within two vertical feet of the expected top of the utility, then hand dig, air lance or otherwise gently remove the remaining soil to expose the utility. Additional precautions shall be described in the work plan if the intrusive work is to be performed in frozen soils.

The performing contractor must witness the utility clearance work to verify that the expected scope is performed and be available to work with the utility location contractor to answer questions and facilitate additional research or discussions with site facilities personnel.

The utility clearance contractor’s report must include details concerning the methods used to locate utilities and documentation of how specific utilities were located in plan and depth, including a copy of instrument output when instruments producing output are used. It is not sufficient for the report to merely state that the utilities on the site plan were verified or that no utilities were found without providing supporting documentation.

Pre-Planning for Soil Fracturing and In Situ Injection Work

If subsurface disturbance activities such as soil fracturing or geophysical techniques that significantly alter the natural soil conditions are to be employed, the utility location survey shall be conducted at least one month prior to any chemical injection. Attention must be given not only to the locations of utilities and underground structures but also to the fact that utilities, structures and earth bedding can provide short-circuit pathways for the injected substance to travel significant distance to be intercepted by other utilities (sewers and drains), to be accumulated in undesirable locations (manholes or handholes) or to be discharged to surface waters.

Additionally, an aquifer assessment should be conducted to determine the nature of the aquifer receiving the chemical injections before and after any subsurface disturbance is conducted. Calculations and chemical injection volumes shall be determined as to what volume of chemical would be expected to fill the opened up pore space. An evaluation must be made of the quality and quantity of the data and assumptions that form the basis for design. Examples of typical data requirements that form the basis for design include aquifer

transmissivity, soil type, effective porosity, contaminated thickness, presence of confining layers, potentiometric surface configuration, and ambient groundwater flow velocity.

Upon completion of soil fracturing, the field data collected shall be thoroughly reviewed and assessed relative to the types and sizes of the resultant fractures and potential connection of fractures to short circuit migration pathways. Injection can proceed only after this review is completed and appropriate monitoring and contingency measures are in place to detect and prevent unwanted migration of injected medium.

A technical expert in the injection technique shall be employed and fully integrated in the project team. The PL will have responsibility for engaging the technical expert. This expert will be part of the managing contractor staff and shall have responsibilities including reviewing and approving the technical and functional requirements, the design, the work plan, and the injection procedures. This expert will engage with the PL to ensure that all potential failure modes and effects have been identified and mitigation strategies employed as necessary. The failure modes and mitigation strategies shall be documented and submitted to the PL for records retention.

Field Implementation Activities

All field personnel must review the approved work plan, subsurface utility location survey data, and related information prior to becoming involved in subsurface disturbance/intrusive activities. The field personnel must sign the authorization form in Appendix C indicating their review. This form shall be scanned and electronically submitted to the PL once all personnel have signed the form.

Change Management

Significant changes made during the field implementation should be avoided as much as possible. If such changes are required to the field work plan, the program should be temporarily suspended as long as is necessary so that effectiveness and unintended consequences can be thoroughly evaluated by the project manager, PL and performing contractors (including specialty subcontractors) and the necessary equipment and procedural changes can be developed, communicated, approved and implemented. The PL should be contacted immediately and the performing contractor overseeing the work shall be included in any decisions to modify the approved work plan.

In Situ Injection Implementation

If soil fracturing is required before chemical injection, injection can proceed only after review of the fracture patterns is completed, as stipulated in the “Pre-Planning” section and appropriate monitoring and contingency measures are in place to detect and prevent unwanted migration of injected medium. The contingency measure shall be outlined in the work plan. If monitoring shows that the injected compound is detected in unwanted locations (such as a storm drain or sewer), injection shall be halted and measures taken to prevent further unwanted migration.

The chemical injection method should be thoroughly defined in the work plan and followed during the field implementation program. If chemical daylighting (surface leaks from subsurface injections) or seeps are observed the injection should be immediately stopped. The surface leaks should then be properly contained to prevent runoff and allowed, if feasible, to percolate back into the subsurface. As a result of this condition, subsequent injection rates should be reduced by at least 20% or until chemical daylighting is no longer observed.

In most cases, low pressure methods should be employed whereby gravity or low flow recirculation systems are established to let the chemical slowly percolate into the subsurface. In no case should the injection pressures at or near the surface be greater than the available water table elevation distance to the ground surface unless approved by the PL or the PL’s designated representative. Water table elevation changes as a result of chemical injections must be monitored and kept to a minimum as much as practicable.

Spill Prevention, Containment, Cleanup and Reporting

Chemicals stored onsite, including oil and fuels, reagents, injection medium, shall be placed in vessels within 110% volume secondary containment. Good housekeeping procedures must be practiced. Even benign reagents are contaminants if they migrate to a sensitive receptor. In no case should incidental spills or transfer leaks be tolerated on the site. All spills must be contained, cleaned and reported immediately to the site's spill response coordinator and the Lockheed Martin PL. Local storm drains should be temporarily plugged or booms or berms be placed to divert storm water flow from the storage area away from active storm drains.

DEVIATIONS

All deviations from this procedure must have prior approval by the Director of Environmental Remediation. The approval shall be documented and uploaded to the Lockheed Martin Document Management System.

APPENDIX A



EO-28



Dig Permit



Risk Handling
Checklist

APPENDIX B



Utility / Underground
Structure Clearance 1

APPENDIX C



Invasive Fieldwork
Authorization

Enterprise Operations Procedure EO-28
Revision No: Original
Effective: January 26, 2009
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Digging Projects

Form EO-28-1, Dig Permit | Form EO-28-2, Risk Handling Checklist

1.0 Applicability

This procedure applies to digging projects at facilities operated by Corporate Headquarters or Enterprise Business Services (collectively, "Enterprise Operations"). A "digging project" or "dig" is any subsurface excavation, including trenching. Small areas of hand excavation (less than four inches deep), where the excavated material is put back in the same location, are not considered digs and are excluded from this procedure.

2.0 Purpose

To prevent facility damage, minimize disruptions to operations, provide for the proper handling of environmental issues, and ensure that digs are properly coordinated and safely performed.

3.0 Implementation

3.1 The Project Manager (the Lockheed Martin employee responsible for the dig) will complete the activities below before the dig begins:

- Coordinate with Enterprise Operations Environment, Safety & Health (ESH), who will review the project plans for environmental risk and develop handling plans as required, obtain any environmental permits required by law or regulation, and determine the method of soil disposal when part of the project.
- Have the local utility identification service and Lockheed Martin organizations such as Telecommunications identify and mark underground utilities/obstacles within 10 feet of the dig area.
- Prepare and sign form [EO-28-1](#), Dig Permit. Obtain signatures from the Building/Facility Manager, local internal customers, Telecommunications, and ESH.
- Review and sign form [EO-28-2](#), Risk Handling Checklist.
- Meet with the contractor or Lockheed Martin organization that will perform the dig to communicate the location of underground utilities/obstacles; ensure that appropriate safety precautions such as those in [EO-20](#), Contractor Requirements, have been taken; and identify any state or local requirements, customer direction such as launch lock-down periods, or other conditions that will affect the dig.
- Inform Industrial Security of the dig and support requirements such as traffic control.
- Put barricades around the excavation site to prevent unauthorized persons from approaching. Put warning lights around the site if the excavation will remain uncovered at night, unless the dig location does not warrant warning lights.

3.2 Lockheed Martin employees must not dig or enter any excavation that is more than four feet deep.

3.3 As applicable, ESH will monitor the dig for environmental compliance, and oversee the implementation of risk handling plans, and disposal of soil.

3.4 When the dig is complete, the Project Manager will inform the individuals who signed the [Dig Permit](#).

4.0 Responsibilities

Building/Facility Manager

4.1 Have overall approval authority and responsibility for dig projects.

Project Manager

4.2 Ensure that the dig complies with this procedure.

4.3 Retain the [Dig Permit](#) and [Risk Handling Checklist](#) until the project is complete. Any other permits related to the dig must be retained in accordance with [RM-001](#), Corporate Records Retention Schedule.

Contractors

4.4 Are responsible for ensuring that their work complies with OSHA regulations.

5.0 Deviation

Any deviation from this procedure requires the prior approval of the Vice President Human Resources Enterprise Operations or designee.

//s// Kimberly S. Adams

Vice President Human Resources Enterprise Operations



Dig Permit

See Enterprise Operations Procedure [EO-28](#), Digging Projects, for instructions.

Date	Project Manager		
Building/Location			
Purpose of excavation			
Company/LM organization performing dig			
Planned dig date	Duration	Start time	
Expected depth	Width	Length	
Underground utilities identified? ☐ Yes ☐ No	Overhead utilities? ☐ Yes ☐ No ☐ N/A	Electrical lines? ☐ Yes ☐ No	Gas lines? ☐ Yes ☐ No
Sewer? ☐ Yes ☐ No	Water? ☐ Yes ☐ No	Telecommunications? ☐ Yes ☐ No	Other? Specify: ☐ Yes ☐ No
Site-specific or customer utility locating requirements completed? ☐ Yes ☐ No ☐ N/A			
Sketch of dig project (or attach drawing)			
Project Manager	Date	Customer	Date
Telecommunications	Date	Customer	Date
ESH	Date	Customer	Date
Building/Facility Manager			Date



Risk Handling Checklist

Project Manager: Use this checklist to develop risk handling plans before the dig starts. You must also review Enterprise Operations Procedure [EO-28](#), Digging Projects.

General Questions	☐ What Lockheed Martin processes could be affected by the dig?
	☐ What are the safety hazards?
	☐ What could fail?
	☐ How could it fail?
	☐ Does the area need to be returned to its normal state when the work is complete?
	☐ How could the dig affect operations/test/production?
	☐ Have potential risks been addressed with area management?
	☐ Am I comfortable with any risk handling plans, understanding the potential impact?
Traffic Control	☐ Ensure proper signage and communication.
	☐ Coordinate road or access closures through Industrial Security before starting the dig.
	☐ Ensure the work area is isolated from foot traffic by placing barriers and warning lights as required by EO-28 .
	☐ Ensure that vehicle traffic will be safe.
	☐ Ensure that product transport will be safe.
Excavation	☐ Review facility drawings to identify utilities. Research old drawings as necessary.
	☐ Discuss the project with Facility Engineering/Maintenance staff who may have unique knowledge about the construction area not documented in facility drawings.
	☐ Process form EO-28-1 , Dig Permit. Use this opportunity to explain the process and relate expectations to the contractor/LM organization that will perform the dig.
	☐ Have LM Telecommunications and the local utility identification service locate and mark utilities/underground obstacles.
	☐ Coordinate with other ongoing projects in the affected area.
	☐ Make every effort not to excavate around live utilities in service. Schedule an outage in advance or have Maintenance temporarily shut down and isolate the utilities while excavating.
	☐ If live utilities cannot be shut down while excavating, know where to isolate or shut them down if they are damaged while excavating.
	☐ Have a spotter(s) work with the equipment operator. Hand dig when necessary.
	☐ Excavate along the side of the utility; not on top.
	☐ Weather may affect the dig. Ensure water pipes are protected during freezing weather, especially if the trench will be left open over night. Rain may cause the side of the trench to slough, which can undermine and break pipes/conduit.
	☐ Ensure care when moving trench boxes in and out of trenches so pipes/conduit aren't damaged by the boxes.
	☐ Ensure surface drainage is controlled so that water doesn't get into the excavation and undermine soil supporting utilities.
	☐ Ensure stocked material is kept far enough back (minimum 2 feet) so that material and rocks don't fall on utilities in the open hole.
	☐ Ensure backfilling is done carefully: Re-bed utilities with proper material, filling all voids below. Keep inappropriate material from falling on or being placed in the trench. Be careful when compacting backfill in the two feet directly above the utility.
	Personal Safety
☐ Ensure that the equipment operator digs slowly and remains in control.	
☐ Ensure that trenching and shoring methods comply with the applicable OSHA regulations and are overseen by a "Competent Person," as defined in those regulations.	
☐ Regularly inspect methods to prevent violations.	
☐ Ensure LM employees do not dig or enter any excavation that is more than four feet deep.	
Project Manager signature indicating completion of checklist review Date	

NOTE: Each project may have unique conditions, therefore do not use this chart as the sole decision selection. Use the chart as a starting point to assess available technology(s) applicable.

KEY	Description
Green	Generally and applicable technology
Yellow	May or may not be applicable
Red	Not generally applicable
*	Indicates best technology for given object. Site structures, rebar in concrete performance and reliability of any electromagnetic method.
□	Metallic lines that have power running through them or can be connected to
◆	Natural gas pipeline locating technicians must be trained/certified. US require Safety Standards.
∇	Most sensitive to interpretation; the skill, training, and experience of the operator
≡	Emerging technology with limited availability.
+	Access: induce unique electronic signature, apply acoustical impulse, or insert

Subsurface Mark-out Technology Application Chart

Technology → Object ↓	Electro-Magnetic Detector	Ground Penetrating Radar (GPR) ∇	Acoustic Plastic Pile Locator	Probe, Beacon Sonde, or Trace Wire
Power/Instrument Line (Energized/Signaled □)	*	Y	R	R
Power Line (Non-energized)	Y	*	R	R
Sewer/Water Line (Metallic)	*	> 12" diameter G < 12" diameter Y	Y	G
Sewer/Water Line (Non-metallic)	R	> 12" diameter G < 12" diameter Y	G	*
Instrument/Telecomm Lines (non-energized)	R	R	R	R
Natural Gas Line (Pipeline) ◆	*	> 12" diameter G < 12" diameter Y	R	R
Metallic/Non-metallic Line (w/ Tracer Wire)	*	> 12" diameter G < 12" diameter Y	Y	Y
Metallic/Non-metallic Line (w/o Tracer Wire)	R	> 12" * diameter G < 12" * diameter Y	Y	Y
Metal UST	*	*	R	R
Fiberglass UST	R	G	R	R

Additional Considerations

Technology → Variable ↓	Electro-Magnetic Detector	Ground Penetrating Radar (GPR) ∇	Acoustic Plastic Pile Locator	Probe, Beacon Sonde, or Trace Wire
Moist Soil	G	Y	G	G
Dry Soil	Y	G	Y	G
Clay	Y	R	G	G
Concrete w/Rebar	R	Y	G	G
Long Horizontal Profile	G	G	G	G
Short Horizontal but Deep Vertical Profile	Y	G	R	R
Access to Line +	G	N/A	G	G
No Access to Line +	Y	G	R	R
Ferrous Metal	G	G	G	G
Non-Ferrous Metal	Y	G	G	G

n criteria for technology

, etc. can significantly affect
a tracer signal generator.
res DOT, Office of Pipeline
rator are critical.
ert probe/beacon/sonde.

Cesium Magnetometer ≡
Y
Y
Y
Y
R
G
Y
R
G
Y

Cesium Magnetometer ≡
Y
G
Y
R
G
G
N/A
G
G
Y

Lockheed Martin Invasive Fieldwork

Project: _____

Fieldwork Description:

By signing this form, you are indicating that you have reviewed the field work plan, utility location survey data, and Health and Safety Plan relevant to the project listed above.

Name:	Date:
1. _____	_____
2. _____	_____
3. _____	_____
4. _____	_____
5. _____	_____
6. _____	_____
7. _____	_____
8. _____	_____
9. _____	_____
10. _____	_____
11. _____	_____
12. _____	_____
13. _____	_____
14. _____	_____
15. _____	_____
16. _____	_____

This form shall be scanned and electronically submitted to the Lockheed Martin Project Lead.

Appendix B

Project Operation Plans (POPs)

Lockheed Martin Wilmington

Project Operating Procedure

POP-001

Recording of Field Data

1.0 Scope and Applicability

1.1 Purpose and Applicability

This Project Operating Procedure (POP) provides instructions for recording data when documenting a sample collection event, field measurements, or a site visit. Field data may be recorded in field logbooks, on standardized forms, as annotated maps, as photo documentation, or electronically.

2.0 Health and Safety Considerations

Not applicable.

3.0 Interferences

Not applicable.

4.0 Equipment and Materials

4.1 The following materials are necessary for this procedure:

- Bound field logbook (preferably waterproof, such as Rite-in-Rain™)
- Standardized field data sheets (refer to individual POPs for test pit logs, boring logs, groundwater sample collection logs, etc.)
- Pen or Sharpie™
- Watch or other time-keeping device

4.2 The following materials may also be needed:

- Site maps
- Clipboard

- Three-ring binder or equivalent
- Camera
- Hand-held electronic recording device (e.g., personal digital assistant [PDA], laptop, or tablet personal computer [PC])

5.0 Procedures

5.1 General

- 5.1.1** Field activities vary widely and no general rules can specify the exact information that must be recorded for each event. However, the field records must contain sufficient detail so that persons going to the site could reconstruct a particular situation without reliance on the collector's memory.
- 5.1.2** Field logbooks may be supplemented by standardized forms (e.g., boring logs, well construction records, well development forms, sample collection forms, waste inventory logs). In that case, the logbook provides a chronology of daily events, summary of personnel on site, and a narration of events not covered by the standardized forms. It is recommended that the details recorded on the standardized forms not be replicated in the logbook due to the potential for transcription errors and inconsistencies. References to standardized forms must be included in the logbook.
- 5.1.3** Entries will be recorded legibly in permanent ink (a black ballpoint pen is preferable) and will be signed and dated. No erasures or obliterations will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark which is initialed and dated by the sampler, and the correct information added.
- 5.1.4** Pencil should not be used. If a ballpoint pen cannot be used because of adverse weather conditions (rain or freezing temperatures), a fine-point Sharpie™ is an acceptable substitute. If conditions are such that only pencil can be used, an explanation must be included in the logbook and the affected data should be photocopied, signed as verified copy, and maintained in the project files as documentation that the data has not been changed.
- 5.1.5** Information to be recorded should address the questions of who, where, what, when, how, and why. A specific list of information that should be recorded is included in Table 1.
- 5.1.6** Entries will be objective, factual, and free of personal feelings or inappropriate language. Cryptic notes and undefined abbreviations or acronyms should be avoided.
- 5.1.7** Information will be recorded in as close to real time as possible. Information recorded significantly after the fact (e.g., the following day) must be dated as such.

5.2 Field Logbooks

- 5.2.1** Field logbooks will be bound water-proof field survey books or notebooks with consecutively numbered pages.
- 5.2.2** Logbooks will be assigned to field personnel, and will be identified by a unique document number. The logbook should be kept in the field person's possession or in a secure location during field activities and archived in the project files upon completion of the field program.
- 5.2.3** Logbooks should be specific to a project. Multiple projects should not be included in one logbook because of document retention and evidentiary reasons.

5.2.4 The title page of each logbook will contain the following:

- AECOM office location and phone number,
- The logbook number,
- Project name, reference information, and Project Manager, and
- Start and end dates of work covered by the logbook.

5.2.5 Logbook entries documenting sample collection or field measurements must clearly identify the task being completed (for example, water level measurements, headspace readings). Units must be included for all measurements.

5.2.6 For ease of reference, it is recommended that a new page be started for each sampling day and that the time be recorded in the far left column. Each day's entries will be signed and dated by the person making the entries. A diagonal line across the bottom of the page will indicate the end of an entry.

5.3 Standardized Forms

5.3.1 At a minimum, each form must include a title identifying the activity being documented and the project identification (name and number).

5.3.2 Each form must be signed and dated by the person completing the form.

5.3.3 There should be no blank spaces on the form. Each space must be filled in with the information requested or "NA" (not applicable).

5.3.4 Forms should not be loose, but should be maintained in an organized manner (e.g., clipboards, binders).

5.4 Maps and Drawings

5.4.1 Maps and drawings that document final sampling locations and which are separate from the field logbook must be referenced in the logbook. These maps or drawings must include the project name and number, site identification and location, and must be signed and dated by the person recording the locations.

5.4.2 Maps and drawings must include compass orientation and scale.

5.5 Photographs and Other Photo Documentation

5.5.1 Photo documentation, if permitted at the site, can provide invaluable information on site conditions, sample locations, and the sample itself.

5.5.2 Photographs, videos, or slides must be cross-referenced to entries in the field logbook or on a photo documentation log. Information to be recorded includes name of photographer, date, time, direction faced, description of subject, and sequential number of the photograph. An indication of scale is also helpful. Image-enhancing techniques (lenses, film) should also be noted.

5.6 Electronic Files

5.6.1 Electronically captured data may include data logging systems and hand-held electronic recording devices such as PDAs, laptops, or tablet PCs.

5.6.2 Field data that is captured electronically must be cross-referenced in the field logbook. Information to be recorded includes the identity of the person recording the data, instrument make and model number, measurement time and date, and file identification.

- 5.6.3** Sufficient backup systems must be in place to protect against the loss of data. Electronic files must be saved to a disk or backed up immediately upon completion. The backup disk or other media (CD, flash drive) should then be stored in a secure location separate from the laptop, tablet, or PDA.
- 5.6.4** Files must be uniquely identified and should be stored in the project files on the network. An unedited version of the file must be maintained and all subsequent manipulations tracked.

6.0 Quality Assurance / Quality Control

- 6.1** Field records provide evidence and support for technical decisions, interpretations, and judgments. It is therefore critical that procedures and systems be in place to ensure that they are legible, identifiable, and retrievable, and protected from loss or damage. In addition, client or regulatory requirements, or the end use of the data (e.g., to support litigation) may determine the format in which the data must be recorded. For example, some projects may require that all field information be recorded in the field logbook and may not allow the use of standardized forms. The requirements necessary to meet the data quality objectives for a particular project will be defined in the site-specific workplan and/or Quality Assurance Project Plan (QAPP) hereafter referred to as the project plan.
- 6.2** The field records will be reviewed by the Field Team Leader, or by the Project Manager or his/her designate, for accuracy, completeness, and adherence to the requirements of this POP. At a minimum, this must occur at the end of the field event. For field activities of extended duration, it is recommended that this review occur more frequently (e.g., daily or weekly).
- 6.3** If information recorded in the field is transcribed to another format, the original record must be retained for comparison purposes.
- 6.4** Periodic copying of the field records should be considered to insure against the loss or destruction of the original documents.

7.0 Data and Records Management

- 7.1** At the end of the field program, original field records must be placed in the project files and maintained for a certain retention time. The duration of record retention will be determined by project-specific requirements, or, in the absence of project requirements, by corporate policy.

8.0 Personnel Qualifications and Training

- 8.1** The Project Manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this POP and the project plan. In the absence of a Field Team Leader, the Project Manager is responsible for ensuring that field records are reviewed and approved as described below.
- 8.2** The Field Team Leader is responsible for reviewing and approving the field records for accuracy, completeness, and conformance to the procedures in this POP.
- 8.3** Field personnel are responsible for recording data according to the procedures outlined in this POP.

9.0 References

USACE. 2001. Requirements for the Preparation of Sampling and Analysis Plans. EM 200-1-3. United States Army Corps of Engineers. 1 February 2001.

USEPA. 2004. Contract Laboratory Program Guidance for Field Samplers. OSWER 9240.0-35. EPA540-R-00-003. United States Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation. August 2004.

USEPA. 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. United States Environmental Protection Agency, Region 4, Athens, GA. November 2001.

USEPA. 1998. Test Methods for Evaluating Solid Wastes. Physical/Chemical Methods (SW-846). Third edition, including all final updates.

USEPA. 1992. RCRA Ground-water Monitoring: Draft Technical Guidance. United States Environmental Protection Agency, Office of Solid Waste, Washington, DC. November 1992.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Table 1 Specific Information to be Recorded

- Site name and location
- Personnel on site (clients, site contacts, regulators, oversight personnel, subcontractors, general public)
- Results of phone calls, conversations
- Chronology of activities, including mobilization, investigatory activities, and demobilization
- Weather conditions (initial and any changes; temperature, barometric pressure, wind conditions, precipitation)
- Tidal stage (if applicable)
- Inspections of equipment, materials, supplies (problems, corrective action)
- Subcontractor name, description of services to be provided, and any issues (problems, stand by time)
- Description of major equipment (drill rigs, backhoe, survey vessels, sampling platforms)
- Field measurements
 - o Description of procedure
 - o Instruments (make, model, serial number, lamp)
 - o Instrument calibration (date, time, personnel, standard, lot number, standard expiration date, true/measured results, units, corrective action, calibration checks and results)
 - o Results (including units of measure, any correction factors applied, documentation of calculations (if applicable))
 - o Total depths of monitoring wells will be measure annually where possible
 - o Date and time of measurement
 - o Identity of person performing the measurements
 - o Atmospheric conditions (if applicable)
- Equipment decontamination procedures and materials
- Well information (depth to water, static water depth, condition of well)
- Well purging information (procedure, equipment, volumes, pumping rate, criteria for acceptance, time and date)
- Presence and detection of immiscible layers, detection method, sampling method
- Sampling information
 - o Procedures and equipment (type and material)
 - o Sample (soil) selection criteria/rationale (PID, staining, water table)
 - o Sample location identification (e.g., boring, well identification)
 - o Sample location description (sketch, GPS coordinates, compass and distance measurements from fixed points).
 - o Sample depth
 - o Sample flow rate/drawdown
 - o Sample description (recovery, moisture, color, odor, texture, turbidity, artifacts)
 - o Sample manipulations (filtration, homogenization, compositing, preservation)
 - o Sample date and time
 - o Unique sample ID
 - o Identity of sampler
 - o Sample parameters, containers (size/type), preservation
 - o QC samples (field duplicates, trip blanks, field/equipment blanks, MS/MSDs, split samples) – include ID, associated field sample, method of collection
- Any pertinent field observations that could affect data quality (instrument problems, contamination sources)
- Deviations from approved plan (schedule modifications, relocation or elimination of sample locations, change orders), including rationale
- Investigation-derived waste (IDW) types, volumes, storage, and disposal
- Health and safety (H&S) meetings, personal protective equipment (PPE) worn, H&S monitoring

Lockheed Martin Wilmington

Project Operating Procedure

POP-002

Chain-of-Custody Procedures

1.0 Scope and Applicability

- 1.1** Chain of custody (COC) is defined as the unbroken trail of accountability that ensures the physical security of samples, data, and records (USEPA Glossary of Quality-Related Terms). This Project Operating Procedure (POP) describes COC procedures applicable to environmental samples collected by AECOM during field sampling and analysis programs. Custody procedures within the laboratories analyzing the samples are not addressed.
- 1.2** Samples are physical evidence. The objective of COC procedures is to provide sufficient evidence of sample integrity to satisfy data defensibility requirements in legal or regulatory situations.
- 1.3** The National Enforcement Investigations Center (NEIC) of the United States Environmental Protection Agency (USEPA) defines custody of evidence in the following manner:
- It is in your actual possession;
 - It is in your view, after being in your physical possession;
 - It was in your possession and then you locked or sealed it up to prevent tampering; or
 - It is in a secure area.

2.0 Health and Safety Considerations

- 2.1** The health and safety considerations for the work associated with this POP, including both potential physical and chemical hazards, will be addressed in the site-specific Health and Safety Plan (HASP). In the absence of a site-specific HASP, work will be conducted according to the AECOM Health and Safety Policy and Procedures Manual and/or direction from the Regional Health and Safety Manager

3.0 Interferences

- 3.1** The following may impact the legal or regulatory defensibility of the data:
- The samples are not accompanied by a COC form,
 - The information recorded on the COC form is incomplete, inaccurate, or differs from the information recorded on the sample containers,

Project Operating Procedure

Chain-of-Custody Procedures

POP-002

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4.0 Equipment and Materials

4.1 The following materials are relevant to this procedure:

- COC Form (Figure 1)
- Sample labels
- COC tape or seal
- Indelible pen or Sharpie™
- Clear plastic sealing tape

4.2 Materials identified in related POPs may also be needed

5.0 Procedures

5.1 Pre-sample collection activities

5.1.1 Some measurement methods require preparation of sample collection media or special treatment of sample containers prior to sample collection. In these cases, COC procedures should be initiated with the media preparation or container treatment. This requires that sample identification numbers or media/container identification numbers be assigned. These numbers should be entered on the COC form, leaving room for the subsequent recording of the associated sample numbers. In this variation, the custodian responsible for media preparation or container treatment has the responsibilities outlined in Section 5.2, and the sampler or field sample custodian has the responsibilities stated in Section 5.3 when he or she receives the prepared media or treated containers. There are a number of acceptable approaches to this variation, and the detailed procedures should be defined in the project-specific QAPP.

5.2 Sample collection phase

5.2.1 As few people as possible should handle the samples. For certain programs, it is helpful if a single person is designated as the sample custodian (the person responsible for the care and custody of the samples until they are transferred to the laboratory for analysis).

5.2.2 While in the field, sampling personnel should be able to testify that tampering of the samples could not occur without their knowledge. Examples of actions taken may include sealing the sample containers with COC tape or locking the samples in a secure area.

5.2.3 If samples are to be shipped by commercial overnight carrier, the field sampler or sample custodian completes a COC form for each cooler/package of samples and places the original of completed form inside the associated cooler/package before the package is sealed (a copy is retained and kept in the field record files). Each completed COC form should accurately list the sample identification numbers of the samples with which it is packaged, and should contain the identification number of the COC tape on the cooler/package. Representatives of commercial carriers are not required to sign the COC form.

5.2.4 If samples are hand carried to a laboratory, the person hand carrying the samples is the sample custodian. If the carrier is a different person than the one who filled out the COC form and packaged the samples, then that person transfers custody to the carrier by signing and dating each form in the "Relinquished By" section. The carrier then signs and dates each form

Project Operating Procedure

Chain-of-Custody Procedures

POP-002

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in the adjacent "Received By" section. When the carrier transfers the samples to the laboratory, he or she signs and dates each form in the next "Relinquished By" section, and the laboratory sample custodian signs and dates each form in the adjacent "Received By" section.

- 5.2.5** If samples are transmitted to the laboratory by courier, the procedures described in either Section 5.2.3 or 5.2.4 are followed, depending on whether the courier is a commercial courier or laboratory representative, and whether the cooler has been secured by COC seals prior to pick up by a laboratory courier.

5.3 Sample labeling

- 5.3.1** Labeling of samples occurs at the time of sample collection.

- 5.3.2** Waterproof, adhesive labels are preferred. Labels should be applied to the container, not the lid whenever possible. Additional interior labels may be required for certain biological samples.

- 5.3.3** Sample tags may be required for certain samples. If tags are utilized, their use will be addressed in the specific work plan or Quality Assurance Project Plan (QAPP).

- 5.3.4** Labels should be completed in waterproof, indelible ink. Covering the label with clear plastic tape is recommended to protect the legibility of the label and to prevent the label from detaching from the sample container.

- 5.3.5** The following information should be recorded on the sample label:

- Project identification (project name and number/client/site)
- Field sample identification code (exactly as it appears on the COC form)
- Sampler's initials
- Date and time of sample collection
- Analyses requested
- Preservation

5.4 Documentation of sample history

- 5.4.1** Sample history includes, but is not limited to, preparation of sample containers or collection media (for example, wipes), collection, handling (such as subsampling or compositing), storage, shipment, analytical preparation and analysis, reporting, and disposal.

- 5.4.2** Refer to the Recording of Field Data POP 001, for specific guidance on documentation of field activities, field measurements, and sample collection.

5.5 Documentation of custody

- 5.5.1** It is recommended that a COC form be initiated upon sample collection. If this is not feasible for a particular event, the COC form may be initiated at the time of sample packaging. If this is the case, the sample collection records will serve as the initial custody document and will document the collection of the sample (sample location and identification, date and time of collection, sampler, and parameters to be analyzed, including containers and preservatives).

5.6 The following information is recorded on the COC form:

- Project identification (AECOM project number, client, site name and location).
- Page number (for example, 1 of 2, 2 of 2).

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Chain-of-Custody Procedures

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- Field sample identification code. This code should be unique to the sampling event and to the program. This code should agree exactly with the field sample identification code recorded on the bottle label.
- Sampling point location (optional if recorded elsewhere in field records).
- Date and time of sample collection.
- Sample matrix (soil, water, air, etc.).
- Preservative.
- Analysis requested.
- Number of containers.
- Type of sample (grab or composite). Identifying if aqueous samples have been filtered in the field is recommended.
- Signature(s) of sampling personnel and signatures of all personnel handling, receiving, and relinquishing the samples.
- Date(s) and time(s) of each sample transfer.
- Sampler remarks. These comments may serve to alert the laboratory to highly contaminated samples or identify quality control (QC) sample requirements.
- Airbill number (if shipped by overnight commercial carrier).
- Laboratory name and address.

5.7 COC tape numbers.

- 5.7.1** The COC is filled out completely and legibly in indelible ink. There should be no unexplained blank spaces. Blank lines should be lined out and initialed and dated.
- 5.7.2** Data will not obliterated. Corrections are made, if necessary, by drawing a single line through and initialing and dating the error. The correct information is then recorded with indelible ink.
- 5.7.3** Information on the COC should agree exactly with that recorded on the sample containers. Discrepancies may result in the samples being incorrectly logged into the laboratory or delays in initiating sample analysis.

5.8 Sample receipt and inspection

- 5.8.1** Upon sample receipt, the coolers or packages are inspected for general condition and the condition of the COC tape. The coolers or boxes are then opened and each sample is inspected for damage.
- 5.8.2** Sample containers are removed from packing material and sample label information is verified against the COC form.
- 5.8.3** The condition upon receipt, including any discrepancies or problems, is documented and the COC form is completed by signing and recording the date and time of receipt.
- 5.8.4** Receipt and inspection of samples by subcontractor analytical laboratories will adhere to written procedures established by the laboratory.

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6.0 Quality Assurance / Quality Control

- 6.1 The records generated in this procedure are subject to review by the sampling team leader, project manager, or designee.
- 6.2 The records generated in this procedure will become a part of the evidence reviewed in the data validation process (see QAPP).
- 6.3 The field team leader is responsible for reviewing the chain-of-custody forms for completeness and accuracy prior to sample shipment.

7.0 Data and Records Management

- 7.1 The records generated in this procedure are part of the permanent record supporting the associated measurements and may include, as applicable, the COC forms, sample tags, carrier waybills, and field and laboratory records of sample history (collection, handling, storage, analysis, etc.).
- 7.2 Unanticipated changes to the procedures or materials described in this POP (deviations) should be appropriately documented in the project records.
- 7.3 Records associated with the activities described in this POP should be maintained according to the document management policy for the project.

8.0 Personnel Qualifications and Training

- 8.1 Qualifications and training
 - 8.1.1 The individual executing these procedures should have read, and be familiar with, the requirements of this POP.
 - 8.1.2 No specialized skills are necessary in order to implement these procedures; however, an understanding of the concept of custody is useful.
- 8.2 Responsibilities
 - 8.2.1 The project manager is responsible for providing the project team with the materials, resources and guidance necessary to properly execute the procedures described in this POP.
 - 8.2.2 The individual performing the work is responsible for implementing the procedures as described in this POP and any project specific work plans.
 - 8.2.3 For certain sampling programs, the project manager, sampling team leader, or designee may assign an individual to serve as sample custodian. This individual is responsible for supervising the implementation of COC procedures in accordance with this POP and any project-specific work plans or QAPP.

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Chain-of-Custody Procedures

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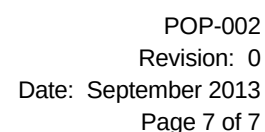
9.0 References

American Society for Testing and Materials (ASTM). 2004. Standard Guide for Sample Chain-of-Custody Procedures. D 4840-99 (Reapproved 2004). ENSR SOP 1009 – Data Validation.

United States Environmental Protection Agency. 2001. Guidance for Preparing Standard Operating Procedures (SOPs). USEPA QA/G-6. EPA/240/B-01/004. USEPA Office of Environmental Information, Washington, DC. March 2001.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP



		CHAIN OF CUSTODY RECORD																		Page ____ of ____					
Client/Project Name:				Project Location:						Analysis Requested										Container Type		Preservation			
AECOM Project Number: AECOM PO Number:				Field Logbook No.:																P – Plastic		1 – HCl, 4"			
Sampler (Print Name)/(Affiliation):				Chain of Custody Tape Nos.:																A – Amber Glass		2 – H2SO4, 4"			
Signature:				Send Report to:				TAT:		G – Clear Glass		3 – HNO3, 4"		V – VOA Vial		4 – NaOH, 4"		O – Other		5 – NaOH/ZnAc, 4"					
										E – Encore		6 – Na2S2O3, 4"		7 – 4"		Matrix Codes:		S – Soil							
Field Sample No./Identification		Date	Time	C O M P	G R A B	Sample Container (Size/Mat'l)	Matrix	Preserv.	Field Filtered											DW – Drinking Water		SL – Sludge			
																				WW – Wastewater		SD – Sediment			
																				SW – Surface Water		SO – Solid			
																				ST – Storm Water		A – Air			
																				W – Water		L – Liquid			
																				P – Product		P – Product			
																				Lab I.D.		Remarks			
Relinquished by: (Print Name)/(Affiliation)				Date:		Received by: (Print Name)/(Affiliation)						Date:		Analytical Laboratory (Destination):											
Signature:				Time:		Signature:						Time:													
Relinquished by: (Print Name)/(Affiliation)				Date:		Received by: (Print Name)/(Affiliation)						Date:													
Signature:				Time:		Signature:						Time:		Sample Shipped Via:										Temp blank	
Relinquished by: (Print Name)/(Affiliation)				Date:		Received by: (Print Name)/(Affiliation)						Date:													
Signature:				Time:		Signature:						Time:													
Relinquished by: (Print Name)/(Affiliation)				Date:		Received by: (Print Name)/(Affiliation)						Date:		UPS		FedEx		Courier		Other		Yes		No	
Signature:				Time:		Signature:						Time:													

Lockheed Martin Wilmington

Project Operating Procedure

POP-003

Packing and Shipment of Environmental Samples

1.0 Purpose and Applicability

This project operating procedure (POP) describes proper packaging methods and transporting/shipment of samples to minimize the potential for sample breakage, leakage, or cross-contamination, and provide a clear record of sample custody from collection to analysis. Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Task Hazard Analysis (THA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

The Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (1976) (RCRA) regulations (40 CFR Section 261.4 (d)) specify that samples of solid waste, water, soil, or air collected for the purpose of testing are exempt from regulation when any of the following conditions apply:

- Samples are being transported to a laboratory for analysis
- Samples are being transported to the collector from the laboratory after analysis
- Samples are being stored:
 - By the collector prior to shipment for analysis
 - By the analytical laboratory prior to analysis
 - By the analytical laboratory after testing but prior to return of sample to the collector or pending the conclusion of a court case

Samples collected by AECOM are generally qualified for these exemptions. POP 110 deals only with these sample types. If you have any additional questions about delivery or shipping requirements contact the AECOM Environment, Health and Safety (EHS) Department.

2.0 Responsibilities

The field sampling coordinator is responsible for the enactment and completion of the chain-of-custody and the packaging and transporting/shipping requirements outlined here and in project-specific sampling plans.

Project Operating Procedure

Packing and Shipment of Environmental Samples

3.0 Health and Safety

This section presents the generic hazards associated with packing and transporting/shipping samples and is intended to provide general guidance in preparing site-specific health and safety documents. The Site-Specific HASP and THAs will address additional requirements and will take precedence over this document. Note that packing and transporting/shipping samples usually requires Level D personal protection unless there is a potential for airborne exposure to site contaminants. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or EHS Coordinator.

Health and safety hazards with packing and transporting/shipping of samples include the following:

- Exposure to sample preservatives – Know the types of sample preservatives sent to you by the analytical laboratory. Understand the potential exposures (inhalation, ingestion skin contact) and use chemically impervious gloves to protect your hands from acids in particular.
- Anticipate the potential for spills – Glass containers are subject to breakage and if dropped on the floor will create a spill. Know how to contain the spill, have spill response materials available, and understand the proper disposal methods for spilled materials. Wear personal protective equipment (PPE) to clean up the spill as appropriate (Level C or D).
- Broken glass – Be aware of the possibility for broken glass in previously used coolers. Inspect the cooler before you place samples in it and clean out any broken glass safely (i.e. with a small brush).
- Coolers can be heavy – Use proper lifting techniques to pick up loaded coolers. Bend your legs and lift with a straight back to avoid a back injury.
- Do not use your teeth to cut tape to size, use a tape dispenser.

4.0 Supporting Materials

The following materials must be on hand and in sufficient quantity to ensure that proper packing and transporting/shipping methods and procedures may be followed:

- Chain-of-custody forms and tape
- Sample container labels
- Coolers or similar transport/shipping containers
- Duct tape or transparent packaging tape
- Zip-lock type bags
- Protective wrapping and packaging materials
- Ice
- Shipping labels for the exterior of the ice chest
- Transportation carrier forms (Federal Express, Airborne, etc.)

Project Operating Procedure

Packing and Shipment of Environmental Samples

- PPE as specified in the Site-Specific HASP
- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants (including sample preservatives)
- A copy of the Site-Specific HASP

5.0 Methods and Procedures

Samples must be packaged so they do not leak, break, vaporize, or cause cross-contamination of other samples. Waste samples and environmental samples (e.g., groundwater, soil, etc.) should not be placed in the same transport/shipping container. Each individual sample must be properly labeled and identified. A chain-of-custody record must accompany each transport/shipping container. When refrigeration is required for sample preservation, samples must be kept cool during the time between collection and final packaging.

Samples must be clearly identified immediately upon collection. Each sample bottle label (example provided as Figure 1) will include the following information:

- Client or project name, or unique identifier, if confidential
- A unique sample description
- Sample collection date and time
- Indication of filtering or addition of preservative, if applicable
- Analyses to be performed

After collection, identification, and preservation (if necessary), the samples will be maintained under chain-of-custody procedures as described below.

5.1 Chain-of-Custody

A sample is considered to be under custody if it is in one's possession, view, or in a designated secure area. Transfers of sample custody must be documented by chain-of-custody forms (example form provided in POP 002 – Chain-of-Custody procedures). The chain-of-custody record will include, at a minimum, the following information:

- Client or project name, or unique identifier, if confidential
- Sample collector's name
- AECOM's mailing address and telephone number
- Designated recipient of data (name and telephone number)
- Analytical laboratory's name and city
- Description of each sample (i.e., unique identifier and matrix)
- Date and time of collection
- Quantity of each sample or number of containers
- Type of analysis required
- Date and method of shipment

Project Operating Procedure

Packing and Shipment of Environmental Samples

Additional information may include type of sample containers, shipping identification air bill numbers, etc.

When transferring custody, both the individual(s) relinquishing custody of samples and the individual(s) receiving custody of samples will sign, date, and note the time on the form. If samples are to leave the collector's possession for transport/shipment to the laboratory, the subsequent packaging procedures will be followed.

5.2 Packing for Transport/Shipment

To prepare a cooler for transport or shipment, the sample bottles should be inventoried and logged on the chain-of-custody form. At least one layer of sorbent protective material should be placed in the bottom of the container. Be careful for any broken glass. A heavy-duty plastic bag, if available, should be placed in the transport/shipping container to act as an inner container. As each sample bottle is logged on the chain-of-custody form, it should be wrapped with protective material (e.g., bubble wrap, matting, plastic gridding, or similar material) to prevent breakage. Each sample bottle should be placed upright in the heavy-duty plastic bag inside the transport/shipping container. Each sample bottle cap should be checked during wrapping and tightened, if needed. Avoid over tightening, which may cause bottle cap to crack and allow leakage. Additional packaging material, such as bubble wrap, should be spread throughout the voids between the sample bottles.

Most samples require refrigeration as a minimum preservative. To ensure that samples are received by the laboratory within required temperature limits, place cubed ice directly over packed samples, making sure that ice is present on all sides of each sample (a 2-inch layer of ice should be present on top of the samples prior to transport/shipment).

Secure the inner heavy-duty bag with clear packing tape. This will prevent water from leaking out of the package, thus stopping shipment (package handling companies will not ship a leaking package). An acceptable alternate chilling option is to fill zipper-lock style bags with cubed ice, preferably double bagged. The bags of ice should be distributed throughout the cooler to insure proper chilling of samples.

Place the original completed chain-of-custody record in a zip-lock type plastic bag and place the bag on the top of the contents within the cooler or transport/shipping container. Alternatively, the bag may be taped to the underside of the container lid. Retain a copy of the chain-of-custody record with the field records.

Close the top or lid of the cooler or transport/shipping container and rotate/shake the container to verify that the contents are packed so that they do not move. Add additional packaging if needed and reclose. Place signed and dated chain-of-custody seal (example provided as Figure 2) at two different locations (front and back) on the cooler or container lid and overlap with transparent packaging tape. The chain-of-custody seal should be placed on the container in such a way that opening the container will destroy the tape. Packaging tape should encircle each end of the cooler at the hinges. Use proper lifting techniques when picking up the cooler.

Samples being shipped via a commercial carrier should be sent via an overnight express service that can guarantee 24-hour delivery. Retain copies of shipment records as provided by the shipper.

If transporting the samples by hand directly to the laboratory, they should be delivered within 24-hours. This applies to samples being picked up by a laboratory courier.

Project Operating Procedure

Packing and Shipment of Environmental Samples

6.0 Quality Assurance/Quality Control

Recipient of sample container should advise shipper and/or transporter immediately of any damage to the container, breakage of contents, or evidence of tampering.

7.0 Documentation

The documentation for support of proper packaging and shipment will include chain-of-custody records and the delivery receipt (if hand carried) or the transportation carrier's airbill or delivery invoice. Documentation will be retained in the project files.

8.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Project Operating Procedure

Packing and Shipment of Environmental Samples**Figure 1 Sample Label**

Sample I.D.	_____
Location	_____
Date	_____ Time _____ Sampled By _____
Test(s)	_____
Pres	_____

Figure 2 Chain-of-Custody Seal

Custody Seal	
Date	_____
Signature	_____
Seal No.	_____

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

Lockheed Martin Wilmington

Project Operating Procedure

POP-004

Procedures for Passive Sampling of Air Using SUMMA Canisters

1.0 Scope and Applicability

This project operating procedure (POP) describes the procedure for passively collecting air samples in SUMMA stainless steel canisters for the analysis of volatile organic compounds (VOCs). This method is applicable for whole-air sampling of ambient air, soil/landfill gas, or stationary sources with compounds of interest measured at the parts per billion by volume (ppbv) level. The target compounds that can be analyzed from samples collected by this method generally have a vapor pressure greater than 0.1 torr at 25 °C and 760 mm Hg.

The procedure describes the collection of passive (i.e. without the use of a pump) samples. The samples can be taken as grab sample (over a short period of time) or as integrated samples which are taken over a longer period.

2.0 Health and Safety Considerations

The health and safety considerations for the work associated with this POP, including both potential physical and chemical hazards, will be addressed in the site specific Health and Safety Plan (HASP). In the absence of a site-specific HASP, work will be conducted according to the AECOM Health and Safety Policy and Procedures Manual and/or direction from the Regional Health and Safety Manager.

Canisters are under vacuum, and should not be dented or punctured. They should be stored in a cool, dry place out of direct sunlight. They should always be placed in their shipping boxes during transport and storage.

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

3.0 Interferences

Contamination may occur in the sampling system if canisters are not properly cleaned before use. Additionally, all other sampling equipment (e.g., flow controllers and sample lines) should be thoroughly cleaned.

Particulates may clog or foul the mass flow controller or critical orifice and result in incomplete and/or inaccurate sampling. Particulate filters must be used (see section 4.2).

Moisture in the sample or liquid in the canister will adversely affect the recovery of polar compounds. Sampling ports should be purged prior to sampling to remove any entrained liquid or water vapor.

Leaks in the sampling train will lead to incomplete and/or inaccurate sampling. The sample could become diluted or the sample could leak out. All valves and fittings must be tightened appropriately. In general, Swagelok[®] fittings are finger-tightened plus ¼ turn with a wrench. Do not overtighten. When properly tightened, the pieces cannot be rotated by hand.

The sampling train should be kept out of direct sunlight to avoid temperature changes and drifting of the sample flow.

To further reduce unnecessary contamination during grab sampling, non-essential personnel should be kept away from the canister and the sampler should avoid breathing near the canister inlet during the actual sampling.

4.0 Equipment and Materials

SUMMA Canisters, 1 Liter (L) or 6L – the canisters are supplied by the analytical laboratory, already pre-cleaned and evacuated (SUMMA refers to the process by which the inside of the canister is made chemically inert). Each canister may be individually certified for the target compound of interest or may be “batch” certified. The degree of certification will depend on the end use of the data. For air sampling used for risk assessment purposes the use of individually certified canisters is recommended. For routine monitoring, “batch” certified canisters may be appropriate. Canisters designated for blanks (field or ambient) should be certified to the same degree as the associated field samples. Each canister will have a valve and inlet cap.

Particulate filter – the filter prevents particulate material from fouling or clogging the valve or flow controller. Typically, a 5 micron filter is used for 1L canisters and a 7 micron filter is used for 6L canisters. The filter may be built into the flow controller by the laboratory providing the equipment.

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

Vacuum gauge – the gauge is used to measure the initial vacuum of the canister as well as the final vacuum upon completion of sampling. It is also used to monitor the progress of sampling as the vacuum in the canister will decrease as the canister fills up. The gauge may be a separate item or may be integrated as part of the valve mechanism.

Flow controllers – regulate the rate at which air enters the canister. There are two types:

Mass flow controller – actively adjusts the sample flow to provide a constant mass through the valve. As the canister fills up and the differential pressure decreases, the sample flow into the canister would tend to decrease. The mass flow controller responds by opening up its diaphragm to allow more samples to flow through.

Critical orifice device – used most commonly. It has a built-in vacuum gauge and is recommended for field sampling. The critical orifice is calibrated by the laboratory to provide a rate at which desired volume of air will be collected over the sampling period, according to the following formula:

$$\text{flow rate (mL/min)} = \text{target fill volume (mL)} / \text{sampling interval (min)}$$

Thus, to collect 5 Liters of air over a one hour sampling interval, a flow rate of 83.3 mL/min is used. It is expected that samples will be collected at 100-200 mL/min.

Air, ultra zero – for use in preparing equipment blanks

Tubing and Fittings – as required for sampling.

Tubing – only chromatographic-grade stainless steel should be used.

Fittings – the nuts, ferrules, and other fittings should be chromatographic-grade, ¼ inch Swagelok®

Wrenches – two wrenches are needed to tighten the fittings on the tubing, valves and canisters. These are ¼ inch Swagelok® fittings, requiring 9/16 inch open ended wrenches.

5.0 Procedures

NOTE: When sampling a process under pressure or vacuum, the effects on the sample must be considered. A process under pressure will fill the canister faster and it is possible to pressurize the canister. (If a canister becomes pressurized, excess pressure must be bled off by temporarily opening the valve.) When sampling a process under vacuum, the canister fills more slowly and it may be difficult to fill the canister with the desired amount of sample.

NOTE: Actual field conditions may require minor modifications to these procedures.

5.1 Prior to sampling

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

- Verify contents of the shipped package (e.g., chain-of-custody, canister, particulate filter, gauge or flow controller)
- Verify that gauge is working properly. If the gauge does not read “zero”, it may need to be equilibrated by cracking the rubber seal at the top of the gauge. If this does not reset the indicator, the gauge may be damaged and is unusable.
- Record the initial vacuum of the canister. Canisters for passive sampling will be under a vacuum of 30 in. Hg.
- Confirm that valve is closed (knob should already be tightened clockwise)
- Remove the brass cap.
- Attach gauge.
- Attach brass cap to side of gauge tee fitting.
- Open and close valve quickly (a few seconds).
- Read vacuum on the gauge. If the vacuum is less than 28 in. Hg, do not use the canister.
- Record gauge reading on “Initial Vacuum” column of chain-of-custody.
- Verify that canister valve is closed then remove gauge.
- Replace the brass cap.

5.2 Sampling

- Remove brass cap.
- For grab samples only:
 - o Attach particulate filter directly to canister.
 - o Open valve 1/2 turn, allowing the sample into the canister (a 6L canister will normally take about 16 sec to fill). As the canister nears capacity, the sound of air rushing into the canister will change pitch.

NOTE: A grab sample can be collected either by allowing the canister to reach ambient conditions or by leaving some residual vacuum in the canister (e.g., 5 in Hg). Leaving residual vacuum is preferable. In either case, the final vacuum should be noted on the “Final Vacuum” column on the chain-of-custody. This will enable the laboratory to compare the final vacuum with the receipt vacuum (i.e., the vacuum measured upon arrival at the laboratory) to ensure sample integrity.

- For integrated samples only

Attach the flow controller to the canister and attach the filter to the flow controller. Make sure that the sample will flow through the filter in the proper direction. Some laboratories supplying the equipment may include the filter as part of the flow controller, and not as a separate piece of hardware.

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

If necessary, attach the canister assembly to the sampling port. The sampling port should be purged of liquid or water vapor prior to connecting the assembly. Do not overtighten the connectors and fittings.

Open valve 1/2 turn, allowing the sample to start flowing into the canister. Periodically monitor the progress of the sampling during the sampling interval. The volume of air sampled has a linear relationship to the canister vacuum. Thus halfway through the sampling interval, half of the sample will have collected (2.5 Liters) and the vacuum gauge should read 17 in Hg (halfway between 29 in Hg and 5 in Hg).

NOTE: Different from a grab sample canister, an integrated sample canister should not be allowed to reach ambient pressure. The flow controller is calibrated to leave approximately 5 in Hg residual vacuum in the canister and because of normal fluctuations during sampling the final vacuum will be between 2-10 in Hg. A residual vacuum less than 1 in Hg indicates that the canister may have come to ambient conditions before the completion of the sampling interval. See Section 6.5 for the effects of residual vacuum on integrated sampling.

- At the conclusion of sampling, close valve by hand tightening knob clockwise.
- Verify and record final vacuum of canister (repeat steps used to verify initial vacuum).

5.3 Post Sampling

- Replace brass cap.
- Fill out canister sample tag. The canister number, initial vacuum and final vacuum must be recorded on the sample tag and chain of custody.
- Return canister to box and place accessories (e.g. gauges, filters) in packaging provided.
- Fill out chain-of-custody and relinquish samples properly. The canister number, initial vacuum and final vacuum must be recorded.
- Tape box shut and affix custody seal (if applicable) across flap.

5.4 Ship or transport accordingly to meet method holding times.

6.0 Quality Assurance / Quality Control

Sample Preservation and Holding Time – The holding time for whole air samples is 14 days from collection to analysis. Although the TO-15 method states that most compounds can be adequately recovered up to 30 days, recovery of polar compounds is significantly reduced after 14 days.

SUMMA Canister Holding Time – Canisters must be analyzed with 30 days of preparation (evacuation by the laboratory). Care must be taken to ensure that the samples can be collected and analyzed within this time frame. If the sampling event is postponed once the canisters are in-house or in the field, it may be necessary to return them and request freshly evacuated canisters in order to meet the 30 day schedule.

Contamination – Contamination may be monitored through the use of field blanks and ambient blank samples. The collection of one blank per sampling event is recommended.

- Field Blanks are prepared by passing ultra zero air through a clean regulator and tubing into a certified canister. It can provide information about the decontamination procedures used on the tubing in the field.
- Ambient Blanks are collected over the same duration as, and are used in conjunction with, integrated samples to assess background conditions around the sampling site.

Precision and Accuracy – Precision can be assessed through the use of field duplicates which are prepared by connecting the canisters to a “tee” and filling them simultaneously. Accuracy can be assessed through the use of performance evaluation samples or certified gas standards.

Affects of Residual Vacuum

- Greater than 5 in Hg – Less than 5 Liters of sample was collected. The sample will be diluted during analysis and the reporting limits will be elevated.
- Less than 5 in Hg – The initial flow rate was high and the sample results will be biased towards the first portion of the sampling interval.
- Near ambient – The canister is “full” and the sampler will not be able to determine the actual sampling interval (when the canister became “full”).

Reporting Limits – Reporting limits are calculated from the method reporting limit adjusted for the effects of sample volume, residual vacuum and dilutions as shown in Table 1.

6.1 Table 1: Effect of Vacuum, Volume, and Dilution on Reporting Limits

Final Vacuum (in. Hg)	0	2.5	5	7.5	10	12.5	15	17.5	20
Volume Sampled (L)	6	5.5	5	4.5	4	3.5	3	2.5	2
Sample Dilution Factor	1.34	1.46	1.61	1.79	2.01	2.30	2.68	3.22	4.02

6.2 Source: Air Toxics Limited

Reporting Limit = (method reporting limit) x (sample dilution factor) x (analysis dilution factor)¹

¹ - The analysis dilution factor is a ratio of the pressurization required for analysis and the vacuum recorded at sample receipt.

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

7.0 Data and Records Management

The chain of custody form will be completed following sample collection describing all pertinent sample information, site information, intended analyses, etc. This form must be completed properly and the intended recipients must receive their respective copies.

All data and information (e.g., sample collection method used) must be documented on field data sheets and/or site log books with permanent ink. Data recorded will include the following:

- weather conditions (humidity has an effect on compound recoveries)
- canister and flow controller type and serial number
- start and stop times (for integrated sampling)
- deviations from the procedure as written

Unanticipated changes to the procedures or materials described in this POP (deviations) will be appropriately documented in the project records.

Records associated with the activities described in this POP will be maintained according to the document management policy for the project.

8.0 Personnel Qualifications and Training

8.1 Qualifications and training

The individual executing these procedures must have read, and be familiar with, the requirements of this POP.

All field samplers are required to take the 40-hour OSHA health and safety training course and annual 8-hour refresher courses prior to engaging in any field collection activities.

Prior to implementation of this procedure, the field sampler will be instructed by a person experienced with this procedure and the collection of air samples using SUMMA canisters. The sampler will demonstrate to the Sampling Task Manager or designee the proper set-up, calibration, operation, and routine maintenance of the air sampling equipment, as well as an understanding of this procedure.

8.2 Responsibilities

The project manager is responsible for providing the project team with the materials, resources and guidance necessary to properly execute the procedures described in this POP.

The individual performing the work is responsible for implementing the procedures as described in this POP and any project-specific work plans.

Project Operating Procedure

Procedures for Passive Sampling of Air Using SUMMA Canisters

9.0 References

Air Toxics Limited. Guide to Air Sampling and Analysis – Canisters and Tedlar Bags. 5th edition.

U.S. Environmental Protection Agency. 1999. Compendium Method TO-15 - Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). EPA/625/R-96/010b.

U.S. Environmental Protection Agency Emergency Response Team. 1995. SUMMA Canister Sampling. SOP 1704.

United States Environmental Protection Agency. 2001. Guidance for Preparing Standard Operating Procedures (SOPs). EPA QA/G-6. EPA/240/B-01/004. USEPA Office of Environmental Information, Washington, DC. March 2001.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Lockheed Martin Wilmington

Project Operating Procedure

POP-005

Monitoring Well Construction and Installation

1.0 Project Scope and Applicability

1.1 Purpose and Applicability

This project operating procedure (POP) provides guidance for installing groundwater monitoring wells at the former General Electric (GE) disposal site located in the towns of Wilmington and North Reading, Massachusetts. Monitoring wells are installed to monitor the depth to groundwater, to measure aquifer properties, and to obtain samples of groundwater for chemical analysis.

This POP is applicable to installation of single and nested monitoring wells within a borehole. This POP applies to overburden and bedrock monitoring wells.

Some states and EPA Regions have promulgated comprehensive guidelines for monitoring well construction and for subsurface investigation procedures. Deviations from this POP to accommodate other regulatory requirements should be reviewed in advance of the field program, should be explained in the project work plan, and must be documented in the field project notebook when they occur.

1.2 General Principles

Monitoring well construction and installation generally involves drilling a borehole using conventional drilling equipment, installing commercially available well construction and filter/sealing materials, and development of the well prior to sampling. This POP covers well construction and installation methods only. Borehole drilling and well development methods are covered under POP-008 (Subsurface Soil Sampling) and POP-012 (Monitoring Well Development), respectively.

2.0 Health and Safety Considerations

Monitoring well installation may involve chemical hazards associated with materials in the soil or groundwater being investigated; and always involves physical hazards associated with drilling equipment and well construction methods. When wells are to be installed in locations where the aquifer and/or overlying materials may contain chemical hazards, a Health and Safety Plan (HASP) must be prepared and approved by the Health and Safety Officer before field work commences. This plan must be distributed to all field personnel and must be adhered to as field activities are performed.

Project Operating Procedure

Monitoring Well Construction and Installation

3.0 Equipment and Materials

3.1 Well Construction Materials

Well construction materials are usually provided by the drilling subcontractor and most often consist of commercially available flush-threaded well screen and riser pipe constructed of PVC or stainless steel. The length of the screen and the size of the screen slots should be specified in the project work plan.

3.2 Well Completion Materials

Well completion materials include silica sand, bentonite, cement, protective casings and locks. Completion materials are generally provided by the drilling subcontractor.

Other required materials include the following:

- Potable water supply
- Fiberglass or steel measuring tape
- Water level indicator
- Well construction diagrams (Figure 1)
- Waterproof marker or paint (to label wells)
- Health and Safety supplies
- Equipment decontamination materials
- Field project notebook/pen

4.0 Procedures

4.1 General Preparation

Borehole Preparation

Standard drilling methods (e.g., hollow stem auger, drive and wash, rotosonic) should be used to achieve the desired drilling/well installation depths specified in the project work plan. Soil sampling, if conducted, should be conducted in accordance with POP-008 (Subsurface Soil Sampling).

For wells to be installed in the bedrock, a permanent casing will be drilled 5-feet into competent bedrock and grouted in place. Following a minimum 24 hour grout curing period, bedrock coring will be performed to completion depth. Bedrock boreholes may be completed with permanent FLUTE liners with multiple sample ports, or with standard PVC wells as described below.

The diameter of the borehole should be a minimum of 2 inches greater than the outside diameter of the well screen or riser pipe used to construct the well. This is necessary so that sufficient annular space is available to install filter packs, bentonite seals, and grout seals. Bedrock wells may require reaming after coring in order to provide a large enough borehole diameter for well installation.

If water or other drilling fluids have been introduced into the boring during drilling, rock coring, and/or well installation, an attempt should be made to recover the quantity of fluid or water that

Project Operating Procedure

Monitoring Well Construction and Installation

was introduced, either by flushing the borehole prior to well installation and/or by overpumping the well during development.

Well Material Decontamination

Although new well materials (well screen and riser pipe) generally arrive at the site boxed and sealed within plastic bags, it is sometimes necessary to decontaminate the materials prior to their use. Well materials should be inspected by the project geologist/engineer upon delivery to check cleanliness. If the well materials appear dirty, or if local or regional regulatory guidance requires decontamination, then well material decontamination should be performed by the drilling subcontractor in accordance with POP-011 (Decontamination).

4.2 Well Construction Procedure

Depth Measurement

Once the target drilling depth has been reached, the drilling subcontractor will measure the total open depth of the borehole with an accurate, weighted, tape measure. Adjustments of borehole depth can be made at this time by drilling further or installing a small amount of sand filter material to achieve the desired depth. If drilling fluids were used during the drilling process, the borehole should be flushed at this time using potable water. The water table depth may also be checked with a water level indicator if this measurement cannot be obtained with the tape measure.

Centralizers

In order to install a well which is centered within the borehole, it is recommended that centralizers be used. Centralizers are especially helpful for deep well installations where it may be difficult to position the well by hand. Centralizers may not be necessary on shallow water table well installations where the well completion depth is within 25 feet of the ground surface.

Well Construction

The well screen and riser pipe generally are assembled by hand as they are lowered into the borehole. Before the well screen is inserted into the borehole, the full length of the slotted portion of the well screen as well as the unslotted portion of the bottom of the screen should be measured with the measuring tape. These measurements should be recorded on the well construction diagram.

After the above measurement has been taken, the drilling subcontractor may begin assembling the well. As the assembled well is lowered, care should be taken to ensure that it is centered in the hole if centralizers are not used. The well should be temporarily capped before filter sand and other annular materials are installed.

Filter Sand Installation

The drilling subcontractor should fill the annular space surrounding the screened section of the monitoring well to at least 1 foot above the top of the screen with an appropriately graded, clean sand or fine gravel. In general, the filter pack should not extend more than 3 feet above the top of the screen to limit the thickness of the monitoring zone. If coarse filter materials are used, an additional 1-foot thick layer of fine sand should be placed immediately above the filter pack to prevent the infiltration of sealing components (bentonite or grout) into the filter pack. As the filter pack is placed, a weighted tape should be lowered in the annular space to verify the depth to the top of the layer. Depending upon depth, some time may be required for these materials to settle. If necessary, to eliminate possible bridging or creation of voids, placement of the sand pack may

Project Operating Procedure

Monitoring Well Construction and Installation

require the use of a tremie pipe. Tremie pipe sandpack installations are generally suggested for deep water table wells and for wells which are screened some distance beneath the water table.

Bentonite Seal Installation

A minimum 2-foot thick layer of bentonite pellets or slurry seal will be installed by the drilling subcontractor immediately above the well screen filter pack in all monitoring wells or between screen intervals in nested monitoring wells. The purpose of the seal is to provide a barrier to vertical flow of water in the annular space between the borehole and the well casing. Bentonite is used because it swells significantly upon contact with water. Pellets generally can be installed in shallow boreholes by pouring them very slowly from the surface. If they are poured too quickly, they may bridge at some shallow, undesired depth. As an option, powdered bentonite may be mixed with water into a very thick slurry and a tremie pipe used to inject the seal to the desired depth.

Annular Grout Seal Installation

This grout seal should consist of a bentonite/cement mix with a ratio of bentonite to cement of between 1:5 and 1:20. The grout ratio should be chosen based on site conditions with a higher percentage of bentonite generally used for formations with higher porosity. A mud balance should be used if a specific mud density is required at a particular site. Grout slurry should be pumped into the annular space using a side-discharging tremie pipe located about 2 feet above the sand pack. The side discharge fitting is not critical but does help preserve the integrity of the sand pack.

In situations where the monitoring well screen straddles the water table, the seal will be in the unsaturated zone and pure bentonites (pellets or powder) will not work effectively as seals without hydration. Dry bentonite may be used if sufficient time to hydrate the seal is allowed. Seal hydration requires the periodic addition of clean water. Optionally, seals in this situation may be a cement/bentonite mixture containing up to 10 percent bentonite by weight. This type of mixture shall be tremied to the desired depth in the borehole.

The borehole annulus will be grouted with seal materials to within 3 feet of the ground surface.

Well Completion

The drilling subcontractor will cut the top of the well to the desired height and install a vented (if possible), locking cap. The upper portion of the well casing can optionally be drilled to allow venting. Well casings are usually cut to be a certain height above ground surface (typically 2.5 to 3 feet) or are cut to be flush with the ground surface.

Protective Casing/Concrete Pad Installation

The drilling subcontractor will install a steel guard pipe on the well as a protective casing. The borehole around the guard pipe will be dug out to an approximate 2 to 3-foot radius to a minimum depth of 1 foot at the center and 6 inches at the edges. After installing the protective casing, the excavation will be filled with a concrete/sand mix. The surface of the concrete pad will be sloped so that drainage occurs away from the well. For wells in the wetlands, the protective stick up casing will either need to be installed inside an outer casing driven into the ground around the permanent drill casing, or within the permanent casing itself, or a locking cover will be installed directly on the drill casing that will extend above the wetland water level.

Project Operating Procedure

Monitoring Well Construction and Installation

Flush-mount protective casings may or may not require an extensive concrete pad depending on the location and volume of traffic at the location, and should be completed such that they are slightly mounded above the surrounding surface to prevent surface water from running over or ponding on top of the casing. It should be noted, however, that in areas subject to snowfall, flush-mount casings may have to be installed so that they are entirely flush with the ground surface as they may be damaged by snow plows.

Above-ground protective casings should also be vented or should have non-air tight caps. Road box installations should not be vented. Installation of additional guard pipes may be necessary around above-ground well completions in traffic areas. Protective casings should be lockable to prevent unauthorized access.

Well Numbering

The project geologist/engineer will number each well casing with an indelible marker or paint to identify the well. This is particularly important with nested or paired wells to distinguish between shallow and deep wells. The well should be labeled on both the outside of the protective casing and inside beneath the protective casing lid.

Measuring Point Identification

The project geologist/engineer will mark the measuring point from which water level measurements will be made at a specific location along the upper edge of the well casing. PVC wells can easily be notched with a pocket knife or saw. Stainless steel wells (or PVC wells) can be marked with a waterproof marker on the outside of the well casing with an arrow pointing to the measuring point location. The measuring point is the point which will require surveying during the well elevation survey task.

Well Measurements

Upon completion, the following well measurements should be taken by the project geologist/engineer and recorded on the well construction diagram (Figure 1):

- Depth to static water level if water level has stabilized,
- Total length of well measured from top-of-well casing,
- Height of well casing above ground surface,
- Height of protective casing above ground surface,
- Depth of bottom of protective casing below ground surface (may be estimated).

Well screen filter pack, bentonite seal and annular seal thicknesses and depths should also be recorded on the well construction diagram.

Disposal of Drilling Wastes

Drill cuttings and other investigation-derived wastes such as drilling mud or well development/purge water must be properly contained and disposed of. Site-specific requirements for collection and removal of these waste materials should be outlined within the project work plan. Containment of these materials should be performed by the drilling subcontractor.

Project Operating Procedure

Monitoring Well Construction and Installation

Well Development

At some point after installation of a well and prior to use of the well for water-level measurements or collection of water quality samples, development of the well shall be undertaken in accordance with POP-012 (Monitoring Well Development). Well development may be performed by the drilling subcontractor if contracted to do so, or by the project geologist/engineer or other project staff.

Well Elevation Survey

At the completion of the well installation program, all monitoring wells are usually surveyed to provide, at a minimum, the top-of-casing measuring point elevation for water level monitoring purposes. Other surveyed points which may be required by the project work plan include: ground surface elevation, top of protective casing elevation, and well coordinate position. Well elevation surveys are usually conducted by a surveying subcontractor.

5.0 Quality Assurance / Quality Control

Field personnel should follow specific quality assurance guidelines as outlined in the site-specific QAPP. The following aspects of monitoring well design and installation procedures depend on project-specific objectives which should be addressed in the QAPP and in the project work plan:

- Borehole drilling method and diameter,
- Type of construction materials for well screen, riser, filter pack and seals,
- Diameter of well materials,
- Length of well screen,
- Location, thickness, and composition of annular seals, and
- Well completion and surface protection requirements.

Certain quality control measures should be taken to ensure proper well completion.

- The borehole will be checked for total open depth, and extended by further drilling or shortened by backfilling, if necessary, before any well construction materials are placed.
- Water level and non-aqueous phase liquid (NAPL) presence will be checked during well installation to ensure that the positions of well screen, sand pack, and seal, relative to water level, conform to project requirements.
- The depth to the top of each layer of packing (i.e., sand, bentonite, grout, etc.) will be verified and adjusted if necessary to conform to project requirements before the next layer is placed.
- If water or other drilling fluids have been introduced into the boring during drilling or well installation, samples of these fluids may be required for analysis of chemical constituents of interest at the site.

6.0 Data and Records Management

All well construction data will be recorded on the Monitoring Well Construction Detail form (Figure 1). All wells will be referenced onto the appropriate site map. A field notebook and/or boring log will be used as additional means of recording data. In no case will the notebook or boring log take the place of the well construction diagram.

7.0 Personnel Qualifications and Training

Well construction and installation requires a moderate degree of training and experience as numerous drilling situations may occur which will require field decisions to be made. It is recommended that inexperienced personnel be supervised for several well installations before working on their own. Experienced drillers are also of great assistance with problem resolution in the field. Field personnel should be health and safety certified as specified by OSHA (29 CFR 1910.120(e)(3)(i)) to work on sites where hazardous waste materials are considered to be present.

7.1 Drilling Subcontractor

It is the responsibility of the drilling subcontractor to provide the necessary equipment for well construction and installation. Well construction materials should be consistent with project requirements.

7.2 Surveying Subcontractor

It is the responsibility of the surveying subcontractor to provide one or more of the following well measurements as specified in the project work plan: ground surface elevation, horizontal well coordinates, top of well casing elevation (i.e., top-of-casing, or measuring point elevation), and/or top of protective casing elevation.

7.3 Project Geologist/Engineer

It is the responsibility of the Project Geologist/Engineer to directly oversee the construction and installation of the monitoring well by the drilling subcontractor to ensure that the well-installation specifications defined in the project work plan are adhered to, and that all pertinent data are recorded on the appropriate forms.

7.4 Project Manager

It is the responsibility of the Project Manager to ensure that each project involving monitoring well installation is properly planned and executed.

8.0 References

Standard References for Monitoring Wells, Massachusetts Department of Environmental Protection, WSC-310-91, 1991.

9.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Figure 1 Monitoring Well Construction Detail

	Client: _____		<i>WELL ID:</i>	
	Project Number: _____			
	Site Location: _____		Date Installed: _____	
	Well Location: _____	Coords: _____	Inspector: _____	
	Method: _____		Contractor: _____	

MONITORING WELL CONSTRUCTION DETAIL				
		Depth from G.S. (feet)	Elevation(feet)	
			Datum _____	
Measuring Point for Surveying & Water Levels	Top of Steel Guard Pipe			
	Top of Riser Pipe			
	Ground Surface (G.S.)	0.0		
Cement, Bentonite, Bentonite Slurry Grout, or Native Materials	Riser Pipe:			
	Length _____			
	Inside Diameter (ID) _____			
	Type of Material _____			
Bottom of Steel Guard Pipe				
Top of Bentonite				
Bentonite Seal Thickness _____				
Top of Sand				
Top of Screen				
▲ Stabilized Water Level				
Screen:				
Length _____				
Inside Diameter (ID) _____				
Slot Size _____				
Type of Material _____				
Type/Size of Sand _____				
Sand Pack Thickness _____				
Bottom of Screen				
Bottom of Tail Pipe:				
Bottom of Borehole				
Borehole Diameter: _____		Approved: _____		
Describe Measuring Point: _____		Signature _____		
		Date _____		

Project Operating Procedure

Operation and Calibration of a Photoionization Detector

Lockheed Martin Wilmington

Project Operating Procedure

POP-006

Operation and Calibration of a Photoionization Detector

1.0 Project Scope and Applicability

1.1 Purpose and Applicability

This document describes the procedures that will be followed by field staff for operation and calibration of a photoionization detector (PID). The PID is primarily used by AECOM personnel for safety and survey monitoring of ambient air, determining the presence of volatiles in soil and water, and detecting leakage of volatiles.

PIDs routinely used by AECOM personnel include the Photovac Microtip, Thermoelectron 580EZ, and MiniRAE 2000. Personnel responsible for using the PID should first read and thoroughly familiarize themselves with the instrument instruction manual.

1.2 Principle of Operation

The PID is a non-specific vapor/gas detector. The unit generally consists of a hand-held probe that houses a PID, consisting of an ultraviolet (UV) lamp, two electrodes, and a small fan which pulls ambient air into the probe inlet tube. The probe is connected to a readout/control box that consists of electronic control circuits, a readout display, and the system battery. Units are available with UV lamps having an energy from 9.5 electron volts (eV) to 11.7 eV.

The PID analyzer measures the concentration of trace gas present in the atmosphere by photoionization. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and become a positive ion. This will occur when the ionization potential of the molecule (in electron volts (eV)) is less than the energy of the photon. The source of photons is an ultraviolet lamp in the probe unit. Lamps are available with energies ranging from 9.5 eV to 11.7 eV. All organic and inorganic vapor/gas compounds having ionization potentials lower than the energy output of the UV lamp are ionized and the resulting potentiometric change is seen as a positive reading on the unit. The reading is proportional to the concentration of organics and/or inorganics in the vapor.

Project Operating Procedure

Operation and Calibration of a Photoionization Detector

Sample gases enter the probe through the inlet tube and enter the ion chamber where they are exposed to the photons emanating from the UV lamp. Ionization occurs for those molecules having ionization potentials near to or less than that of the lamp. A positive- biased polarizing electrode causes these positive ions to travel to a collector electrode in the chamber. Thus the ions create an electrical current which is amplified and displayed on the meter. This current is proportional to the concentration of trace gas present in the ion chamber and to the sensitivity of that gas to photoionization.

In service, the analyzer is first calibrated with a gas of known composition equal to, close to, or representative of that to be measured. Gases with ionization potentials near to or less than the energy of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials greater than the energy of the lamp will not be detected. The ionization potentials of the major components of air, i.e., oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to 15.6 eV and are not ionized by any of the lamps available. Gases with ionization potentials near to or slightly higher than the lamp are partially ionized, with low sensitivity.

1.3 Specifications

Refer to the manufacturer's instructions for the technical specifications of the instrument being used. The operating concentration range is typically 0.1 to 2,000 ppm isobutylene equivalent.

2.0 Health and Safety Considerations

The health and safety considerations for the site, including both potential physical and chemical hazards, will be addressed in the site-specific Health and Safety Plan (HASP). In the absence of a site-specific HASP, work will be conducted according to the AECOM Health and Safety Policy and Procedures Manual and/or direction from the Regional Health and Safety Manager.

Only PIDs stamped Division I Class I may be used in explosive atmospheres. Refer to the project HASP for instructions pertaining to instrument use in explosive atmospheres.

3.0 Interferences

Regardless of which gas is used for calibration, the instrument will respond to all analytes present in the sample that can be detected by the type of lamp used in the PID.

Moisture will generate a positive interference in the concentration measured for a PID and is characterized by a slow increase in the reading as the measurement is made. Care must be taken to minimize uptake of moisture to the extent possible. Refer to the manufacturers' instructions for care, cleaning, and maintenance.

Project Operating Procedure

Operation and Calibration of a Photoionization Detector

Uptake of soil into the PID must be avoided as it will compromise instrument performance by blocking the probe, causing a positive interference, or dirtying the PID lamp. Refer to the manufacturers' instructions for care, cleaning, and maintenance.

The user should listen to the pitch of the sampling pump. Any changes in pitch may indicate a blockage and corrective action should be initiated.

4.0 Equipment and Materials

- Calibration Gas: Compressed gas cylinder of isobutylene in air or similar stable gas mixture of known concentration. The selected gas should have an ionization potential similar to that of the vapors to be monitored, if known. The concentration should be at 50-75% of the range in which the instrument is to be calibrated.
- Regulator for calibration gas cylinder
- Approximately 6 inches of Teflon® tubing
- Tedlar bag (optional)
- Commercially-supplied zero grade air (optional)
- "Magic Marker" or "Sharpie" or other waterproof marker
- Battery charger
- Moisture traps
- Spare lamps
- Manufacturer's instructions
- Field data sheets or logbook/pen

5.0 Procedures

5.1 Preliminary Steps

Preliminary steps (battery charging, check-out, calibration, maintenance) should be conducted in a controlled or non-hazardous environment.

5.2 Calibration

The PID must be calibrated in order to display concentrations in units equivalent to ppm. First a supply of zero air (ambient air or from a supplied source), containing no ionizable gases or vapors is used to set the zero point. A span gas, containing a known concentration of a photoionizable gas or vapor, is then used to set the sensitivity.

Project Operating Procedure

Operation and Calibration of a Photoionization Detector

Calibrate the instrument according to the manufacturer's instructions. Record the instrument model and identification number, the initial and adjusted meter readings, the calibration gas composition and concentration, and the date and the time in the field records.

If the calibration cannot be achieved or if the span setting resulting from calibration is 0.0, then the lamp must be cleaned.

5.3 Operation

Turn on the unit and allow it to warm up (minimum of 5 minutes). Check to see if the intake fan is functioning; if so, the probe will vibrate slightly and a distinct sound will be audible when holding the probe casing next to the ear. Also, verify on the readout display that the UV lamp is lit.

Calibrate the instrument as described in Section 5.2, following the manufacturer's instructions. Record the calibration information in the field records.

The instrument is now operational. Readings should be recorded in the field records.

When the PID is not being used or between monitoring intervals, the unit may be switched off to conserve battery power and UV lamp life; however, a "bump" test should be performed each time the unit is turned on and prior to taking additional measurements. To perform a bump test, connect the outlet tubing from a Tedlar bag containing a small amount of span gas to the inlet tubing on the unit and record the reading. If the reading is not within the tolerance specified in the project plan, the unit must be recalibrated.

At the end of each day, recheck the calibration. The check will follow the same procedures as the initial calibration (Section 5.2) except that no adjustment will be made to the instrument. Record the information in the field records.

Recharge the battery after each use (Section 5.4).

When transporting, ensure that the instrument is packed in its stored condition in order to prevent damage.

5.4 Routine Maintenance

Routine maintenance associated with the use of the PID includes charging the battery, cleaning the lamp window, replacing the detector UV lamp, replacing the inlet filter, and replacing the sample pump. Refer to the manufacturer's instructions for procedures and frequency.

All routine maintenance should be performed in a non-hazardous environment.

5.5 Troubleshooting Tips

One convenient method for periodically confirming instrument response is to hold the sensor probe next to the tip of a magic marker. A significant reading should readily be observed.

Project Operating Procedure

Operation and Calibration of a Photoionization Detector

Air currents or drafts in the vicinity of the probe tip may cause fluctuations in readings.

A fogged or dirty lamp, due to operation in a humid or dusty environment, may cause erratic or fluctuating readings. The PID should never be operated without the moisture trap in place.

Moving the instrument from a cool or air-conditioned area to a warmer area may cause moisture to condense on the UV lamp and produce unstable readings.

A zero reading on the meter should not necessarily be interpreted as an absence of air contaminants. The detection capabilities of the PID are limited to those compounds that will be ionized by the particular probe used.

Many volatile compounds have a low odor threshold. A lack of meter response in the presence of odors does not necessarily indicate instrument failure.

When high vapor concentrations enter the ionization chamber in the PID the unit can become saturated or “flooded”. Remove the unit to a fresh air environment to allow the vapors to be completely ionized and purged from the unit.

6.0 Quality Assurance / Quality Control

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific Work Plan or Quality Assurance Project Plan (QAPP), hereafter referred to as the project plan.

Calibration of the PID will be conducted at the frequency specified in the project plan. In the absence of project-specific guidance, calibration will be performed at the beginning of each day of sampling and will be checked at the end of the sampling day or whenever instrument operation is suspect. The PID will sample a calibration gas of known concentration. The instrument must agree with the calibration gas within $\pm 10\%$. If the instrument responds outside this tolerance, it must be recalibrated.

Checks of the instrument response (Section 5.5) should be conducted periodically and documented in the field records.

7.0 Data and Records Management

Safety and survey monitoring with the PID will be documented in a bound field logbook, or on standardized forms, and retained in the project files. The following information is to be recorded:

Project Operating Procedure

Operation and Calibration of a Photoionization Detector

- Project name and number.
- Instrument manufacturer, model, and identification number.
- Operator's signature.
- Date and time of operation.
- Calibration gas used.
- Calibration check at beginning and end of day (meter readings before adjustment).
- Span setting after calibration adjustment.
- Meter readings (monitoring data obtained).
- Instances of erratic or questionable meter readings and corrective actions taken.
- Instrument checks and response verifications – e.g., battery check, magic marker response (Section 5.5) or similar test.

8.0 Personnel Qualifications and Training

The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this POP and the project plan.

The field operator is responsible for verifying that the PID is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this POP and the project plan.

9.0 References

United States Environmental Protection Agency. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM). USEPA, Region 4, SEDS, Enforcement and Investigations Branch, Athens, GA. November 2001.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Lockheed Martin Wilmington

Project Operating Procedure

POP-007

Headspace Screening

1.0 Purpose and Applicability

This project operating procedure (POP) describes the basic techniques for using headspace analysis to screen for volatile organics in contaminated soils using a portable Photo Ionization Detector (PID) or Flame Ionization Detector (FID).

Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Task Hazard Analysis (THA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

2.0 Responsibilities

The project manager/task manager is responsible for overseeing work activities to ensure that field screening is performed and documented in accordance with the methods described here and in the project-specific sampling plan. In addition, a THA will be conducted to assess any potential hazards associated with headspace screening. Copies of THA forms are available in the Site-Specific HASP.

3.0 Health and Safety

This section presents the generic hazards associated with headspace screening and is intended to provide general guidance in preparing site-specific health and safety documents. The Site-Specific HASP and THA will address additional requirements and will take precedence over this document. Note that headspace screening usually requires Level D personal protection unless there is a potential for airborne exposure to site contaminants. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or Environment, Health, and Safety (EHS) Coordinator.

Health and safety hazards and corresponding precautions include, but are not limited to, the following:

- Dermal contact with contaminated soil. Personnel should treat all soil as potentially contaminated and wear chemically impervious gloves. Minimize skin contact with soil by using sampling instruments such as stainless steel spades or spoons. Do not touch any exposed skin with contaminated gloves.

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Headspace Screening

- Inhalation hazards. Appropriate air monitoring should be conducted to ensure that organic vapor concentrations in the breathing zone do not exceed action levels as specified in the Site-Specific HASP. When ambient temperatures are low enough to require warming samples using the vehicle heater, the vehicle's windows should be opened enough to prevent the build-up of any organic vapors. Use the PID or FID to verify the airborne concentrations in the vehicle remain below applicable action levels. Note that many volatile organic compounds (VOCs) are flammable and all precautions must be observed to eliminate any potential ignition sources.
- Shipping limitations. Follow applicable regulations when shipping FID/PID equipment. When shipping an FID by air, the hydrogen tank must be bled dry. Calibration gas canisters are considered dangerous goods and must be shipped according to DOT regulations. Consult your EHS Coordinator and check with your shipping company to determine the correct shipping procedures.

4.0 Supporting Materials

The following materials must be on hand in good operating condition and/or in sufficient quantity to ensure that proper field analysis procedures may be followed.

- Calibrated PID/FID instrument
- Top-sealing "Zip-Loc" type plastic bags – or – 16 ounces of soil or "mason-" type glass jars and aluminum foil
- Project field book and/or boring logs
- PPE as specified in the Site-Specific HASP
- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants
- A copy of the Site-Specific HASP

5.0 Methods and Procedures

5.1 Preparation

Review available project information to determine the types of organic vapors that will likely be encountered to select the right instrument. The two basic types of instruments are FIDs and PIDs.

FIDs work well with organic compounds that have relatively lightweight molecules, but may have problems detecting halogenated compounds or heavier organic compounds; FIDs can detect methane for example. Since the FID uses a flame to measure organic compounds, ensure that work is conducted in an atmosphere, which is free of combustible vapors. If ambient temperatures are below 40°F, the flame of the FID may be difficult to light.

When using a PID, select an instrument that can measure the ionization potential of the anticipated contaminants of concern. PIDs work well with a range of organic compounds and can detect some halogenated hydrocarbons; PIDs cannot detect methane. The correct ultraviolet (UV) light bulb must be selected according to the types of organic vapors that will likely be encountered. The energy of the UV light must equal or exceed the ionization potential of the organic molecules that the PID will measure. The NIOSH *Pocket Guide to Chemical Hazards* is one source for determining ionization potentials for different chemicals. Bulbs available for PIDs

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Headspace Screening

include 9.4 eV, 10.6 (or 10.2) eV, and 11.7 eV bulbs. The 10.6 eV bulb is most commonly used as it detects a fairly large range of organic molecules and does not burn out as easily as the 11.7 eV bulb. The 9.4 eV bulb is the most rugged, but detects only a limited range of compounds. Under very humid or very cold ambient conditions, the window covering the UV light may fog up, causing inaccurate readings. Ask your EHS coordinator about correction factors when high humidity conditions exist.

After selecting the correct instrument, calibrate the PID/FID according to the manufacturer's instructions. Record background/ambient levels of organic vapors measured on the PID/FID after calibration and make sure to subtract the background concentration (if any) from your readings. Check the PID/FID readings against the calibration standard every 20 readings or at any time when readings are suspected to be inaccurate, and recalibrate, if necessary. Be aware that, after measuring highly contaminated soil samples, the PID/FID may give artificially high readings for a time.

5.2 Top-Sealing Plastic Bag

Place a quantity of soil in a top-sealing plastic bag and seal the bag immediately. The volume of soil to be used should be determined by the project manager or field task manager. The volume of soil may vary between projects but should be consistent for all samples collected for one project. Ideally, the bag should be at least 1/10th-filled with soil and no more than half-filled with soil. Once the bag is sealed, shake the bag to distribute the soil evenly. If the soil is hard or clumpy, use your fingers to gently work the soil (through the bag) to break up the clumps. Do not use a sampling instrument or a rock hammer since this may create small holes in the plastic bag and allow organic vapors to escape. Alternatively, the sample may be broken up before it is placed in the bag. Use a permanent marker to record the following information on the outside of the bag:

- Site identification information (i.e., borehole number)
- Depth interval
- Time the sample was collected
- For example: "SS-12, 2-4 ft, @1425"

Headspace should be allowed to develop before organic vapors are measured with a PID/FID. The amount of time required for sufficient headspace development will be determined by the project-specific sampling plan and the ambient temperature. Equilibration time should be the same for all samples to allow an accurate comparison of organic vapor levels between samples. However, adjustments to equilibration times may be necessary when there are large variations in ambient temperature from day to day. When ambient temperatures are below 32°F, headspace development should be within a heated building or vehicle. When heating samples, be sure there is adequate ventilation to prevent the build-up of organic vapors above action levels.

Following headspace development, open a small opening in the seal of the plastic bag. Insert the probe of a PID/FID and seal the bag back up around the probe as tightly as possible. Alternatively, the probe can be inserted through the bag to avoid loss of volatiles. Since PIDs and FIDs are sensitive to moisture, avoid touching the probe to the soil or any condensation that has accumulated inside of the bag. Since the PID/FID consumes organic vapors, gently agitate the soil sample during the reading to release fresh organic vapors from the sample. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case, headspace data should be discounted. Record the highest reading on the field form or in the field notebook as described in Section 7.

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5.3 Jar and Aluminum Foil (Alternate Method)

Half-fill a clean glass jar with the soil sample to be screened. Quickly cover the jar's opening with one to two sheets of clean aluminum foil and apply the screw cap to tightly seal the jar. Allow headspace development for at least ten minutes. Vigorously shake the jar for 15 seconds, both at the beginning and at the end of the headspace development period. Where ambient temperatures are below 32°F (0°C), headspace development should be within a heated area. When heating samples be sure there is adequate ventilation to prevent the build-up of organic vapors above action levels.

Subsequent to headspace development, remove the jar lid and expose the foil seal. Quickly puncture the foil seal with the instrument sampling probe, to a point about one-half of the headspace depth. Exercise care to avoid uptake of water droplets or soil particulates. As an alternative, use a syringe to withdraw a headspace sample, and then inject the sample into the instrument probe or septum-fitted inlet. This method is acceptable contingent upon verification of methodology accuracy using a test gas standard. Following probe insertion through the foil seal or sample injection to probe, record the highest meter response on the field form or in the field notebook. Using foil seal/probe insertion method, maximum response should occur between two and five seconds. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case, headspace data should be discounted.

6.0 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) will include the collection of duplicate samples. In general, one duplicate will be collected per 20 samples. Organic vapor concentrations measured in the primary and duplicate samples should be similar within plus or minus 20 percent. The frequency of headspace duplicate collection will be determined by the project manager/task manager. The PID/FID instrument must be calibrated according to the manufacturer's instructions before beginning screening, and checked or recalibrated every 20 analyses or when readings are suspected to be inaccurate. Record ambient organic vapor levels in the field notebook and on the field form. Periodically check ambient organic vapor levels. If ambient levels have changed more than 20 percent, recalibrate the PID/FID. Make sure readings are not collected near a vehicle exhaust or downwind of the drill rig exhaust. If grossly contaminated soil is encountered, decontaminate sampling instruments between samples and/or change contaminated gloves to avoid cross contaminating less contaminated samples.

7.0 Documentation

All data generated (results and duplicate comparisons) will be recorded in the field notebook and/or on the field form. Any deviation from the outlined procedure will also be noted. Field conditions (ambient temperature, wind, etc.) should also be recorded in the field notebook.

Readings may be recorded in a field notebook, on a boring log, or on an appropriate form specific to the project. The form should include the following information:

- When the PID/FID was calibrated (date/time) and calibration standard used
- Background/ambient concentrations measured after PID/FID calibration
- Location of sample (i.e., bore-hole number)

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- Depth interval of sample measured
- Lithology of material measured
- PID/FID reading and units of measure

Note that if PID/FID measurements are recorded on a boring log, it is not necessary to duplicate information in the column where the PID/FID readings are recorded (e.g., borehole number, depth interval, lithology type).

All documentation will be stored in the project files and retained following completion of the project.

8.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Project Operating Procedure

Subsurface Soil Sampling Procedures

Lockheed Martin Wilmington

Project Operating Procedure

POP-008

Subsurface Soil Sampling Procedures

1.0 Purpose and Applicability

This project operating procedure (POP-008) describes methods used to obtain soil samples for physical testing, stratigraphic correlations, and chemical analysis. Soil samples may be obtained in conjunction with surface sampling, test pit excavation, soil boring, and monitoring well installation programs. These procedures provide specific information for determining the physical makeup of the surface and subsurface environment, as well as how to estimate the extent and magnitude of soil contamination, if present. POP 008 will discuss sampling of the subsurface material by augers and split spoons, and within test pits by backhoes and hand tools.

Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Task Hazard Analysis, AECOM Safety, Health and Environment (SHE), or Site-Specific Health & Safety Plan (HASP) will take precedence over the procedures described in this document.

2.0 Responsibilities

The project geologist/engineer will be responsible for the proper use and maintenance of all types of equipment used for obtaining soil samples. The geologist/engineer will determine the location, total depth, and overall size of each surface sample collection point and test pit, and the location and depth of all subsurface borings based on the project specific sampling plan. The project geologist/engineer will be responsible for locating any subsurface utilities or structures, and disseminating this information to the contractor prior to commencing the sampling program. The location of overhead utilities and obstructions relative to the sampling locations will also be noted. In addition, a Task Hazard Analysis will be conducted to assess any other potential health and safety hazards associated with soil sample collection.

It shall be the responsibility of the project geologist/engineer to observe all activities pertaining to soil sampling and subsurface investigations to ensure that all the standard procedures are followed properly, and to record all pertinent data on a field log or field book. The collection, handling, and storage of all samples will be the responsibility of the geologist/engineer.

It is the responsibility of the contractor to provide safe and well-maintained equipment for obtaining subsurface samples in borings and for decontamination of the equipment. Test pit construction, split-spoon sampling, and subsurface augering will be conducted by the contractor. In addition, the contractor will be responsible for containment of cuttings, if required.

3.0 Health and Safety

This section presents the generic hazards associated with soil sampling techniques and is intended to provide general guidance in preparing site-specific health and safety documents. The Site-Specific Health & Safety Plan, and Task Hazard Analyses will address additional requirements and will take precedence over this document. Note that sample collection usually requires Level D personal protection unless there is a potential for airborne exposures to site contaminants.

Health and safety hazards include but are not limited to the following:

Rotosonic Drilling

- Heavy equipment operation
- Pinch points
- Rotating parts
- Loose clothing
- Heavy lifting
- Air quality (i.e., chemical, dust, explosive conditions)
- Hazardous materials (exposure and release)
- Pressurized lines
- High noise levels
- Utilities (underground or overhead)
- Hoisting
- Overhead hazards
- Hand hazards
- Increased noise hazard
- Increased dust hazard (air rotary)
- Cyclones/Diversers (pressurized lines should be anchored with whip-stops)
- Investigation derived waste containment
- Blow protect inspection/replacement
- Sample collection (i.e., there are increased hazards when taking samples from air rotary rigs resulting from overhead hazards (cyclones), pressurized lines, increased noise, and air quality at sample collection outlets. Field personnel must be aware of these hazards and initiate engineered controls to limit these hazards.)
- Same as above
- Elevated work platform
- Maneuvering rig and support truck

If site/project conditions warrant the use of other drilling techniques, hazards associated with these techniques will be evaluated by amendment in the site-specific Health & Safety Plan, Job Hazard Analyses, or Safety Task Analysis Reviews. Drill rig inspections, if applicable, will be completed prior to initiating soil sampling.

4.0 Supporting Materials

In addition to materials provided by the contractor, the geologist/engineer will provide:

- Sample bottles/containers and labels
- Boring or test pit logs
- Field notebook
- Chain-of-custody forms
- Depth-measurement device
- Stakes and fluorescent flagging tape
- Decontamination solution
- Camera for photographing sections
- Sampling equipment (e.g., knives, trowels, shovels, hand augers, aluminum foil, etc.)
- Plastic garbage bags
- Material Safety Data Sheets (MSDSs) for any chemicals or site specific contaminants
- A copy of the site-specific Health and Safety Plan

5.0 Methods and Procedures

Specific sampling equipment and methodology will be dictated by characteristics of the soil to be sampled, type of soil samples required, and by the analytical procedures to be employed.

There are two types of samples that may be required by the project sampling plan, grab or composite. A grab sample is collected from a specific location or depth and placing it in the appropriate sample container. A composite sample consists of several discrete locations (or depths) mixed to provide a homogeneous, representative sample. To ensure that the sample is representative, the soil volume and collection method from each discrete location should be as identical as possible. It should be noted that samples analyzed for volatile organic compounds cannot be composited since it is necessary to expose the soil to the atmosphere prior to transfer into the sample container.

Most subsurface explorations by AECOM will be on privately owned land, often an industrial facility. Prior to commencing subsurface exploration, AECOM will work with the facility manager to locate any subsurface utilities or structures and discuss any pertinent health and safety issues. Utility companies, (electric, gas, water, phone, sewer, etc.) who may have equipment or transmission lines buried in the vicinity, will also be notified. Many regions have organizations, which represent all utilities for these notification purposes. Allow enough time after notification (typically three working days) for the utilities to respond and provide locations of any equipment, which may be buried on site. Overhead lines must also be kept in consideration when a drilling rig is used. As a rule of thumb, the rig and derrick should be at least 25 feet away from overhead lines unless special shielding and grounding are provided. In addition, consult the site-specific health and safety documentation.

5.1 General Applications

General locations shall be mapped by the field geologist/engineer using a stationary structure as the reference point. Specific locations for test pits and sampling locations will be documented by

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survey or by using topographic maps and/or plans. A preliminary log of the test pit, or boring shall be prepared in the field by the field geologist/engineer. A sketch of the test pit may be necessary to depict the strata encountered. Before measuring the depth to groundwater, if encountered, the field geologist/engineer will allow sufficient time for stabilization of the water table in the excavation or boring. All information shall be recorded on the field log or the field book.

5.2 Subsurface Sampling

The casing shall be of the flush-joint or flush-couple type and of sufficient size to allow for soil sampling, coring, and/or well installation. All casing sections shall be straight and free of any obstructions. Hollow-stem augers or solid-flight augers with casing may be used according to specific project requirements.

In general subsurface soil samples shall be obtained using a split-tube type sampler (split spoon), however, other devices (Shelby tubes, continuous samples, rotasonic soil cores, etc.) may be used as specified in the project specific sampling plan. Split-spoons come in a variety of sizes with the most standard having a 2-inch OD, a 1 3/8-inch ID and a 24-inch long barrel with an 18-inch sample capacity. Split spoons shall be equipped with a flap valve or basket-type retainer at the bottom. Samples shall be obtained using the standard penetration test (SPT), which allows for qualitative determination of mechanical properties and aids in identification of material type. The number of hammer blows shall be recorded on the boring log for each six-inch drive distance.

The soil sampler shall be opened immediately upon removal from the casing. If the recovery is inadequate (i.e., most of the penetrated material was not retained inside the soil sampler), a note will be made on the boring log stating that "no recovery" was possible at that depth. In the event that gravels or other material prevent penetration by the split spoon, samples may be collected from the auger flights. Slowly remove the auger and collect the sample at the point corresponding to the required depth. Samples collected in this manner must be documented on the boring log.

Subsurface groundwater samples may be obtained from the borings. Groundwater samples may be collected using a peristaltic pump lowered into hollow-stem augers, open drill casing, through a power punch sampling technique, or through a packer assembly.

Depth discrete samples would be best collected through use of the power punch or packer techniques. Samples collected using a power punch would be collected by driving the sampler to the desired depth, pulling back on the sampler to expose the screen, and withdrawing the tool after a sufficient collection time has elapsed. Alternatively, a sample may be collected from the exposed screen by using a small diameter bailer or a peristaltic pump to collect the groundwater entering the screen. Samples collected using a packer assembly would be collected from a stainless screen attached to a two inch diameter black pipe; the packer would be inflated to isolate the desired depth interval and a bailer or peristaltic pump would be used to collect the sample.

Photographs of specific geologic features or sample location may be required for documentation purposes. A scale or item providing a size perspective should be placed in each photograph. The frame number and picture location shall also be documented in the field book. All equipment will be decontaminated following POP 011 between sample locations and sample depths unless otherwise specified in the project specific sampling plan.

Upon completion of the boring, backfill may be required. The backfill may consist of native material, hydrated bentonite chips/pellets, Portland cement/bentonite grout, or other low

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permeability material as specified in the project specific sampling plan. All applicable state/federal regulations concerning plugging of boreholes should be reviewed prior to the commencement of field activities.

5.3 Sample Logging

To ensure consistent descriptions of soil or rock material, the following criteria should be included on the sampling logs:

- Soil or rock type
- Depth ranges, recorded in feet
- Grain size
- Roundness
- Sorting
- Moisture
- Color
- Degree of staining or other visual impacts
- Remarks

Examples of soil types would be gravel, sand, silt, or clay. Soil types should be based on the Unified Soil Classification System (USCS). Examples of rock types include limestone, shale, claystone, siltstone, and sandstone. Soil/rock classifications determined in the field may be subject to change based upon laboratory tests. Factors to consider before changing a field determination include the expertise of the field geologist/engineer and laboratory personnel, representative character of the tested sampling, labeling errors, etc. Any changes made after this consideration shall be discussed and incorporated in the project report.

Grain size, roundness, and degree of sorting should also be included on the log if they are discernable. In addition to composition, blow counts and the length of the sample recovered should also be recorded on the sampling log. The degree of sample moisture should be described as dry, moist, and wet.

The color(s) or range of color(s) of the soil or rock type should be defined. If a Munsell color chart is used, the number designation of the color will also be recorded in the description. A notation of the degree of oil contamination should be included on the sample log. The contamination should be noted as high (30 %), medium (10-30 %), low (1-10 %), or none. Other classifiers may include odor (low to high) and mottling (low to high).

Remarks should include anything pertinent to the sample description or sample collection that is not described above. Other information to be placed on the logs as appropriate is:

- PID readings
- Appearance of contamination (consistency)
- Degree of fracturing or cementation in the rock
- Drilling equipment used (rod size, bit type, pump type, rig manufacturer and model, etc.)
- Special problems and their resolution (hole caving, recurring problems at a particular depth, sudden tool drops, excessive grout takes, drilling fluid losses, lost casing, etc.)

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- Dates of start and completion of borings
- Depth of first encountered free water
- Definitions of special abbreviations used on log

5.4 Sample Handling

Specific procedures pertaining to the handling and shipment of samples shall be in accordance with POP 003. A clean pair of gloves and decontaminated sampling tools will be used when handling the samples during collection to prevent cross contamination. A representative sample will be placed in the sampling container. Sample containers (jars or bags) shall be labeled with the following information:

- Client or project name, or unique identifier, if confidential
- Unique sample description (i.e., test pit, boring, or sampling point number and horizontal/vertical location)
- Sample collection date and time
- Sampler's name or initials
- Analyses to be performed

These data shall be recorded on the field logs and/or field book. Larger bulk samples shall be placed in cloth bags with plastic liners or plastic five-gallon buckets. Sample bags shall be marked with the information listed above.

6.0 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) requirements include, but are not limited to, blind field duplicates, blind rinsate blanks, and blind field blanks. These samples will be collected on a frequency of one QA/QC sample per 20 field samples or a minimum of one QA/QC sample per day unless otherwise specified in the project specific sampling plan.

7.0 Documentation

Documentation may consist of all or part of the following:

- Test pit or boring log
- Sample log sheets
- Field log book
- Chain-of-custody forms
- Shipping receipts
- Health & Safety forms (Job Hazard Analysis, Safety Task Analysis Review, and/or Site Specific Health & Safety Plan amendments)
- PID calibration records

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All documentation shall be placed in the project files and retained following completion of the project.

8.0 References

Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA/600/4-89/034, published by National Water Well Association, 1991.

RCRA Ground Water Monitoring Technical Enforcement Guidance Document, published by National Water Well Association, 1986.

A Compendium of Superfund Field Operations, EPA 540/P-87/001, published by the Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, US EPA, 1987.

Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies, EPA/600/R-92/128, published by the Environmental Research Center, 1992.

9.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

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Project Operating Procedure

POP-009

Rock Core Drilling

1.0 Scope and Applicability

1.1 Purpose and Applicability

This Project Operating Procedure (POP) describes the methods used for obtaining rock core samples for establishing the stratigraphy, structure, fracture characteristics, and geotechnical properties of rock.

Rock core drilling is a sample collection technique used during the drilling of fractured bedrock. In addition to reviewing the Rock Core POP, the AECOM field geologist must also review POP 101 that describes the procedures for Sonic Drilling.

Rock core drilling, in addition to providing rock samples for characterization, is completed to provide an open borehole for in-situ testing such as permeability/pressure testing, fracture orientation analysis, and various borehole geophysical tests. In addition, rock core drilling is often accomplished for preparation of a borehole for groundwater monitoring well installation.

1.2 General Principles

Rock core drilling involves the use of a core barrel assembly which consists of diamond or carbide-tipped coring bit and a sample retaining barrel with inner sleeve. The core barrel assembly is spun or rotated into the rock until the desired drilling depth is reached, then the assembly is removed and the core sample is extracted. Water is recirculated down the hole for cooling the core barrel as it is advanced. Typically, a recirculation tub is used by the driller to contain the cooling water.

This POP describes the methodology used in the collection and handling of rock core samples. Rock core logging procedures are presented in POP 013 (Logging of Rock Cores).

2.0 Health and Safety Considerations

Rock core drilling may involve chemical hazards associated with the type of contaminants potentially encountered and will always involve physical hazards associated with rotating drilling equipment and handling of core samples.

When rock core drilling is performed, adequate Health and Safety measures must be taken to protect sampling personnel. These measures must be addressed in the project Health and Safety Plan (HASP). This plan must be approved by the project Health and Safety Officer before work commences, must be distributed to all personnel performing core drilling, and must be adhered to as field activities are performed.

3.0 Interferences

At sites being monitored for hydrocarbons, inherently complex rotary rigs may introduce grease and oil to the monitoring system. Mud pumps, water swivels, rotary drives, rod connections, and drill- fluid components all may contribute hydrocarbons inadvertently to the system, despite the best decontamination/degreasing efforts.

4.0 Equipment and Materials

4.1 Drill Rigs/Coring Equipment

Rock core drilling can be conducted using most drilling rigs that have the ability to spin drill rods with a rotary action. This may include rigs also capable of conducting air rotary, rotosonic (sonic) or even hollow-stem auger drilling. Ideally, the rig is capable of rotating the drill rods and core barrel at speeds up to 700-800 revolutions per minute (rpm) and has at least 4,000 foot-pounds (ft-lb) of torque for wire line coring. Most air rotary rigs, full-size sonic and larger hollow-stem auger rigs have this capability and will allow for relatively good production (coring rates). The mini-sonic and smaller hollow-stem auger rigs may be needed for special circumstances (e.g., tight spaces, limited access, etc.), however, the use of such rigs will likely result in lower production rates. The Project Manager should check with the driller to ensure that the rig is appropriate for the intended purpose.

All drill rigs used for rock coring typically are equipped with hydraulic feed. Driven or drilled-in flush joint casing shall be employed. For driving casing, it is not necessary to record the casing blows which oftentimes can be difficult to count, because they are fairly rapid blows; however, this information can be useful in assessing the relative density of unconsolidated deposits. It also may be required by a project specific QAPP. Drill rods for drilling rock should be NW in size to minimize vibration and chattering. Rock core size shall be NQ or HQ (Wire Lines) or as required by the Quality Assurance Project Plan (QAPP) or Project Work Plan. Different types of core barrel assemblies and coring bits are available for different applications. The Project Manager should be aware of the specific type of coring required on a particular project and should specify the necessary equipment when subcontractor arrangements are made. This POP assumes that the proper coring equipment has been made available for the required application. Some examples of standard core barrel sizes are provided below for reference. It should be noted that sonic rigs have their own tooling sizes and will be slightly different than those shown below.

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Standard Core Barrel	ID	OD
NQ	1.875	2.98
HQ	2.50	3.78
NX	1.77	2.98
PQ	3.27	4.83

In general, 5-foot barrels will be employed at the discretion of the project geologist. Some rigs can generate 10-foot runs.

4.2 Core Boxes

Core boxes shall be provided by the driller for core storage purposes. Core boxes are typically constructed of wood and are capable of holding 10 to 20 feet of rock cores.

4.3 Other Required Materials

- Subcontractor-supplied drill equipment
- Waterproof marker to label core boxes
- Hand lens
- Tape measure
- Camera
- Cell phone or 2-way radio
- Health and Safety supplies as required by the HASP
- Protractor
- Equipment decontamination materials
- Field project notebook/pen

5.0 Procedures

5.1 Borehole Preparation

Typically, soil sampling and rock coring will be performed in the same borehole. To set up the rig for coring, the boring needs to be advanced to the first competent bedrock surface following established drilling procedures. The drilling casing shall be firmly seated and grouted at least 5 feet into the competent bedrock surface to provide a seal to allow for circulation of water and removal of rock

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cuttings. Casing shall be required for the full depth of the unconsolidated deposits and is often driven at least 5 feet into competent bedrock.

5.2 Coring Preparation

The coring methods employed shall be adjusted continuously by the drilling subcontractor to obtain maximum core recovery of the rock being drilled. This will involve careful attention and adjustment of the rates of feed, rotation, and drilling fluid.

The types of coring bits shall also be carefully selected by the drilling subcontractor in consultation with the project geologist prior to start of coring. Bit specifications including diamond size, matrix and the configuration of the bit face, and water ports will have a bearing on the maximum recovery of each type of rock. The project geologist may request that the type of bits be varied in each hole if different rock types are encountered. In no case shall worn or damaged bits be used as this will affect coring time, sample recovery, and sample quality. If production rates drop, the project geologist should consult with the driller to ensure that the bit is not overly worn or damaged. Worn or damaged bits shall be checked and replaced as soon as excessive wear is evident.

The project geologist shall make an independent determination of depth measurements prior to start of coring and check his/her determinations with those made by the drilling subcontractor. Any discrepancy shall be resolved in the field as soon as it is discovered. All depth measurements shall be made in feet and tenths of feet.

Every effort should be made to use clear potable water as a drilling fluid. Depending upon boring completion requirements, sampling and analysis of the water source may be required. Drilling mud is typically not used for environmental applications. The use of drilling muds would need approval from the Project Manager in advance.

To minimize core losses in soft, erodible rock, the following measures shall be required by the project geologist:

- Drilling shall be restricted to short runs of 2 to 3 feet.
- The driller should switch to a triple-tube core barrel.
- Drilling water pressure shall be kept low (under 150 pounds per square inch [psi]).
- Feed pressure shall be kept under 100 psi.

Split-spoon drive samples may be taken in any weathered zones where it is not possible to drill and obtain satisfactory recovery of soft erodible rocks. Satisfactory recovery for this purpose is defined as 50% or greater, although 50% recovery may be unavoidable due to weathering along fractures.

The project geologist shall not permit a full coring run to be drilled if he/she suspects the core was left in the hole on the previous run. If this is believed to have occurred, he/she shall direct that the next coring run be shortened by the length of core believed to have been left in the hole. This is necessary to prevent blocking the core barrel and grinding of the core.

Core barrels and other down-hole equipment will require decontamination between borings if bedrock coring is being completed as part of an environmental investigation as opposed to a geotechnical

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investigation. Equipment decontamination will be required between borings in suspected or known contamination areas and should be the responsibility of the drilling contractor.

5.3 Core Collection

Lower the core barrel assembly into the borehole to the bedrock surface. The drilling subcontractor shall then initiate coring by starting water circulation, core barrel rotation, and feed pressure.

The drilling subcontractor shall mark the core barrel stem at approximate 6-inch intervals above the outer casing. This will allow for determination of coring rate in inches or feet per minute. The project geologist, as well as the drilling subcontractor, shall monitor and record the coring rate on the boring log. The rig slide pistons may also be used as an alternative location for marking and recording the coring rate. The AECOM geologist shall record feed pressure, average rotation speed (RPM) and the coring rate per run.

Core return water should be observed for changes in color or visible signs of contamination as coring proceeds. Water samples may be screened for headspace volatile organic compounds (VOC) with a photoionization detector (PID) if desired following established PID headspace procedures. Changes in water color/quality should be noted on the boring log or field notebook.

Once the desired coring interval has been achieved, the water circulation and feed pressure should be stopped, the core broken off by raising the core barrel slightly, and the core barrel removed from the drill casing. If 100% recovery was not obtained, sound the borehole to determine if the missing core still remains in the bottom of the borehole.

5.4 Sample Handling and Storage

Upon removal of the core barrel from the drill hole, the split inner tube shall be removed and opened, and, if necessary to facilitate accurate logging, the core shall be washed while it rests in the other half. Care shall be used in washing to avoid removing small pieces of core or soft joint or vein fillings. If the rock is soft, friable, or otherwise erodible and, if the geologist believes washing will damage the core, the washing process shall be omitted. This is also a good time to take a picture of the core before it is removed from the inner tube.

The core shall be placed in core boxes (typically wooden) provided by the drilling subcontractor and be placed with the top of the run at the upper (rear) left corner and the remaining core placed sequentially from left to right and from the rear (nearest the cover hinge) of the box to the front.

Wooden blocks marked with the appropriate depth and run number shall be placed between each separate core run. In addition, wherever core is lost due to the presence of a cavity or large joint (open or filled), a spacer (section of wood dowel) shall be placed in the proper relative position in the core box. The spacer shall be the same length (optional or just marked with a section of wood dowel) as that of the lost core and the depth range shall be marked on the spacer along with the reason for the missing core (e.g., cavity, large joint, etc.).

The core box shall be marked on the top and two ends with the client's name, site identification, boring number, depth range, box number, and date. The box number shall indicate the total number of boxes and which box it is (e.g., 1 of 4). Inside the core box lid, the above information should be recorded, as

well as a line-by-line inventory of each core run contained in the box shall be recorded. Each line shall record the following information as an example:

Run Number	Depth Range	Penetration	Recovery	RQD
NQ1	25-30'	60"	59"	90%
NQ2	30-35'	60"	60"	95%
- Rock Quality Designation (RQD) is a percent ratio determination of rock quality and is applicable to core samples with a minimum diameter of 1-7/8 inches (NQ size and greater). The RQD value is determined by measuring all core pieces within a single core run that are two times greater than the core diameter, adding the total length, dividing the total length of good quality core by the total core run length (usually 60 inches), then multiplying the resultant total by 100 to arrive with a percent value. Additional information on RQD determination and rock core logging appears in POP 013 (Logging of Rock Cores).
- Care must be taken by the field geologist to distinguish between mechanical fractures resulting from the drilling and naturally-occurring fractures. See POP 013 (Logging of Rock Cores). If still uncertain, the field geologist should obtain the driller's opinion in this regard.

The above procedures shall be repeated until the entire designated coring interval has been cored.

6.0 Quality Assurance / Quality Control

Sampling personnel should follow specific quality assurance guidelines as outlined in the project-specific QAPP and/or Sampling Plan. Proper quality assurance requirements should be provided which will allow for collection of representative core samples from representative boring locations. Unless core samples are to be submitted for laboratory analysis, no additional quality assurance samples are collected. (MERC testing may require collection/retention of core samples in accordance with POP 25 [Bedrock Sample Collection and MERC Analysis].)

Rock core samples may be submitted for environmental analysis (MERC testing) and/or geotechnical analysis to determine porosity, rock strength characteristics, or rock type.

Field blank samples of the coring water supply may be requested for analysis if monitoring wells for water quality testing are installed. Such samples should be collected directly from the water source prior to its use. The project work plan should indicate the requirement for collection of these samples.

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7.0 Data and Records Management

7.1 Core Sample Log

The rock core shall be described in accordance with the procedures outlined in the POP 010 (Logging of Rock Cores).

7.2 Field Project Notebook

A field log book will also be kept in which observations on the drilling procedures shall be kept including, but not limited to the following:

- Rate of penetration of the coring run;
- Rotation speed during the coring run in RPMs (if available);
- Information on any blocking or grinding of the core during the run;
- Changes in color or flow rate of the return water;
- Any loss of circulation of the drilling fluids during drilling;
- Any unusual action of the drill rods, sudden chattering of the core barrel, rapid drop of the drill rods, etc.
- Recording the pressure of the pressure gauges (if possible) on the drill rig;
- Rock type and description, including RQD calculations; and
- Any observations made by the driller. It is expected the field geologist will consult with the driller on a regular basis about their observations.

Unanticipated changes or deviations to the procedures or materials described in this POP will be appropriately documented in the project records.

8.0 Personnel Qualifications and Training

Rock core drilling is generally conducted by experienced drilling subcontractors. The project geologist should be knowledgeable with general coring procedures to provide field judgments or opinions regarding method variations or changes when necessary. It is recommended that initial coring attempts be conducted with more experienced personnel as a measure of training. Field project personnel should be health and safety certified as specified by OSHA (29 CFR 1910.120(e)(3)(i)) to work on sites where hazardous materials are considered to be present.

Drilling subcontractor

It is the responsibility of the drilling subcontractor to provide the necessary equipment for coring and to collect the designated samples in accordance with project requirements and QAPP.

Project geologist

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It is the responsibility of the project geologist to observe the coring operation and to log all cores as they are collected. The project geologist is also responsible for making decisions regarding core run lengths and coring completion depths. It is the project geologist's responsibility to be familiar with the sampling procedures outlined within this POP and with specific sampling, quality assurance, and health and safety requirements outlined within the project-specific work plans (Sampling Plan, QAPP, and HASP).

Project manager

It is the responsibility of the project manager to ensure that the project is properly executed and staffed with knowledgeable and trained personnel who are appropriately equipped.

9.0 References

Acker Drill Co. Inc., Basic Procedures for Soil Sampling and Core Drilling, 1974.

Midwest GeoSciences Group. Field Guide for Rock Core Logging and Fracture Analysis. 2001-2005. Waverly, Minnesota.

Midwest GeoSciences Group. 2002. Improving Hydrogeologic Analysis of Fractured Bedrock Systems Workshop Notebook. University of Massachusetts.

Standard References for Monitoring Wells, Massachusetts Department of Environmental Protection, DEP #WSC-310-91, 1991.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Lockheed Martin Wilmington

Project Operating Procedure

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Logging of Rock Cores

1.0 Scope and Applicability

1.1 Purpose and Applicability

This Project Operating Procedure (POP) describes applicable procedures for logging of rock core in the field. The basic objective of logging rock cores is to determine various geologic and physical characteristics of the rock core including: rock type/name, lithological/structural features, and any notable physical conditions, including fracturing, faulting, or alterations.

This POP is applicable to all drilling programs where core samples are collected for the purpose of determining rock type and rock conditions. This POP provides general guidance for logging of rock cores with information obtained from various other sources of technical guidance. This POP is not designed to cover all aspects of core logging in detail. It is assumed that field personnel involved with logging of core samples will have some familiarity with logging procedures and access to more detailed logging references if needed.

1.2 General Principles

Rock core logging generally involves visual inspection and measurement of sections of cored bedrock recovered from rock core drilling operations. Rock core is usually removed from the core barrel and placed into a core box before logging takes place. Procedures for rock core drilling and handling of rock core are presented in POP 011 (Rock Core Drilling).

In a rock description, the main characteristics should be given in the following order:

- Name of stratigraphic formation (if known)
- Rock type (e.g., dolomite or granite), including grain or crystal size
- Field hardness/strength
- Color
- Texture
- Geologic structure

- State of weathering
- Fracture density
- Presence/absence of typical minerals associated with faults (e.g., slickensides, etc.)
- Additional geologic information (e.g., photographs, recovery, size range of core pieces, rock quality designation [RQD], etc.)

2.0 Health and Safety Considerations

Rock core logging may involve chemical hazards associated with the type of contaminants potentially encountered and physical hazards associated with handling of core samples. When rock core logging is performed, adequate Health and Safety measures must be taken to protect sampling personnel. These measures must be addressed in the project Health and Safety Plan (HASP). This plan must be approved by the project Health and Safety Officer before work commences, must be distributed to all personnel performing core logging, and must be adhered to as field activities are performed.

3.0 Interferences

Not applicable.

4.0 Equipment and Materials

- Health & Safety Plan
- Blank boring logs
- Blank rock core logs
- Field Rock and Mineralogy Handbook
- Hand lens for close inspection
- Waterproof marker for labeling the core and core boxes
- Core boxes (usually provided by drilling subcontractor)
- Dilute hydrochloric acid (optional but needed if logging carbonates)
- Grain size/sphericity gauge
- Knife
- Rock hammer/pick (optional)

- Rock color chart
- Standard ruler with metric scale
- Six-foot folding rule marked in tenths of a foot or tape measure
- Squirt bottle with water
- Protractor, clinometer, or other device for measuring the angle of fracture orientation to the core axis
- Camera
- Other mineralogical/geologic references for rock identification (e.g., past boring or geologic logs from the area)
- Field notebook/pen
- Color pencils for the rock core logs (optional)
- Personal protective equipment (PPE), if working on a contaminated site (consult Health & Plan)

5.0 Procedures

5.1 General Information

This procedure assumes that borehole drilling and rock coring has been completed in accordance with POP 011 (Rock Core Drilling) and any other drilling specifications outlined within the project-specific Work Plan.

The inspecting geologist shall prepare a boring log for each drilled boring. A standard boring log (Attachment 1) should be used to log general overburden and bedrock information and other standard drilling information such as drilling method, boring width, depth, etc. A rock core log (Attachment 2) shall be used to indicate detailed information specific to each recovered core sample. This log allows for detailed characterization of one 5-foot length of core per page. A field notebook shall also be kept to record pertinent drilling information. A brief glossary of geologic terms is provided in Attachment 3.

5.2 Core Preparation

Once the core run is completed and the rock sample is laid out in the core box, the rock sample may be moistened to highlight the rock features (particularly color) using the squirt bottle with water. If photographs are required, this may a good time to take them while the rock sample is still wet with a color chart and scale. But, ideally, the photo was taken before the core was removed from the core barrel.

5.3 Core Logging Procedures

Label Fractures and Mark Core

- Mark each fracture interpreted to be natural with a strike perpendicular across the fracture. Natural fractures are typically fractures that do not have a fresh surface visible.

Fresh surface can be indicative of the core being fractured at the time of drilling (mechanical fractured). Curving or highly irregular breaks are usually (but not always) indicative of induced breaks and are not natural fractures. Mineralized or a generally smoothed or weathered surface can indicate a natural fracture. The presence of slickensides or grooves also is indicative of a natural fracture. If uncertain whether a core fracture is natural the geologist can look to see if other, obviously natural, fractures are parallel to it. The geologist should also check with driller to ask his opinion. Mark the core with a two-color parallel strike along the whole core to indicate the correct orientation for "up".

Calculate Core Recovery and Rock Quality Designation

- Three common measurements are used to quantify core recovery:
- **Total core recovery** is the percentage ratio of the sum of all the total pieces recovered of the core divided by the core run length. Areas where loss of is likely to have occurred (soft seams, fractures with edges that do not match, zones of decay, etc.) should be noted.
- **Solid core recovery** is the percentage ratio of the sum of all the solid pieces of the core divided by the core run length.
- **Rock quality designation (RQD)** is a percentage value obtained by dividing the sum of all the good quality recovered core pieces equal to or greater than two times the core diameter by the total length of the core run and then multiplying by 100. RQD is a general indicator of rock quality for engineering purposes and is also an indicator of the relative amount of natural fracturing or zones of weathering within the rock. The calculation of RQD is only applicable to core samples with a minimum diameter of 1-7/8 inches (NQ size and greater). Only naturally occurring discontinuities will be considered and drilling-induced core fractures (mechanical breaks) are not included in determining the RQD value. In addition, only sound bedrock is used in the calculation of RQD. Weak and/or weathered rock core is not included in the RQD calculation. A graphical summary of the RQD calculation procedure is provided in Attachment 4.

Core Sample Characterization

- The nature and level of detail of the description depends on the project objectives. Most descriptions will not entail all of the parameters described below.
- Formation name, if known should be used for the rock being described. The geologist should have a basic understanding of the local geology of the area from a geologic map of the study area or field reconnaissance. Oftentimes, however, the specific Formation Name of the core is difficult to determine. If this is the case, it is best to not guess at the Formation Name and leave this section blank.
- Rock type - Rock samples will fall into one of three basic categories of rock. These categories are igneous, metamorphic, or sedimentary rocks. Each rock group or type will exhibit different physical and/or structural characteristics resulting from their individual morphologies. See section 5.3.4 for more specifics on describing the rock type.
- Field strength/hardness - The following table lists the rock hardness categories:

Table 1 Rock Hardness

DESCRIPTION	LONG DESCRIPTION
Very soft rock	Can be scratched with fingernail. Slight indentation produced by light blow of point of geologic pick. Requires power tools for excavation.
Soft rock	Hand-held specimen crumbles under firm blows with point of geologic pick.
Moderately soft rock	Shallow indentations (0.04 to 0.12 in. (1 to 3 mm)) can be made by firm blows with point of geologic pick. Can be peeled with pocket knife with difficulty.
Moderately hard rock	Can't be peeled or scraped with knife. Can be distinctly scratched with a steel nail.
Hard rock	Intact hand-held specimen requires more than one hammer blow to break it. Can be faintly scratched by steel nail.
Very hard rock	Cannot be scratched with a steel nail. Intact specimen breaks only by repeated, heavy blows with geologic hammer.
Extremely hard rock	Intact specimen can only be chipped, not broken, by repeated, heavy blows of a geologic hammer.

Notes:

in = inches

mm = millimeter

- Color - The color of the recovered rock is determined by comparing the core pieces with color chips in the Geological Society of America (GSA) Rock Color Chart. Basic rock color shall be determined from viewing a core sample under normal light. Degree of color (i.e., light, medium, dark) shall also be indicated. Variations in color, if considered important, are to be noted. In addition, the distinction should be made as to whether the color is primary or secondary (e.g., oxidation color) in nature.
- Texture - Rock texture classification differs between each basic rock group and is determined from the size (fine to coarse), shape, and arrangement (fabric) of individual grains in the sample as well as any resultant structures imparted on the rock by this arrangement of grains. Examples of rock texture are provided in Attachment 4 for each basic rock group.
- Fabric refers more specifically to the arrangement of the constituent grains or crystals in a rock.
 - In sedimentary rocks, preferred orientations of the grains and their position to any cementing material are usually the most important aspects of the fabric. In igneous rocks, the fabric is the pattern produced by the various shapes and orientations of the crystalline and non-crystalline parts of the rock.

- Fabric may also include any small discontinuities or planes of separation through or between grains or crystals. These are usually referred to as “microfractures” which may be caused by mechanical weathering, tectonic activity, stress-relief, or other factors.
- In metamorphic rocks, foliation is also an important fabric element and its characteristics (thickness, type of layering, etc) should also be described.
- Other descriptions for texture and fabric should be noted if small scale structures or physical appearances are seen within the rock.
- Geologic Structure - Structure descriptions typically refer to large-scale features within a rock mass. For rock core, the descriptions are based on sedimentary banding, metamorphic foliation, or metamorphic and igneous banding. The following table lists the categories of bedding used in describing sedimentary rock:

Table 2 Sedimentary Rock Bedding

BEDDING*	DESCRIPTION
Very Thick-Bedded	Greater than 4 ft. (> 1.2 m)
Thick-Bedded	1 ft. to 4 ft. (0.3 m to 1.2 m)
Medium-Bedded	4 in. to 12 in. (100 mm to 300 mm)
Thin-Bedded	1.2 in. to 4 in. (30 mm to 100 mm)
Very Thin-Bedded	0.5 in. to 1.2 in. (13 mm to 30 mm)
Thickly Laminated	0.1 in. to 0.5 in. (3 mm to 13 mm)
Thinly Laminated	Less than 0.1 in. (< 3 mm)
None (“massive”)	Rock is uniform

Notes:

* bedding, foliation or bands

ft = feet

m = meters

mm = millimeter

- For igneous and metamorphic rocks, any observable planar features (foliation, banding, etc.) may be recorded using the same thickness designations as sedimentary bedding.

- Weathering - The following table lists the weathering categories:

Table 3 Weathering Categories

DEGREE OF WEATHERING	DETAILED DESCRIPTION
Residual soil	Advanced state of decomposition resulting in plastic soils. Rock fabric and structure completely destroyed. Large volume change.
Completely weathered	Minerals decomposed to soil but fabric and structure preserved (saprolite). Specimens easily crumbled or penetrated.
Highly weathered	Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becoming indistinct but fabric preserved.
Moderately weathered	Discoloration throughout. Strength somewhat less than fresh rock but cores cannot be broken by hand or scraped with knife. Texture observed.
Slightly weathered	Slight discoloration inwards from open fractures.
Fresh	No visible sign of decomposition or discoloration. Rings under hammer impact.

5.4

- Fracture Characteristics - As mentioned above, describing fractures are as important as describing the rock mass. These descriptions are usually done by lumping a group of similar fractures (i.e., orientation, spacing, size, etc.) together and then describing their characteristics. If more detail is needed for describing natural or induced fracturing the reader is encouraged to reference "Fractured Core Analysis: Interpretation, Logging, and Use of Natural and Induced Fractures in Core" by Kulander, Dean, and Ward (1990).
- Fracture Density - The following table lists the fracture density (FD) categories:

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Table 4 Fracture Density

DEGREE OF FRACTURING	DESCRIPTION
Unfractured	No observed fractures.
Very slightly fractured	Core recovered in lengths greater than 3 ft. (1 m).
Slightly to very slightly fractured	Core recovered in lengths from 1 to 3 ft. (0.3 to 1 m).
Slightly fractured	Core recovered mostly in lengths from 1 to 3 ft. (0.3 to 1 m) with few scattered lengths less than 1 ft. (0.3 m) or greater than 3 ft. (1 m).
Moderately to slightly fractured	Core recovered mostly in lengths averaging 1 ft. (0.3 m).
Moderately fractured	Core recovered mostly in lengths from 0.33 to 1 ft. (0.1 to 0.3 m) with most lengths about 0.67 ft. (0.2 m).
Intensely to moderately fractured	Core recovered mostly in lengths of 0.33 to 0.67 ft. (0.1 to 0.2 m) with most lengths about 0.5 ft. (0.15 m).
Intensely fractured	Core recovered mostly in lengths from 0.1 to 0.33 ft. (0.03 to 0.1 m) with most lengths less than 0.33 ft. (0.1 m) and with fragmented intervals.
Very intensely to intensely fractured	Core recovered as short core lengths averaging less than 0.1 ft. (0.03 m).
Very intensely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

Notes:

ft = feet

m = meters

- Size Range of Core Pieces - Indicate the range of size of pieces of core recovered in the run. The size may range from fragments too small to measure up to a single piece the entire length of the run. Note the locations of significant fragmented zones.
- Fracture Dip Angle - This is angle is measured with respect to either the long axis of the core or is measured from the horizon. The angle of natural bedding planes, foliations, and natural or drilling-induced fractures should be estimated or measured with a protractor or clinometer and documented on the rock core log and/or field project notebook. Documentation of the angle of these features is often important with respect to determining groundwater flow patterns. Some projects may require collection of oriented core samples or borehole video monitoring to determine the orientation of open fractures.
- Aperture

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- For Fractures:
 - Wide* >200 mm
 - Moderately Wide.* 60-200 mm
 - Moderately Narrow* 20-60 mm
 - Narrow* 6-20 mm
 - Very Narrow* 2-6 mm
 - Extremely Narrow* >0-2 mm
 - Tight* No Visible Separation
- For Voids:
 - Pitted.* Pinhole Openings
 - Vuggy* Openings up to 4 Inches
 - Cavity* Opening > 4 Inches
 - Honeycombed* Cell-like form of vugs or pits
 - Vesicle* Opening form from trapped gas
- Healing - The following table lists the fracture healing (FH) categories:

Table 5 Fracture Healing

DEGREE OF HEALING	DESCRIPTION
Totally Healed	Fracture is completely healed or re-cemented to a degree at least as hard as surrounding rock.
Moderately Healed	Greater than 50% of fracture material, fracture surfaces or filling is healed or re-cemented and/or strength of the healing agent is less hard than surrounding rock.
Partly Healed	Less than 50% fracture material, filling or fracture surface is healed or re-cemented.
Not Healed	Fracture surface(s), fracture zone, or filling is not healed or re-cemented.

- Infilling
 - Clean.* No oxidation or staining evident.

- *Surface Oxidation or Staining.* Oxidation is present or secondary staining is visible along the fracture face.
- *Decomposed or Disintegrated Rock.* Decomposition or disintegration is visible along the fracture face.
- *Non-Cohesive Sediment.* The sediment present is non-ductile.
- *Cohesive Sediment.* The sediment present yields in a ductile manner.
- *Mineralization (describe the mineral, if possible).* Secondary mineralization is present on the fracture face or filling the fracture.
- *Other.* Other characteristics of the fracture that should be noted.
- Unevenness
 - *Rough.* The fracture is large or has angular asperities (irregularities).
 - *Smooth.* The fracture has no asperities.
 - *Slickensided.* The fracture face has slickensides (polished or striated face).
 - These next terms can be used in conjunction with the terms above:
 - *Stepped.* The fracture face has near normal steps or ridges.
 - *Undulating.* The fracture face shows a “wavy” characteristic.
 - *Planar.* The fracture face is flat.
- Moisture Conditions
 - *Restricted.* Flow along the fracture does not seem evident or possible.
 - *Dry.* Flow along the fracture has occurred in the past, but it is currently dry.
 - *Dry with Staining or Leaching.* Fracture surface show staining or leaching, but is currently dry.
 - *Damp.* The fracture filling is damp, but there does not appear to be any water flow.
 - *Wet with Minor Seepage.* The fracture filling is wet or stained and shows apparent minor seepage.
 - *Wet with Continuous Seepage.* The fracture filling is wet and shows continuous seepage.
- Photographs - The field geologist will take representative digital photographs of the individual core runs and additional photographs of important portions of the cores (e.g., fragmented zones, soft seams, lithology changes, etc.) where applicable.

Rock Classification - Classification of a specific rock type; i.e., actually naming a core specimen, often requires knowledge of additional rock characteristics that are particular to each of the three major rock groups. Geologists divide rocks into three groups based on origin and then subdivide

them into smaller groups on the basis of composition and texture. Tables 6 through 8 provide information on the various rock types.

- **Igneous Rocks** - Rocks formed from the solidification of molten material (magma or lava). Igneous rocks can be intrusive (solidifying below the surface from magma) or extrusive (solidifying at the surface from lava). Intrusive igneous rocks are generally composed of larger crystals/grains (coarser texture) while extrusive igneous rocks are generally composed of smaller crystals/grains (finer texture). In general, igneous rocks tend to have an interlocking, crystalline texture with little to no appearance of layering, banding, or bedding.
- **Metamorphic Rocks** - Metamorphic rocks are Igneous and/or Sedimentary rocks whose textures and /or mineral content have been changed by heat, pressure and/or chemically active solutions (invading gasses and/or liquids). In some instances, metamorphic rocks have been re-metamorphosed into other higher or lower grade metamorphic rocks. Metamorphic rocks can appear banded or layered (due to the alignment of platy, tabular, or elongated mineral grains or the concentration of different minerals into distinct bands).
- **Sedimentary Rocks** - Sedimentary rocks are formed by lithification of accumulated sediments that were transported and deposited by water, wind, ice, biological activity and/or chemical precipitation. In general, sedimentary rocks are composed of the weathering products of pre-existing rocks. Sedimentary rocks usually, but not always, have a layered appearance due to the presence of bedding planes. The grains of sedimentary rocks can range from sharply angular to well-rounded and from very fine to very coarse. Sedimentary rocks may contain fossils. Two important processes in the formation of sedimentary rocks from original sediments are compaction and cementation.
 - **Compaction** is the physical process by which the volume of a sediment is reduced by pressure. The weight of overlying deposits compact the underlying sediments, forcing out water and air and decreasing the porosity by squeezing the grains of sediment closer together. When muds are compacted in this manner, weak attractive forces may cause the grains to adhere to one another, converting the loose sediment into rock. Claystone, mudstone and shale are examples of sedimentary rocks which may be formed in this manner.

- **Cementation** occurs as water circulates through the sediment and dissolved elements in the water precipitate out and bind the grains of sediment together. Changes in the physical and/or chemical environment initiate the precipitation. Common cementing agents include silica compounds and calcium carbonate (calcite or aragonite, CaCO_3). Various iron compounds (such as FeCO_3 , FeS_2 , and Fe_2O_3) can also act as cements. The cement may partially or completely fill the pore spaces in the sediment. Rocks formed by cementation of sediments can range from very soft to very hard. Cemented claystone, mudstone, shale, siltstone, sandstone and limestone are examples of rocks which may be formed by cementation.

Note: Rocks formed by cementation (with or without compaction) are more durable than rocks formed by compaction alone.

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Table 6 Common Igneous Rocks

IGNEOUS ROCKS				
ROCK NAME	COLOR GROUP	TEXTURE	MINERALS	PROPERTIES
PEGMATITE	Light colored	Very coarse grained.	Quartz Feldspar Mica	Quartz and feldspar predominate but can contain many minerals. Feldspar is white, pink or green. Moderately difficult to drill.
GRANITE		Coarse to fine interlocking grains.	Quartz Feldspar Mica Hornblende Pyroxene	White, gray or pink. Quartz is a major constituent. Can have a salt and pepper texture. Feldspar is white, pink or green. Moderately difficult to drill.
SYENITE		Coarse to fine interlocking grains.	Feldspar Mica Hornblende Pyroxene	Little or no quartz. Feldspar is white or pink. Can have a salt and pepper texture. Moderately difficult to drill.

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Table 6 Common Igneous Rocks (Continued)

IGNEOUS ROCKS				
ROCK NAME	COLOR GROUP	TEXTURE	MINERALS	PROPERTIES
DIORITE	Dark colored	Coarse to fine interlocking grains.	Feldspar Biotite Hornblende Pyroxene	Often greenish in appearance. Often contains quartz (quartz diorite). Feldspar is white or gray. Moderately difficult to drill.
GABBRO		Coarse interlocking grains.	Feldspar Hornblende Pyroxene	No quartz. Feldspar is white or gray. Difficult to drill. The intrusive variety of basalt.
DIABASE		Medium to fine interlocking grains.	Feldspar Hornblende Pyroxene	No quartz. Commonly called traprock. Moderately difficult to drill.
BASALT		Fine interlocking grains.	Feldspar Hornblende Pyroxene	No quartz. Feldspar is white or gray. Difficult to drill. The extrusive variety of gabbro.

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Table 7 Common Metamorphic Rocks

METAMORPHIC ROCKS				
ROCK NAME	COLOR	STRUCTURE	MINERAL COMPOSITION	PROPERTIES
QUARTZITE	White Gray Red	Massive	Quartz	Glassy appearance. Hard. Can scratch glass and steel. Breaks across grains (no pre-existing fracture planes). Very difficult to drill.
MARBLE	White Gray		Calcite Dolomite	Often distinctly crystalline. Can be scratched with a knife or nail. Can contain flakes of graphite. Effervesces in dilute (5%) hydrochloric acid. Drills easily.
SERPENTINITE	Yellowish Green		Serpentine	Soft. Can be easily scratched with a knife or nail. Often fractured. Drills easily.
GNEISS	Gray Green Pink	Banded	Quartz Feldspar Mica	Banded appearance due to alignment of elongate and platy minerals. Usually moderately difficult to drill.
SCHIST	Green Gray Brown	Foliated (coarse-grained)	Mica Quartz Feldspar	Foliation due to alignment of platy minerals. Contains a lot of mica. Drills easily.
SLATE/ PHYLLITE	Gray Red Green Purple	Foliated (fine-grained)	Mica Quartz Feldspar	Foliation due to alignment of platy minerals. Can be distinguished from shale by its usually shiny surface. Moderately easy to drill.

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Table 8 Common Sedimentary Rocks

SEDIMENTARY ROCKS						
ROCK NAME	STRUCTURE	COLOR	PARTICLE SHAPE AND SIZE	PREDOMINANT MINERAL COMPOSITION	CEMENT/ MATRIX	PROPERTIES
CONGLOMERATE	Massive or layered.	Red Gray Brown	Very coarse to fine grains.	Rock fragments.	Iron Calcite Silica Clay	Major portion composed of pebbles up to or more than an inch in diameter. Moderate to difficult to drill (depending on type of fragments & matrix).
SANDSTONE		Red Gray Brown	Medium to fine grains.	Rock fragments. Quartz Feldspar	Iron Calcite Silica Clay	Moderate to difficult to drill (depending on type of fragments & matrix).
LIMESTONE		Light Gray To Black	Angular to rounded grains.	Calcite	Calcite Silica Clay	Often dense. Effervesces freely in dilute (5%) hydrochloric acid. Often fossiliferous. May contain veins of calcite. Can be scratched with a knife or nail. Easy to drill. May contain chert (microcrystalline quartz) which is very difficult to drill. May contain Dolomite.
DOLOSTONE		White To Dark Gray	Angular to rounded grains.	Dolomite	Calcite Silica Clay	Similar to limestone but effervesces feebly in dilute (5%) hydrochloric acid. Can be scratched with a knife or nail. Drills easily. May contain chert which is very difficult to drill. May contain Calcite.

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Table 8 Common Sedimentary Rocks (Continued)

SEDIMENTARY ROCKS						
ROCK NAME	STRUCTURE	COLOR	PARTICLE SHAPE AND SIZE	PREDOMINANT MINERAL COMPOSITION	CEMENT/ MATRIX	PROPERTIES
SILTSTONE MUDSTONE SHALE CLAYSTONE	Laminated	Red Black Gray Green Purple	Fine to very fine particles.	Clay Quartz Feldspar	Clay Calcite Silica	Generally dull in appearance. Can be confused with fine-grained limestone but will not effervesce (when pure) in hydrochloric acid. May contain pyrite (fool's gold) crystals. May contain calcite and/or quartz veins. Can be scratched with a knife or nail. Drills easily. The different names (siltstone to claystone) are based on diminishing grain size.

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Other Information to document on the standard boring log and/or in the field notebook may include:

- Information on blocking or grinding of the core during the run;
- Any unusual action of the drill rods, sudden chattering of the core barrel, rapid drop of the drill rods, etc.;
- Depth of the bottom of the casing in feet below ground surface (bgs) when seated in rock;
- Depth at which rock was encountered in feet below ground surface;
- Type of core drill, including core size;
- Sequential number of each core run prefixed with the size of the core barrel (e.g., NQ-1, NQ-2, etc.);
- Time required to advance core barrel in minutes per foot;
- Depth interval, penetration, and core recovery in feet;
- Depth of each change in bedrock type in feet below ground surface;
- Changes in color and/or flow rate of the return water;
- Depth at which drill water is lost;
- Depth at which artesian or "flowing" water is observed; and
- Any visual or olfactory evidence of contamination.

6.0 Quality Assurance / Quality Control

Sampling personnel should follow specific quality assurance guidelines as outlined in the project-specific Quality Assurance Project Plan (QAPP) and/or Sampling Plan. Proper quality assurance requirements should be provided which will allow for collection of representative core samples from representative boring locations. Unless core samples are to be submitted for laboratory analysis, no additional quality assurance samples are collected. Rock core VOC analysis (MERC testing) may require collection/retention of core samples (see POP 025 for Bedrock Sample Collection and MERC Analysis).

Rock core samples may be submitted for environmental analysis (MERC testing), petrographic, or geotechnical analysis to determine porosity and/or rock strength characteristics. Duplicates or field blanks may be required if conducting MERC analysis; see associated QAPP for QA/QC requirements.

7.0 Data and Records Management

Boring Log - General borehole drilling information should be described on the standard boring log (Attachment 1).

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Core Sample Log - The rock core shall be described in detail on the Core Sample Log (Attachment 2).

Field Project Notebook - A field project notebook will also be kept in which observations on the drilling procedures shall be described. Information on rock type characterization as well as miscellaneous drilling procedures and observations listed in Section 5.3.5 of this procedure, should be documented in the project notebook, in accordance with POP 001 (Recording of Field Data).

8.0 Personnel Qualifications and Training

The project geologist should have knowledge of general geology and logging procedures. It is recommended that initial logging attempts be conducted with more experienced personnel as a measure of training. Field project personnel should be health and safety certified as specified by OSHA (29 CFR 1910.120(e)(3)(i)) to work on sites where hazardous materials are considered to be present.

It is the responsibility of the project geologist to log all cores as they are collected. It is the project geologist's responsibility to be familiar with the procedures outlined within this POP and with specific sampling, quality assurance, and health and safety requirements outlined within the project-specific work plans (Sampling Plan, QAPP, HASP).

9.0 References

Standard References for Monitoring Wells, Massachusetts Department of Environmental Protection, DEP #WSC-310-91, 1991.

Midwest GeoSciences Group. Field Guide for Rock Core Logging and Fracture Analysis. 2001-2005. Waverly, Minnesota (see Attachment 4).

Midwest GeoSciences Group. 2002. Improving Hydrogeologic Analysis of Fractured Bedrock Systems Workshop Notebook. University of Massachusetts.

New York State Department of Transportation, 2007. Geotechnical Engineering Manual: Rock Core Evaluation, GEM-23, Revision #1. NYDOT Geotechnical Engineering Bureau, New York.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

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ATTACHMENT 1 - Boring Log Form

		Client:					BORING ID:				
		Project Number:									
		Site Location:									
		Coordinates:					Elevation:		Sheet: 1 of		
		Drilling Method:					Monitoring Well Installed:				
		Sample Type(s):					Boring Diameter:				
Weather:					Logged By:		Start Date/Time:		Depth of Boring:		
Drilling Contractor:					Finish Date/Time:		Water Level:				
Depth (ft)	Geologic sample ID	Sample Depth (ft)	Recovery (inches)	Headspace (ppm)	Moisture	U.S.C.S.	MATERIALS: Color, size, range, MAIN COMPONENT, minor component(s), moisture content, structure, angularity, maximum grain size, odor, and Geologic Unit (If Known)			Lab Sample ID (Depth)	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
NOTES:							Date/Time	Depth to groundwater while drilling			
Checked by _____							Date: _____				

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ATTACHMENT 2 - Rock Core Log Form

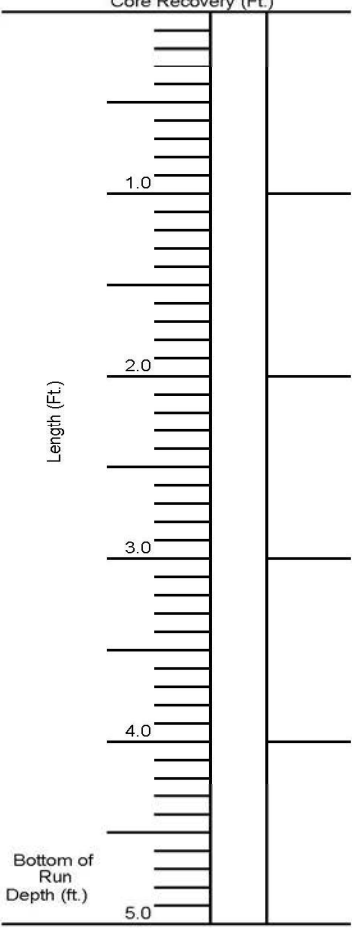
Boring ID: _____

VISUAL IDENTIFICATION OF ROCK CORES

Client	Project Number	Location	Sheet _____ of _____
Logged By	Sample	Core Dia. (In.)	Depth (Ft.)
Core Length (Ft.)	Core Recovery (Ft.)	RQD %	Rock Quality
Driller	Drill Equipment	Start Time	Finish Time

Top of Run Depth (ft.)

Core Recovery (Ft.)

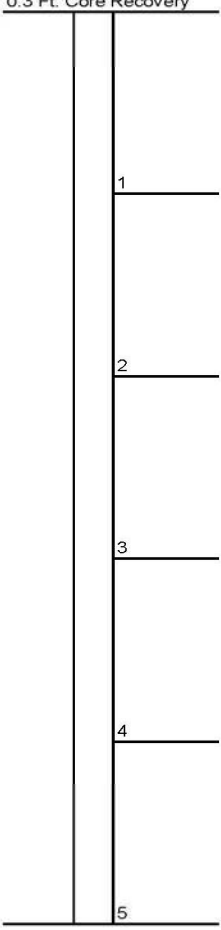


Length (Ft.)

Bottom of Run Depth (ft.)

Total _____ Ft.
_____ (%)

0.3 Ft. Core Recovery



Total _____ Ft.
_____ (%)

Rock Description and Identification
(include fracture dip & description, bedding planes, and other geologic features.)

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ATTACHMENT 3
Glossary of Geologic Terms

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- Banding:** Layering in the rock. The layers may be bedding, parallel to bedding, or be at an angle to bedding in sedimentary rock.
- In metamorphic rock, the layering is called foliation. The foliation is a result of the alignment of platy (flat) and/or elongated minerals due to the heat and pressure of metamorphism. The foliations may be parallel with or at an angle to the original bedding. Sometimes the original bedding has been obliterated and only the foliations can be observed.
- Igneous rocks normally do not exhibit banding except in cases of differential settlement during hardening.
- Bedding:** The layers in sedimentary rock parallel to the original surface of deposition. The original bedding planes were often, but not always, horizontal. The rock will often tend to break along bedding planes.
- Cement:** The material, usually chemically precipitated, which binds the particles of some sedimentary rocks together (see grains and matrix).
- Cleavage:** Closely spaced parallel planes along which rock can break. The cleavage may be a result of weakness along bedding planes in sedimentary rock (fracture cleavage) or may be a secondary development by alignment of platy minerals in metamorphic rock (slaty cleavage). Slaty cleavage may be parallel with or at an angle to original bedding.
- Diagenesis:** The process of chemical, physical and/or biological change in deposited sediment during its conversion into rock, exclusive of metamorphosis and weathering (see lithification).
- Effervescence:** The fizzing action that occurs when a carbonate rock (containing CaCO_2 or CaCO_3) is placed in contact with hydrochloric acid (HCl).
- Fault:** A fracture in rock along which there has been observable movement (see joint). In rock cores, a fault can sometimes be recognized by the displacement of mineral veins.
- Foliation:** The alignment of platy (flat) or elongate minerals, usually in metamorphic rocks, giving the rock a banded appearance. The foliation is usually a result of the heat and pressure rock is subjected to during metamorphism.
- Fracture:** Breakage in rock. The fracture may be parallel with or at an angle to banding, bedding, cleavage, foliation or lamination. Faults and joints are examples of fracture.
- Grains:** The particles of which a rock or sediment is composed (see cement and matrix).
- Joint:** A fracture in rock along which there has been no observable movement (see fault).
- Lamination:** Very thin layering in rock, less than 0.4 in. (10 mm). The layers may be a result of physical or chemical variations. Laminations may be parallel with or at an angle to bedding (cross-laminations) in sedimentary rock.
- Lithification:** The process by which loose sediment becomes rock (see diagenesis).

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- Lithology:** The character of a rock described in terms of its structure, color, mineral composition, grain-size, and arrangement of its component parts.
- Matrix:** The fine-grained portion, not necessarily cement, of some sedimentary rocks (sandstone, conglomerate, etc.) in which the coarser particles are embedded. The matrix may or may not be cemented (see cement).
- Mineral:** An inorganic substance, not necessarily of inorganic origin, that has (1) a definite chemical composition, or range of composition and (2) distinctive physical properties and/or molecular structure. The basic building block of rock.
- Sediment:** Solid material, either mineral or organic, that has been transported from its site of origin, by air, water, ice or biological activity, and has been re-deposited on the earth's surface, above or below water.
- Weathering:** The process by which rocks are broken down and decomposed by the action of external agencies such as wind, water (rain and/or ground water), temperature change, plants and bacteria.

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ATTACHMENT 4

Field Guide for Rock and Core Logging and Fracture Analysis

FIELD GUIDE FOR ROCK CORE LOGGING AND FRACTURE ANALYSIS		midwest GEOSCIENCES group
STEP 1 LABEL FRACTURES AND MARK CORE - Place a strike mark perpendicularly across all fractures judged to be "natural" - Place a two-color parallel strike mark along the entire core to indicate correct end up - Photograph core with color chart and scale		
STEP 2 CALCULATE CORE RECOVERY & ROCK QUALITY DESIGNATION		
STEP 3 DESCRIBE CORE SAMPLE		
FORMATION NAME USE FORMAL STATE GEOLOGICAL SURVEY NOMENCLATURE WHEN POSSIBLE; IF NOT POSSIBLE, ASSIGN SITE-SPECIFIC UNIT NAME ACCORDING TO STRATIGRAPHIC POSITION		
ROCK TYPE DOCUMENT ROCK LITHOLOGY FOR GENERAL LIST OF COMMON ROCK TYPES, USE CHART ON REVERSE		
FIELD STRENGTH CRUMBLED BY HAND, SCRATCHED EASILY WITH THUMBNAIL BROKEN BY HAND INTO PIECES, PEELED BY POCKET KNIFE BROKEN WITH DIFFICULTY IN TWO HANDS, EASILY SCRATCHED WITH KNIFE SCRATCHED WITH KNIFE, INDENTATION MADE BY FIRM BLOW WITH ROCK HAMMER CHIPPED BY FIRM BLOW WITH ROCK HAMMER		
COLOR USE STANDARD MUNSSELL COLOR DESIGNATIONS		
IS MATRIX FRESH? (Note wet or dry sample) YES → MATRIX COLOR (List dominant color first) NO → IS DISCOLORATION DUE TO OXIDATION? YES → OXIDIZED COLOR (Note distribution & occurrence) NO → SECONDARY COLOR(S) (Note distribution, position, & occurrence)		
TEXTURE SEDIMENTARY ROCK: CRYSTALS ARE INDISTINGUISHABLE (for biochemical rocks), CONSTITUENTS ARE INDISTINGUISHABLE (for detrital rocks). 0.06 mm to 0.25 mm 0.25 mm to 0.5 mm 0.5 mm to 2.0 mm METAMORPHIC ROCK: GRAINS ARE INDISTINGUISHABLE, MAY BE CLEAVABLE BUT CAN BE OBLIQUE TO BEDDING, DULL. GRAINS ARE INDISTINGUISHABLE, PARALLELISM IS SILKY, OR CRENULEATED. GRAINS ARE PLATY OR ENLONGATED AND PARALLEL. CRUDELY FOLIATED WITH SUBPARALLEL AND UNEVENLY DISTRIBUTED GRAINS. NO VISIBLE PREFERRED ORIENTATION OF GRAINS. IGNEOUS ROCK: CONTAINS MEGACRYSTS. COMPATIBLE IN COMPOSITION → PORPHYRITIC. FOREIGN IN COMPOSITION → XENOCRYSTIC. CONSTITUENTS ARE INDISTINGUISHABLE → APHANITIC. CONSTITUENTS ARE DISTINGUISHABLE → PHANERITIC.		
STRUCTURE UNIFORM BEDDING, FOLIATION, OR BANDS from 1 to 10 ft [300mm to 3m] BEDDING, FOLIATION, OR BANDS from .3 to 1 ft [100 to 300mm] BEDDING, FOLIATION, OR BANDS from .1 to .03 ft [10 to 100mm] LAMINATIONS, FOLIATION, OR BANDS less than 0.03 ft (<10mm) MASSIVE THICKLY BEDDED or FOLIATED or BANDED MEDIUM BEDDED or FOLIATED or BANDED THINLY BEDDED or FOLIATED or BANDED LAMINATED or INTENSELY FOLIATED or INTENSELY BANDED		
DECOMPOSITION NO DECOMPOSITION OR DISCOLORATION APPARENT MOSTLY FRESH BUT DISCOLORATION NEAR FRACTURES MOSTLY DISCOLORED, EASILY BROKEN BY HAMMER COMPLETELY DISCOLORED, EASILY BROKEN BY HAND CAN BE CRUMBLED BY HAND (and in near-surface position) FRESH SLIGHTLY DECOMPOSED MODERATELY DECOMPOSED HIGHLY DECOMPOSED RESIDUAL SOIL (note pedogenic development)		
DISINTEGRATION NO MINERALIZATION OR DISSOLUTION (to either rock or cementation) TRACE MINERALIZATION OR DISSOLUTION SOME MINERALIZATION OR DISSOLUTION HIGHLY MINERALIZED OR DISSOLVED COMPETENT SLIGHTLY DISINTEGRATED MODERATELY DISINTEGRATED INTENSELY DISINTEGRATED For Voids: Characterize using Terms on Reverse		
FRACTURE DENSITY NO OBSERVED FRACTURES CORE MOSTLY IN LENGTHS GREATER THAN 1 FOOT CORE MOSTLY IN LENGTHS FROM 0.33 TO 1 FOOT CORE RECOVERED IN LENGTHS AVERAGING FROM 0.1 TO 0.33 FOOT CORE RECOVERED MOSTLY NON-INTACT (NI) FRAGMENTS UNFRACTURED SLIGHTLY FRACTURED MODERATELY FRACTURED INTENSELY FRACTURED VERY INTENSELY FRACTURED Characterize Fractures Using Chart on Reverse		
STRATIGRAPHIC CONTACT CONTACT WHEN BEDS OR UNITS ARE IN FORMATION OR DEPOSITIONAL SEQUENCE CONTACT WHEN BEDS OR UNITS ARE NOT IN FORMATION OR DEPOSITIONAL SEQUENCE CONFORMABLE UNCONFORMABLE (note transition interval)		

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FRACTURE CHARACTERIZATION GUIDE			
DEPTH	DISTANCE BELOW GROUND SURFACE		
TYPE	STRUCTURAL BREAK WHERE LITTLE OR NO DIFFERENTIAL MOVEMENT HAS OCCURRED STRUCTURAL BREAK WHERE DIFFERENTIAL MOVEMENT HAS OCCURRED DIVISION PLANE THAT SEPARATES SUCCESSIVE LAYERS OR BEDS TIGHT, OFTEN DISCONTINUOUS PLANE, MAY BE SEPARATED BY HAND ALONG PLANE NUMEROUS INTERSECTING JOINTS WIDTH OF FRACTURE ZONE INDICATING NUMEROUS JOINTS, SHEARS OR FAULT BREAK DUE TO DRILLING, BLASTING, OR HANDLING		
DIP ANGLE	DEGREES FROM HORIZONTAL		
APERTURE	>200mm 60-200mm 20-60mm 6-20mm 2-6mm >0-2mm NO VISIBLE SEPARATION	WIDE MODERATELY WIDE MODERATELY NARROW NARROW VERY NARROW EXTREMELY NARROW TIGHT	PINHOLE OPENINGS SMALL OPENING UP TO 4 INCHES OPENING LARGER THAN 4 INCHES CELL-LIKE FORM OF VUGS AND PITS OPENINGS FORMED BY TRAPPED GAS
HEALING	ALL PARTS BONDED, COMPLETELY HEALED OR RE-CEMENTED >50% FRACTURED/SHEARED DISCONTINUITIES HEALED, RE-CEMENTED, OR FILLED <50% FRACTURED/SHEARED DISCONTINUITIES HEALED, RE-CEMENTED, OR FILLED NO FRACTURES OR SHEARS ARE HEALED, RE-CEMENTED, OR FILLED		
INFILLING	NO APPARENT INFILLING OR COATING OXIDATION OR SECONDARY STAINING ALONG FRACTURE FACE DECOMPOSITION OR DISINTEGRATION ALONG FRACTURE SEDIMENT THAT IS NON PLASTIC SEDIMENT THAT YIELDS PLASTICITY SECONDARY MINERALIZATION OTHER		
UNEVENNESS	LARGE OR ANGULAR ASPERITIES NO ASPERITIES POLISHED OR STRIATED	ROUGH SMOOTH SLICKENSIDED	WITH NEAR NORMAL STEPS OR RIDGES WITH WAVY SURFACE WITH EVEN SURFACE
MOISTURE CONDITIONS	WATER FLOW DOES NOT APPEAR POSSIBLE ALONG FRACTURE FRACTURE IS DRY, BUT WATER FLOW APPEARS POSSIBLE FRACTURE IS DRY, BUT SHOWS STAINING OR LEACHING FRACTURE FILLING (WHERE PRESENT) IS DAMP, BUT NO APPARENT WATER FLOW FRACTURE FILLING IS WET (OR STAINED), WITH APPARENT MINOR SEEPAGE FRACTURE FILLING IS WASHED AND WET, WITH APPARENT CONTINUOUS SEEPAGE		

LIST OF COMMON ROCK NAMES			
METAMORPHIC ROCKS	NON-FOLIATED	FAULT BRECCIA QUARTZITE MARBLE HORNFELS	
	FOLIATED	AMPHIBOLITE GNEISS	SCHIST SLATE MYLONITE PHYLLITE
IGNEOUS ROCKS	QUARTZ RICH	COARSE-GRAINED GRANITE DIORITE MONZONITE GABRO	MEDIUM-GRAINED APLITE GRANODIORITE QUARTZ MONZONITE DIORITE
	SOME QUARTZ	FINE-GRAINED RHYOLITE DACITE QUARTZ LACITE QUARTZ TRACHYTE TRACHYANDESITE ANDERITE	RHYOLITE DACITE QUARTZ LACITE QUARTZ TRACHYTE TRACHYANDESITE ANDERITE
	QUARTZ POOR	BASALT PERidotite	BASALT PERidotite
		AMPHOPHYRE	AMPHOPHYRE
PYROCLASTIC ROCKS	PYROCLASTIC BRECCIA LAPILLI TUFF COARSE ASH TUFF FINE ASH TUFF		
SEDIMENTARY ROCKS	Chemical & Biochemical Rocks	LIMESTONE, DOLOMITE, AND EVAPORITES CHERT	
	Detrital Rocks	SEDIMENTARY BRECCIA CONGLOMERATE	SANDSTONE SILTSTONE SHALE COAL

CORE BOX LABELING	
OUTSIDE BOX COVER LOCATION & PROJECT ID BORING ID BOX NUMBER DRILLING CONTRACTOR BEGIN & END DATE ORIENTATION (for angled borings)	INSIDE BOX COVER RUN NUMBER RUN DEPTH TOTAL AND SOLID CORE RECOVERY % RCD %

Lockheed Martin Wilmington
Project Operating Procedure
POP-011
Decontamination of Field Equipment

1.0 Purpose and Applicability

This project operating procedure POP-011 describes the methods to be used for the decontamination of items that may become contaminated during field operations. Decontamination is performed as a quality assurance measure, and as a safety and health precaution. It prevents cross-contamination between samples and also helps maintain a clean working environment. Equipment requiring decontamination may include hand tools, monitoring and testing equipment, personal protective equipment (PPE), or heavy equipment (e.g., loaders, backhoes, drill rigs, etc.).

Decontamination is achieved mainly by rinsing with liquids, which may include soap and/or detergent solutions, tap water, distilled water, and methanol or isopropyl alcohol. Equipment may be allowed to air dry after being cleaned or may be wiped dry with paper towels or chemical-free cloths.

All sampling equipment will be decontaminated prior to use and between each sample collection point. Waste products produced by the decontamination procedures, such as rinse liquids, solids, rags, gloves, etc., will be collected and disposed of properly, based on the nature of contamination and site protocols. Any materials and equipment that will be reused must be decontaminated or properly protected before being taken off site.

Specific project requirements as described in an approved Work Plan/Field Sampling Plan, Quality Assurance Project Plan, AECOM Safety, Health, and Environment (SHE) Manual, Task Hazard Analysis (THA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

2.0 Responsibilities

It is the responsibility of the field sampling coordinator to ensure that proper decontamination procedures are followed and that all waste materials produced by decontamination are properly managed. It is the responsibility of any subcontractors (e.g., drilling or sampling contractors) to follow the designated decontamination procedures that are stated in their contracts and outlined in the project HASP. It is the responsibility of all personnel involved with sample collection or decontamination to maintain a clean working environment and to ensure that no contaminants are inadvertently introduced into the environment, tracked out of the contamination reduction zone (CRZ), or passed from one sample point to another.

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3.0 Health and Safety

This section presents the generic hazards associated with decontamination and is intended to provide general guidance in preparing site-specific health and safety documents. The Site-Specific HASP and THAs will address additional requirements and will take precedence over this document. Note that decontamination usually requires Level D personal protection unless there is a potential for airborne exposures to site contaminants. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or SHE Coordinator.

Health and safety hazards potentially involved decontamination include the following:

- Skin contact with decontamination solvents. Wear solvent impervious gloves when decontaminating equipment. Methanol and isopropanol are approved but use the solvents sparingly and dispense only from pre-labeled polypropylene solvent wash bottles. Whenever possible use an aqueous based non-toxic cleaning agent in lieu of solvents. **Hexane is prohibited from use for decontamination.**
- Avoid contact with site contaminants. Exposure to contaminated media is possible when either removing contaminated personal protective equipment (PPE) or decontaminating heavy equipment. Take care to prevent slips and falls when scrubbing over boots in the CRZ and remove PPE using proper “inside-out” techniques to minimize airborne exposure to potentially contaminated particulate. In addition to Level D PPE, wear a face shield when brushing off heavy equipment or using a pressure washer. Consult the Corporate EHS Manual for additional precautions.
- Decontamination pad liquids. If large volumes of rinsates are generated, wash water must be properly characterized prior to disposal. Avoid contact and wear PPE during liquids transfer.

4.0 Supporting Materials

The following materials should be on hand in sufficient quantity to ensure that proper decontamination methods and procedures are followed:

- Cleaning liquids and dispensers (phosphate-free soap and/or detergent solutions, tap water, distilled water, deionized water, reagent grade methanol or isopropyl, etc.)
- PPE, as defined in the project HASP
- Paper towels or chemical-free cloths
- Disposable chemically impervious gloves
- Waste-storage containers (e.g., drums, boxes, plastic bags)
- Drum labels, if necessary
- Cleaning containers (e.g., plastic and/or galvanized steel pans or buckets)
- Cleaning brushes
- Plastic sheeting

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- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants and decontamination solvents
- A copy of the Site-Specific HASP (consult for heavy equipment decontamination)

5.0 Methods and Procedures

The extent of known contamination will determine the degree of decontamination required. When the extent of contamination cannot be readily determined, cleaning should be done according to the assumption that the equipment is highly contaminated.

Standard operating procedures listed below describe the method for full field decontamination. If different technical procedures are required for a specific project, they will be spelled out in the project plans.

Such variations in decontamination may include all or an expanded scope of these decontamination procedures:

- Remove gross contamination from the equipment by brushing and then rinse with tap water.
- Wash with detergent or soap solution (e.g., Alconox and tap water).
- Rinse with tap water or distilled water.
- Repeat entire procedure or any parts of the procedure, as necessary.
- After decontamination procedure is completed, avoid placing equipment directly on ground surface to avoid re-contamination.

Downhole drilling equipment, such as augers and split spoons, will be decontaminated as described above. No additional decontamination procedures will be required if the equipment appears to be visually clean. If contamination remains visible then hot water/steam cleaning will be considered. Items heavily contaminated with product may require more aggressive decontamination techniques. If the items cannot be discarded, consult your EHS coordinator to obtain guidance in this regard.

6.0 Quality Assurance/Quality Control

To assess the adequacy of decontamination procedures, rinsate blanks should be collected and analyzed for the same parameters as the field samples. Specific number of blanks will be defined in the project-specific sampling plan. In general, one rinsate blank will be collected per 20 samples.

7.0 Documentation

Field notes describing procedures used to decontaminate equipment/personnel and for collection of the rinsate blanks will be documented by on-site personnel. Field notes will be retained in the project files.

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8.0 Revision History

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Project Operating Procedure

POP-012

Monitoring Well Development

1.0 Project Scope and Applicability

1.1 Purpose and Applicability

This project operating procedure (POP) describes the methods used for developing newly installed monitoring wells and/or existing wells which may require redevelopment/ rehabilitation. This POP is applicable to overburden and bedrock monitoring wells.

Monitoring well development and/or redevelopment is necessary for several reasons:

- To improve/restore hydraulic conductivity of the surrounding formations as they have likely been disturbed during the drilling process, or may have become partially plugged with silt.
- To remove drilling fluids (water, mud), when used, from the borehole and surrounding formations.
- To remove residual fines and cuttings from well filter materials and reduce turbidity of groundwater, therefore, reducing the chance of chemical alteration of groundwater samples caused by suspended sediments and potentially clogging the well screen or bedrock fractures.

Respective state or federal agency (regional offices) regulations may require specific types of equipment for use or variations in the indicated method of well development. Deviations from this POP to accommodate other regulatory requirements should be reviewed in advance of the field program, should be explained in the project work plan, and must be documented in the field project notebook when they occur.

1.2 General Principles

Well development generally involves withdrawal of an un-specified volume of water from a well using a pump, surge block or other suitable method such that, when completed effectively, the well is in good or restored hydraulic connection with the surrounding water bearing unit and is suitable for obtaining representative groundwater samples or for other testing purposes.

2.0 Health and Safety Considerations

Monitoring well development may involve chemical hazards associated with materials in the soil or aquifer being characterized and may involve physical hazards associated with use of well

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Monitoring Well Development

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development equipment. When wells are to be installed and developed on hazardous waste investigation sites, a Health and Safety Plan must be prepared and approved by the Health and Safety Officer before field work commences. This plan must be approved by the project Health and Safety Officer before work commences, must be distributed to all field project personnel, and must be adhered to as field activities are performed.

3.0 Equipment and Materials

Well development can be performed using a variety of methods and equipment. The specific method chosen for development of any given well is governed by well type (overburden or bedrock), purpose of the well, well diameter and materials, depth, accessibility, geologic conditions, static water level in the well, and type of contaminants present, if any.

The following list of equipment, each with their own particular application, may be used to develop and/or purge monitoring wells.

3.1 Bailer Purging

A bailer is used to purge silt-laden water from wells after using other devices such as a surge block. In some situations, the bailer can be used to develop a well by bailing and surging, often accompanied with pumping. A bailer should be used for purging in situations where the depth to static water is greater than 25 feet and/or where insufficient hydraulic head is available for use of other development methods. This method is not recommended for development of an open bedrock borehole.

3.2 Surge Block Development

Surge blocks are commercially available for use with Waterra™-type pumping systems or may be manufactured using a rubber or teflon "plunger" attached to a rod or pipe of sufficient length to reach the bottom of the well. Well drillers usually can provide surge blocks if requested. A recommended design is shown in Figure 1. The use of surge blocks in open bedrock holes should be used with caution since over-agitation may disturb loose rock and entrap the downhole equipment.

3.3 Pump Development

A pump is often necessary to remove large quantities of silt-laden ground water from a well after using the surge block. In some situations, the pump alone can be used to develop the well and remove the fines by overpumping. Since the purpose of well development is to remove suspended solids from a well and surrounding filter pack, the pump must be capable of moving some solids without damage. The preferred pump is a submersible pump which can be used in both shallow and deep ground water situations. A centrifugal pump may be used in shallow wells but will work only where the depth to static ground water is less than approximately 25 feet. Pumping may not be successful in low-yielding aquifer materials or in wells with insufficient hydraulic head. This method is not recommended for development of an open bedrock borehole since the pump will likely only draw water from the most productive fracture. It could be used for bedrock borehole development if used in conjunction with straddle packers over short (< 5 ft) intervals, however that would be very time consuming and equipment could become entrapped if the borehole wall collapses. The air-lift method is the preferred choice for development of an open bedrock borehole.

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3.4 Compressed Gas Development (Air-Lift Method)

Compressed gas, generally compressed air through a compressor or nitrogen from a tank, can be used to both surge and develop a monitoring well. This is also referred to as the "air-lift" method for well development. The method works by injection of compressed gas at the bottom of the water column, "lifting" sediment-laden water to the surface. This is the preferred method for well development of open bedrock boreholes.

Compressed gas can also be used for "jetting" - a process by which the gas is directed at the slots in the well screen to cause turbulence (thereby disturbing fine materials in the adjacent filter pack). Compressed gas is not limited by any depth range.

Since the compressed gas will be used to "lift" water from the monitoring well or open bedrock borehole, provisions must be made for controlling the discharge from contaminated wells. This is generally accomplished by attaching a "tee" discharge to the top of the casing and providing drums to contain the discharged water. Gas-lifting should never be done in contaminated wells without providing a means to control discharge.

3.5 Other Required Materials:

- Well development records (Figure 2)
- Health and Safety equipment
- Equipment decontamination materials
- Water quality instrumentation: nephelometer, pH, temperature, specific conductance meters, as required
- Field project notebook/pen

4.0 Procedures

4.1 General Preparation

Well Records Review: Well completion diagrams should be reviewed to determine well construction characteristics. Formation characteristics should also be determined from review of available boring logs.

Site Preparation: Well development, similar to groundwater sampling, should be conducted in as clean an environment as possible. This usually requires, at a minimum, placing sheet plastic on the ground to provide a clean working area for development equipment.

IDW Containment: Provisions should be in place for collection and management of investigation-derived wastes (IDW), specifically well development water and miscellaneous expendable materials generated during the development process. The collection of IDW in drums or tanks may be required depending on project-specific requirements. The QAPP should specify the requirements for IDW containment.

Water Level/Well Depth Measurement: The water level and well depth should be measured with a water level indicator and written on the well development record. This information is used to calculate the volume of standing water (i.e., the well volume) within the well.

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Equipment Decontamination: All down-well equipment should be decontaminated prior to use in accordance with POP-011 (Decontamination).

Removal of Drilling Fluids: Drilling fluids such as mud or water, if used during the drilling and well installation process, should be removed during the well development procedure. It is recommended that a minimum of 1.5 times the volume of added fluid be removed from the well during development. Drilling muds should initially have been flushed from the drilling casing during the well installation procedure with water added during the flushing process. If the quantity of added fluid is not known or could not be reasonably estimated, removal of a minimum of 10 well volumes of water is recommended during the development procedure.

4.2 Development Procedures

Development Method Selection

The construction details of each well shall be used to define the most suitable method of well development. Some consideration should be given to the potential degree of contamination in each well as this will impact IDW containment requirements.

The criteria for selecting a well development method include well diameter, total well depth, static water depth, screen length, the likelihood and level of contamination, and characteristics of the geologic formation adjacent to the screened interval.

The limitations, if any, of a specific procedure are discussed within each of the following procedures.

General Water Quality Measurements

Measure and record water temperature, pH, specific conductance, and turbidity periodically during development using the available water quality instruments. These measurements will aid in determining whether well development is proceeding efficiently, will assist in identifying when well development is complete, will determine whether the development process is effective or not with any given well and, potentially, may identify well construction irregularities (i.e., grout in well, poor well screen slot-size selection). Water quality parameters should be checked a minimum of 3 to 5 times during the development process.

Bailer Procedure

- As stated previously, bailers shall preferably not be used for well development but may be used in combination with a surge block to remove silt-laden water from the well.
- When using a bailer to purge well water; select the appropriate bailer, then tie a length of bailer cord onto the end of it.
- Lower the bailer into the screened interval of the monitoring well. Silt, if present, will generally accumulate within the lower portions of the well screen.
- The bailer may be raised and lowered repeatedly in the screened interval to further simulate the action of a surge block and pull silt through the well screen.
- Remove the bailer from the well and empty it into the appropriate storage container.

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- Continue surging/bailing the well until sediment-free water is obtained. If moderate to heavy siltation is still present, the surge block procedure should be repeated and followed again with bailing.
- Check water quality parameters periodically.

Surge Block Procedure

- A surge block effectively develops most monitoring wells. One needs to be careful using this method in open bedrock boreholes so as not to cause borehole wall collapse. This device first forces water within the well through the well screen and out into the formation, and then pulls water back through the screen into the well along with fine soil particles. Surge blocks may be manufactured to meet the design criteria shown in the example (Figure 1) or may be purchased as an adaptor to fit commercially available well purging systems such as the Waterra system.
- Insert the surge block into the well and lower it slowly to the level of static water. Start the surge action slowly and gently above the well screen using the water column to transmit the surge action to the screened interval. A slow initial surging, using plunger strokes of approximately 3 feet, will allow material which is blocking the screen to separate and become suspended.
- After 5 to 10 plunger strokes, remove the surge block and purge the well using a pump or bailer. The returned water should be heavily laden with suspended silt and clay particles. Discharge the purged water into the appropriate storage container.
- Repeat the process. As development continues, slowly increase the depth of surging to the bottom of the well screen. For monitoring wells with long screens (greater than 10 feet) surging should be undertaken along the entire screen length in short intervals (2 to 3 feet) at a time. Continue this cycle of surging and purging until the water yielded by the well is free of visible suspended material.
- Check water quality parameters periodically.

Pump Procedure

- The pump method is most effective in productive overburden wells. It should not be used in tight formations or open bedrock boreholes.
 - Well development using only a pump is most effective in monitoring wells that will yield water continuously. Theoretically, pumping will increase the hydraulic gradient and velocity of groundwater near the well by drawing the water level down. The increased velocity will move residual fine soil particles into the well and clear the well screen of this material. Effective development cannot be accomplished if the pump has to be shut off to allow the well to recharge.
 - When using a submersible pump or surface pump, set the intake of the pump or intake line in the center of the screened interval of the monitoring well.
 - Pump a minimum of three well volumes of water from the well and raise and lower the pump line through the screened interval to remove any silt/laden water.
 - Continue pumping water from the well until sediment-free water is obtained. This method may be combined with the manual surge block method if well yield is not rapid enough to extract silt from the surrounding formations.
 - Check water quality parameters periodically.
-

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Compressed Gas (Air-Lift) Procedure

- This is the preferred procedure for developing open bedrock boreholes.
- Although the equipment used to develop a well using this method is more difficult to obtain and use, well development using compressed gas is considered to be a very effective method. This method is also not limited by well depth, well diameter, or depth to static water. Caution must be exercised, however, in highly permeable formations not to inject gas into the formation. Drilling subcontractors will often provide the necessary materials, as well as, perform this method, if requested. When using a compressor, an oil-less compressor should be used, or an oil trap/filter should be placed on the air discharge line which enters the well.
- Lower the gas line into the well, setting it near the bottom of the screened interval or bottom of the open bedrock borehole. Install the discharge control equipment (i.e., tee fitting) at the well head.
- Set the gas flow rate to allow continuous discharge of water from the well.
- At intervals during gas-lifting, especially when the discharge begins to contain less suspended material, shut off the air flow and allow the water in the well to backflush through the screened interval to disturb any bridging that may have occurred. Re-establish the gas flow when the water level in the well has returned to the pre-development level.
- Continue gas-lifting and/or jetting until the discharged water is free from suspended material.
- Check water quality parameters periodically.

5.0 Quality Assurance / Quality Control

Field project personnel should follow specific quality assurance guidelines as outlined in the site-specific Quality Assurance Project Plan (QAPP) and/or Sampling Plan. The plan should indicate the preferred method of well development at a particular site based on project objectives, aquifer conditions, and agency requirements. Specific well performance criteria such as low turbidity values to be achieved following well development should also be specified as well as any requirements for collection/containerization and disposal of well development water.

A well has been successfully developed when one or more of the following criteria are met:

- The sediment load in the well has been eliminated or greatly reduced. Regulatory requirements may be in place which state that water turbidity values ranging from 5 to 50 NTU must be achieved at the end of the development procedure. Use of a nephelometer is required during the well development procedure to measure water turbidity if meeting a specific turbidity value is required by the regulations. Attaining low turbidity values in fine-grained formations or open bedrock boreholes may be difficult to achieve.
- Permeability tests that yield repeatable hydraulic conductivity values.

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6.0 Data and Records Management

The Monitoring Well Development Record (Figure 2) will be completed by the geologist or hydrogeologist conducting the development. In addition, a field project notebook should be maintained detailing any problems or unusual conditions which may have occurred during the development process.

7.0 Personnel Qualifications and Training

Well development procedures vary in complexity. It is recommended that initial development attempts be supervised by more experienced personnel. Field personnel should be health and safety certified as specified by OSHA (29 CFR 1910.120(e)(3)(i)) to work on sites where hazardous waste materials are considered to be present.

7.1 Project Geologist/Engineer

Development or oversight of development of new monitoring wells is the responsibility of the project geologist/engineer involved in the original installation of the well. Records of well development methods and results will be retained in the project file.

7.2 Project Manager

The project manager is responsible for ensuring that the appropriate method of well development has been chosen which best meets project objectives, site hydrogeologic conditions, and/or relevant regulatory requirements.

8.0 References

Standard References for Monitoring Wells, Massachusetts Department of Environmental Protection, WSC-310-91, 1991.

9.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

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APPENDIX: DEFINITIONS

Bridging: A condition within the filter pack outside the well screen whereby the smaller particles are wedged together in a manner that causes blockage of pore spaces.

Hydraulic Conductivity: a characteristic property of aquifer materials which describes the permeability of the material with respect to flow of water.

Hydraulic Connection: A properly installed and developed monitoring well should have good hydraulic connection with the aquifer. The well screen and filter material should not provide any restriction to the flow of water from the aquifer into the well.

Permeability Test: Used to determine the hydraulic conductivity of the aquifer formation near a well screen. Generally conducted by displacing the water level in a well and monitoring the rate of recovery of the water level as it returns to equilibrium. Various methods of analysis are available to calculate the hydraulic conductivity from these data.

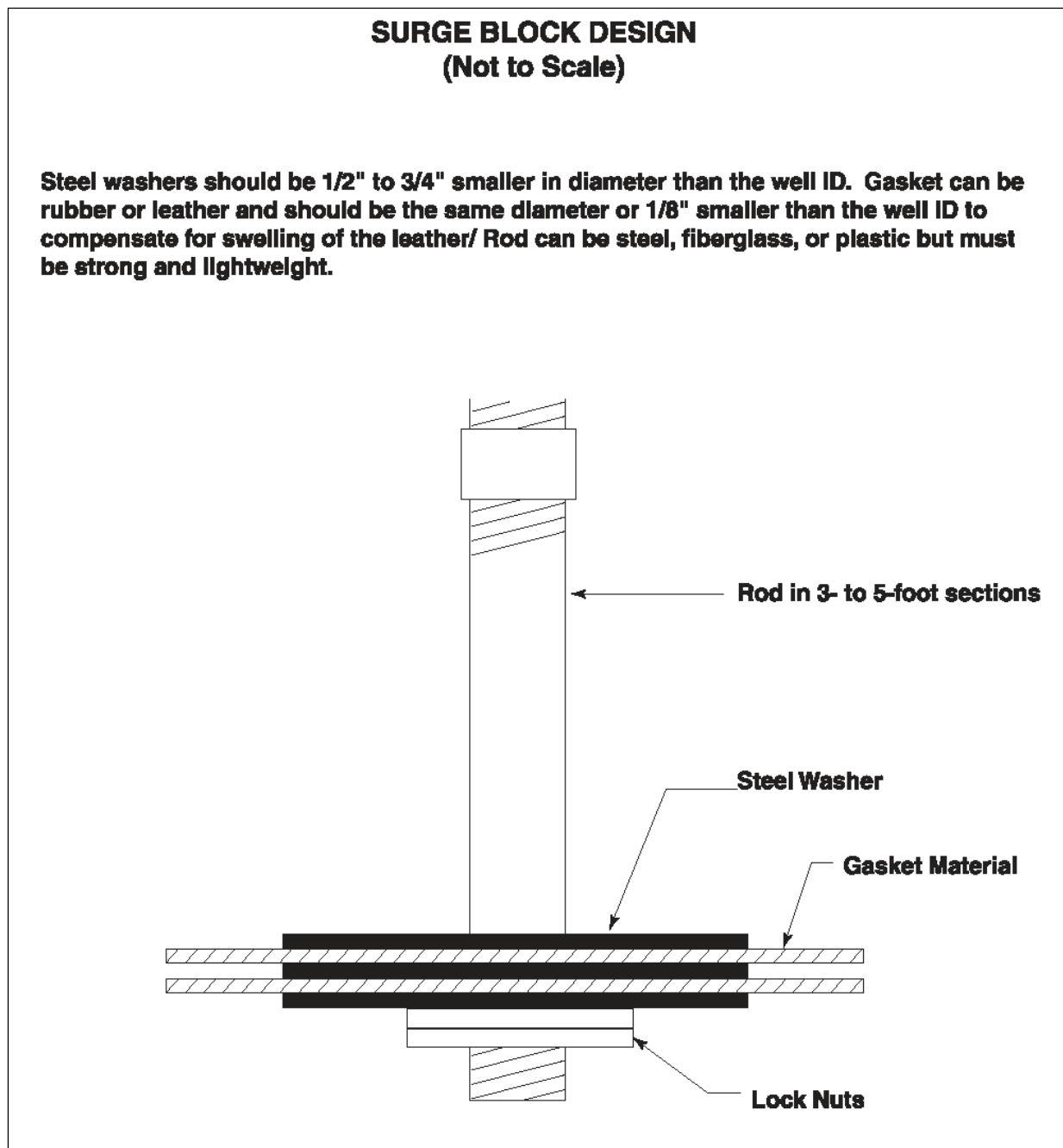
Static Water Level: The water level in a well that represents an equilibrium or stabilized condition, usually with respect to atmospheric conditions in the case of monitoring wells.

Well Surging: That process of moving water in and out of a well screen to remove fine sand, silt and clay size particles from the adjacent formation.

Well Purging: The process of removing standing water from a well to allow surrounding formation water to enter the well.

Well Screen: That portion of the well casing material that is perforated in some manner so as to provide a hydraulic connection to the aquifer. The perforated, or slotted, portion of a well is also known as the screened interval.

Figure 1 Recommended Surge Block Design



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Figure 2 Well Development Record

MONITORING WELL DEVELOPMENT RECORD		
DATE: _____	WELL I.D.: _____	
PROJECT NAME: _____	LOCATION: _____	
PROJECT NUMBER: _____	DEVELOPER: _____	
☐ ORIGINAL DEVELOPMENT ☐ REDEVELOPMENT	ORIGINAL DEVELOPMENT DATE: _____	
WELL DATA		
Well Diameter: _____ Total Well Depth: _____ Depth to Top of Screen: _____ Depth to Bottom of Screen: _____ Depth to Static Water Level: _____	Geology at Screened Interval: Likely Contaminants: Purge Water & Sediment Disposal Method:	
DEVELOPMENT METHOD	PURGE METHOD	PERMEABILITY TEST RESULTS
ACCEPTANCE CRITERIA		
Signature: _____ Date: _____		

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Project Operating Procedure

POP-013

Water-Level Measurements

1.0 Purpose and Applicability

This project operating procedure POP-013 describes the measurement of water levels in groundwater monitoring wells or piezometers. Water-level measurements are fundamental to groundwater and solute transport studies. Water-level data are used to indicate the directions of groundwater flow and areas of recharge and discharge, to evaluate the effects of manmade and natural stresses on the groundwater system, to define the hydraulic characteristics of aquifers, and to evaluate stream-aquifer relations. Measurements of the static-water level are also needed to estimate the amount of water to be purged from a well prior to sample collection.

Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Task Hazardous Analysis (THA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

2.0 Responsibilities

The field sampling coordinator will have the responsibility to oversee and ensure that all procedures are performed in accordance with the project-specific sampling program and this POP.

3.0 Health and Safety

This section presents the generic hazards associated with the collection of water-level measurements. The site-specific HASP, and THA will address additional requirements and will take precedence over this document. Appropriate personal protective equipment (PPE) must be worn as determined in the Site-Specific HASP, which typically consists of Level D protection. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or Safety, Health and Environment (SH&E) Coordinator.

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Water-Level Measurements

Health and safety hazards during groundwater level measurements may involve:

- Slip, trips, and falls in tall grasses over obstacles and berms near well locations. Review terrain hazards prior to conducting these operations. Ensure that you have safe means of access/egress to the wellhead.
- Exposure to site contaminants. If there is product in the well (especially gasoline) take all precautions necessary to prevent fire/explosion and/or exposure to airborne vapors.
- Ergonomics. Use appropriate ergonomic techniques when inserting or retrieving equipment for the wells to preclude injury to the arms, shoulders or back.

If the well is suspected of being contaminated, or has a history of contamination, the static water-level measurements should be made while wearing appropriate personal protective equipment (PPE). The air in the wellhead may also be sampled for organic vapors using a Photo Ionization Detector (PID). The results shall be recorded in the Fluid-Level Monitoring Log or the project field book. This would be the first indication of the presence of a non-aqueous phase liquid (NAPL). If the potential for fire or explosion exists, use of the probe ground wire is required.

4.0 Supporting Materials

This section identifies the types of equipment that may be used for measurement of groundwater levels. Based on project objectives, observed or probable well contamination, and well construction, a project-specific equipment list will be determined from the following equipment:

- Water-level and/or product-level measuring device
- Distilled water dispenser bottle
- Plastic sheeting
- PPE as specified in the Site-Specific HASP
- Fluid-level monitoring logs and field book
- Paper towels or chemical-free cloths
- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants
- A copy of the Site-Specific HASP

5.0 Methods and Procedures

When taking a series of fluid-level measurements at a number of monitoring wells, it is generally good practice to go in order from the least- to the most contaminated well. Additionally, the measurement of all site wells should be done consecutively and before any sampling activities begin. This will ensure the data are representative of aquifer conditions. All pertinent data should be entered in the Fluid-Level Monitoring Log or the project field book.

5.1 Well Evaluation

Upon arrival at a monitoring well, the surface seal and well protective casing should be examined for any evidence of frost heaving, cracking, or vandalism. All observations should be recorded in the fluid-level monitoring log or the project field book.

Project Operating Procedure

Water-Level Measurements

The area around the well should be cleared of weeds and other materials prior to measuring the static-water level (avoid contact with poison ivy or other allergenic plants). A drop cloth or other material (e.g., plastic garbage bag) should be placed on the ground around the well, especially if the ground is disturbed or potentially contaminated. This will save time and work for cleaning equipment or tubing if it falls on the ground during preparation or operation. The well protective casing should then be unlocked and the cap removed.

5.2 Measuring Point Location

The measuring point location for the well should be clearly marked on the outermost casing or identified in previous sample collection records. This point is usually established on the well casing itself, but may be marked on the protective steel casing in some cases. In either case, it is important that the marked point coincide with the same point of measurement used by the surveyor. If not marked from previous investigations, the water-level measuring point should be marked on the north side of the well casing and noted in the Fluid-Level Monitoring Log or the project field book. Monitoring well measurements for total depth and water level should be consistently measured from one reference point so that these data can be used for assessing trends in the groundwater.

5.3 Water-Level Measurement

Water-level measurements shall be made using an electronic or mechanical device. Several methods for water-level measurement are described below. An electronic measuring device is the primary measurement method used for this project

5.3.1 Graduated Steel Tape

The graduated steel-tape method is considered an accurate method for measuring the water level in nonflowing wells. Steel surveying tapes in lengths of 100, 200, 300, 500, and 1,000 feet are commonly used; a black tape is better than a chromium-plated tape. The tapes are mounted on hand-cranked reels up to 500-foot lengths; for greater depth, a motor-driven tape drive is usually required. A slender weight is attached to the ring at the end of the tape to ensure plumbness and to permit some feel for obstructions.

The lower few feet of tape is chalked by pulling the tape across a piece of blue carpenter's chalk. The wet chalk mark identifies the portion of the tape that was submerged. Lower the graduated steel-tape from the measuring point at the top of the well until a short length of the tape is submerged. The weight and tape should be lowered into the water slowly to prevent splashing. Submergence of the weight and tape may temporarily cause the water level to rise in wells or piezometers having very small diameters. This effect can be significant if the well is in materials of very low hydraulic conductivity.

Under dry surface conditions, it may be desirable to pull the tape from the well by hand, being careful not to allow it to become kinked, and reading the water mark before rewinding the tape onto the reel. In this way, the watermark on the chalked part of the tape is rapidly brought to the surface before the wetted part of the tape dries. In cold regions, rapid withdrawal of the tape from the well is necessary before the wet part freezes and becomes difficult to read. Read the tape at the measuring point, and then read the watermark on the tape. The difference between these two readings is the depth to water below the measuring point. Errors resulting from the effects of thermal expansion of tapes and of stretch due to the suspended weight of the tape and plumb weight can become significant at high temperatures and for measured depths in excess of 1,000 feet.

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Water-Level Measurements

The observer should make two measurements. If two measurements of static-water level made within a few minutes do not agree within 0.01 or 0.02 foot in observation wells having a depth to water of less than a couple hundred feet, continue to measure until the reason for the lack of agreement is determined or until the results are shown to be reliable. Where water is dripping into the well or covering the well casing wall, it may be impossible to get a good watermark on the chalked tape.

Water-level measurement should be entered in the fluid-level monitoring log or the project field book. The water-level measurement device shall be decontaminated immediately after use.

5.3.2 Electrical Methods

Many types of electrical instruments are available for water-level measurement; most operate on the principle that a circuit is completed when two electrodes are immersed in water. Electrodes are generally contained in a weighted probe that keeps the tape taut while providing some shielding of the electrodes against false indications as the probe is being lowered into the well. Before lowering the probe into the well, the circuitry can be checked by dipping the probe in water and observing the indicator (a light, sound, and/or meter).

To obtain a water-level measurement, slowly lower the decontaminated probe into the monitoring well until the indicator (light, sound, and/or meter) shows water contact. At this time, the precise measurement should be determined by repeatedly raising and lowering the tape or cable to converge on the exact measurement.

In wells having a layer of NAPL floating on the water, the electric tape will not respond to the oil surface and, thus, the fluid level determined will be different than would be determined by a steel tape. The difference depends on how much NAPL is floating on the water. Dual media tapes are recommended in that instance to measure both NAPL and water levels using the same measuring device. The procedure is discussed in Section 5.4.

Water-level measurement should be entered in the fluid-level monitoring log or the project field book. The water-level measurement device shall be decontaminated immediately after use.

5.3.3 Airline

The airline method is especially useful in pumped wells where water turbulence may preclude using more precise methods. A small diameter air-type tube of known length is installed from the surface to a depth below the lowest water level expected. Compressed air is used to purge the water from the tube. The pressure, in pounds per square inch (psi), needed to purge the water from the airline multiplied by 2.31 (feet of water for one psi) equals the length in feet of submerged airline. The depth to water below the center of the pressure gage can be easily calculated by subtracting the length of airline below the water surface from the total length of airline (assuming the airline is essentially straight).

Accuracy depends on the precision to which the pressure can be read. The accuracy of an airline or pressure gage measurement depends primarily on the accuracy and condition of the gage. It is normally within 1 foot of the true level as determined by means of a steel-tape measurement. The airlines themselves, however, have been known to become clogged with mineral deposits or bacterial growth, or to develop leaks and consequently yield false information. A series of airline measurements should be checked periodically by the use of a steel tape or an electric water-level indicator.

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Water-Level Measurements

The airline and any connections to it must be airtight throughout the entire length. A long-term increase in airline pressure may indicate gradual clogging of the airline. A relatively sudden decrease in airline pressure may indicate a leak or break in the airline. Airline pressures that never go above a constant low value may indicate that the water level has dropped below the outlet orifice of the airline. To minimize the effect of turbulence, the lower end of the airline should be at least 5 feet above or below the pump intake. Corrections should be made for fluid temperatures much different from 20° C and for vertical differences in air density in the well column for cases where the depth to water is very large.

5.4 Procedures for Immiscible Fluids

At those facilities where monitoring to determine the presence or extent of immiscible fluids is required, the sampler will need to use special procedures for the measurement of fluid levels. The procedures required will depend on whether light NAPL (LNAPL) that form lenses floating on top of the water table or dense NAPL (DNAPL) that sink through the aquifer and form lenses over lower permeability layers are present.

In the case of LNAPL, measurements of immiscible fluid and water level usually cannot be accomplished by using normal techniques. For example, a chalked steel-tape measurement will only indicate the depth to the immiscible fluid (not the depth to water) and a conventional electric water-level probe will not generally respond to nonconducting immiscible fluids.

To circumvent these problems, the use of special techniques and equipment can be specified. These techniques have been specially developed to measure fluid levels in wells containing LNAPL or DNAPL, particularly petroleum products. One method is similar to the chalked steel-tape method. The difference is the use of a special paste or gel rather than ordinary carpenter's chalk. Such indicator pastes, when applied to the end of the steel tape and submerged in the well, will show the top of the oil as a wet line and the top of the water as a distinct color change. Another method, similar to the electric-tape method, uses a dual purpose probe and indicator system (e.g., oil-water interface probe). The probe can detect the presence of any fluid (through the wetting effect) and can also detect fluids that conduct electricity. Thus, if a well is contaminated with low density, nonconducting LNAPL such as gasoline, the probe will first detect the surface of the gasoline, but it will not register electrical conduction. However, when the probe is lowered deeper to contact water, electrical conduction will be detected. The detection of a DNAPL would be similar.

5.5 Measurement of Total Depth

During water-level measurement, the total depth of the well may also be measured. Although, measurement of well bottom is not recommended if contaminants that tend to strongly sorb to sediments are present. These may include metals, PCBs, PAHs or other semi-volatile compounds. In the absence of such contaminants, measurement of total well bottom depth gives an indication of possible sediment buildup within the well that may significantly reduce the screened depth. The same methods used for measuring water levels (e.g., steel tape or electrical probes) may be used to measure the total well depth. The most convenient time to measure the total well depth is immediately following measurement of the water level and prior to removing the measurement device completely from the well. The measurement device (steel tape or electrical probe) is lowered down the well until the measurement tape becomes slack indicating the weighted end of the tape or probe has reached the bottom of the well. While the probe remains touching the bottom and the tape pulled taut, the total well depth shall be recorded into the field book.

Project Operating Procedure

Water-Level Measurements

6.0 Quality Assurance/Quality Control

To ensure that accurate data are collected, repeated measurements of the fluid depths should be made. The readings should be within 0.01 to 0.02 feet of each other. A secondary check, if data are available, is to compare previous readings collected under similar conditions (e.g., summer months, wells pumping, etc.).

7.0 Documentation

Data will be recorded into the fluid-level monitoring log form, the project field book, or, if groundwater sampling, the groundwater sample collection record. Additional comments, observations, or details will also be noted. These documents will provide a summary of the water-level measurement procedures and conditions and will be kept in the project files.

8.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

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Project Operating Procedure

POP-014

Low Stress Groundwater Sampling Procedures

1.0 Scope and Applicability

This project operating procedure (POP) is for the collection of groundwater samples using low stress groundwater sampling techniques. The POP emphasizes the need to minimize stress on the aquifer by using low pumping rates (below 1 liter per minute) and allowing minimal or no drawdown to collect samples with minimal alterations to water chemistry. The procedure also reduces the volume of purge water generated, thereby reducing disposal costs.

The POP is suited for monitoring wells that have a screen, or open interval, of 10 feet or less but is also applicable to wells with longer well screens. The monitoring wells must be sufficiently wide to simultaneously accept a submersible pump or intake tubing, and the probe from an electronic water level indicator. The screened or open interval must be positioned to intercept the existing contaminant plume, and the monitoring well must be properly constructed, developed, and maintained. This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPL/DNAPL).

2.0 Health and Safety Considerations

All maintenance and servicing of the instrumentation should be performed in a safe area, away from hazardous locations.

Refer to the Site Specific Health and Safety Plan for additional Health and Safety issues.

3.0 Interferences

Contaminants that are known to adsorb to particulates, such as metals, polychlorinated biphenols (PCBs), etc., will be impacted by elevated turbidity (>25 NTU). Although filtering would help to reduce the amount of particulates suspended in the sample, groundwater samples should not be filtered prior to analysis unless an unfiltered sample will also be submitted for the same analysis. Decisions

to sample when turbidity remains above 5 NTU shall be made in consideration of the analyses that will be performed and the project objectives.

Oxidation reduction potential (ORP) is a difficult parameter to measure in the field because the length of time which is necessary for the probe to obtain an accurate measurement is too long to be conducive to use during low-stress monitoring. Consequently, ORP readings may continue to increase or decrease slowly over the purging period.

Gas bubbles present in discharge tubing during purging and sampling are a problem; their presence indicates off-gassing from groundwater or poor purging connections in the airline or groundwater tubing. Sunlight can exacerbate this problem when low pumping rates are used. Check connections at the surface. If bubbles persist, check connections at the pump. During purging and sampling, observe the flow of groundwater in the sample tubing and keep the tubing filled with groundwater, removing all air pockets and bubbles, to the extent possible. Gas bubbles may be reduced by increasing flow, if possible, and keeping tubing and the transparent flow-through cells shaded. The flow-through cell assembly must be insulated and kept out of direct sunlight to minimize potential fluctuations in the readings.

4.0 Equipment and Materials

4.1 Submersible pumps, bladder pumps, gas displacement methods, or peristaltic pump

In selecting the appropriate pump, the sampler must consider the head pressure the pump must overcome (the distance between the water level and the highest point over which the purge water must be raised), the depth to the desired sampling interval, the inner diameter of the inner well casing, the analyses to be performed, and the associated logistics (power source, well accessibility). The pump selected must have sufficient lift capacity for the head pressure anticipated. Peristaltic pumps are effective up to a depth to water of approximately 27 feet (note that this must be measured from the highest point that the water must be raised, such as the top of the outer casing). The pump must be sufficiently small to fit into the well along with the water level indicator. The associated pressure lines, power lines, and purge and intake lines must be sufficiently long to reach to the intended sampling interval.

- **Bladder Pump**
 - The bladder pump system contains the following components: a pressurized cylinder of inert gas (typically nitrogen) or an air compressor, a pump controller, air intake and discharge lines, and bladder pumps. Dedicated bladder pumps installed at some sites, may also have an extension designed to lower the pump intake below the level of the pump. The controller regulates total flow of nitrogen or compressed air from the pressurized nitrogen cylinder to the pump assembly located in the well.
 - The tubing bundle connected to the pump has three components: an air line with fittings to the pump and the controller, a sample line, and a support cable. The sample line, through which the purge water is removed, should be composed entirely of polyethylene. In locations where dedicated bladder pumps are installed, the tubing bundle and support cable may be connected to a well plate recessed below the locking cap.

- Peristaltic Pump
 - Peristaltic pumps are not submerged in the well, but remain outside of the well and function by pulling water to the surface. A peristaltic pump has a rotating pump head with stepless variable speed that compresses a short stretch of flexible (Pharmed) silicone tubing to pull water up from the well using mechanical peristalsis. The sample water does not come into direct contact with the pump. Polyethylene tubing is connected to either end of the silicone tubing. Typical pumps, the GeoPump or GeoPump II by GeoTech, operate off an external 12 V battery or 120 V AC power source. Commercially available marine 12 volt batteries are typically preferred since electrical hookup is typically not available; since they are safe, and easy to recharge; and since the potential contamination issues associated with use of a generator are avoided.
- Submersible Pump
 - Submersible pumps used are typically electrical centrifugal pumps. A centrifugal submersible pump consists of impellers or vanes that are spun or rotated by a sealed electric motor. The spinning of the impellers that causes water to be accelerated outward and then upward into the pump's discharge line. The higher the pumping rate, the greater the potential for sample alteration by sample agitation, increased turbulence and pressure changes in the sample. However, maintaining flow in the low-flow range (less than 1,000 mL per minute) is considered acceptable. A centrifugal submersible pump is usually suspended in a monitoring well by a support cable. Typical electrical submersible pumps are the Grundfos Redi-Flo 2, Whale pump, or similar. These are centrifugal pumps cooled and lubricated with water rather than with hydrocarbon-based coolants and lubricants that could contaminate groundwater samples. The pumps can achieve flow rates as low as 100 mL per minute. The Grundfos requires a 115 or 230 volt electrical supply, therefore a generator is typically required. The Whale pump operates off an external 12 V battery. Pumps are available for wells 2 inches in diameter or larger. If these pumps are used, they require a separate flow controller to be able to regulate flow. These pumps are generally only used when no other options are available.

4.2 Tubing suited to the pumps and flow-through cells to be used

Silicone tubing shall be used around the rotor head of the peristaltic pump, and if necessary as a connecting tubing to the flow-through cells. Inner tubing diameter should be kept to the smallest size possible to reduce the generation of air pockets during low flow. Other tubing used with submersible pumps consists of polyethylene.

4.3 Electronic water level indicator: Solinst Model 101 or similar.

Inner casing diameter and pump diameter should be considered in selecting a water level indicator that will fit into the well with the pump. A smaller diameter probe is required for smaller diameter wells.

4.4 Flow controllers and compressed inert gases for submersible bladder pumps.

QED MP-10 flow controller, or similar model, and nitrogen gas or compressed air are typically used unless nitrogen is an analyte of interest.

4.5 Power source: marine battery, battery pack, compressed gas and flow-controller, or generator and heavy duty extension cords depending on pump.

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Bladder Pumps: For bladder pump operation, the cylinders of inert compressed gas function with the flow controller as the power source, although the flow controller does require batteries.

Peristaltic Pumps: The peristaltic pumps typically require an external 12 volt battery or 120 volt AC power source.

Submersible Pumps: An external power source is required. If use of a generator is required, precautions must be taken to avoid cross-contamination when handling fuel and when locating the generator to prevent contamination of the samples and sampling equipment by fumes and exhaust.

4.6 Water Quality Meter with Transparent Flow-Through Cell: YSI 556 Water Quality Meter and transparent Flow-through cell with 650MDS data manager, or similar model.

4.7 Turbidity Meter: LaMotte 2020 turbidity meter, or similar model.

4.8 Other equipment:

- Graduated cylinders
- Watch with seconds hand
- Graduated plastic purge buckets or carboys
- Cloth towel(s) or other suitable insulating material to wrap around and insulate the flow-thru cell to minimize fluctuations of temperature and other field monitoring parameters.
- Well information consisting of well casing diameter, depth to bottom, depth to top and bottom of screened interval, desired depth for sample collection, depth of pump intake (if dedicated pumps are in place) and results of synoptic water level measurements and LNAPL/DNAPL survey. Results from past sampling events should also be available as reference so that the sampling personnel understand how each of the wells typically respond to low flow purging (flow rates, drawdown, past geochemical data, etc.). The volumes per foot of screen length for common casing diameters are shown on the back of the collection record.

5.0 Procedures

5.1 This section includes the procedures for performing field activities that should be conducted prior to sampling, procedures for purging the wells using the different pumps, and the sampling and post-sampling procedures (which are the same for the different pump types).

5.2 Pre-Sampling Field Activities

- Prior to beginning sampling activities in any wells, all synoptic water level measurements and well soundings should be completed in accordance with the water level measurements in accordance with POP 013 (Water Level Measurements). Note, it is best to avoid measuring total depth to well bottom before performing low-flow purging and sampling so as to not stir up sediment, if present. Rely on historic depth to bottom measurements whenever possible. The depth to bottom can be measured following completion of sampling, if needed.

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- Wells should be inspected for the presence of DNAPL or LNAPL. In the event that NAPL is detected within a well, alternate purging and sampling procedures will be developed for those wells.
- All non-dedicated down-well measuring devices will be thoroughly decontaminated before sampling and between monitoring locations in accordance with POP 011 (Decontamination of Field Equipment).
- Sampling should begin at the monitoring well likely to have the lowest levels of contamination, generally upgradient or farthest from the site or suspected source, and proceed in order such that the most contaminated wells are sampled last.
- Record the monitoring location identification number. Check the monitoring location for damage or evidence of tampering, and record observations.
- Unlock the protective outer casing (if present) and remove the outer well cap. Immediately screen the top of the well casing for vapors with a PID, if required per the scope of work or the HASP.

5.3 Purging the Wells

5.3.1 The procedure for sampling with bladder pumps is as follows:

- Connect all the lines to the pump. If a dedicated bladder pump is in place, the tubing will already be connected to the pump and is likely connected to the well plate.
- Carefully lower the pump to the desired sampling depth using the suspension cable. Secure the pump using the suspension cable.
- Connect the pump power cable to the power source. Bladder pumps are driven by compressed gas (or air) through a controller. The controller typically requires batteries. Connect the regulator, pressurized inert gas cylinder (or air compressor), flow controller, and pump. Use a crescent wrench to attach the regulator to the pressurized nitrogen cylinder. Connect the air line from the regulator to the intake valve of the flow controller. Connect the air line from the outflow valve of the flow controller to the airline of the bladder pump.
- Carefully install a flow-through cell on the water quality meter. Avoid touching the oxygen probe. Connect a purge water discharge line to the flow-through cell of the water quality meter.
- Position the meter/flow-through cell assembly as close as possible to the well to minimize potential temperature and pressure changes of the discharge water as it flows from the well to the flow-through cell.
- Connect the purge water discharge line from the well to the water quality meter using silicone fittings for connections with polyethylene tubing. Use a short piece of silicone tubing to connect the well discharge to the flow-through cell. .Connect a piece of polyethylene tubing to the out flow of the flow-through cell to the purge bucket. Be sure to use a piece of polyethylene tubing sufficiently long to allow purge water to flow easily into the purge bucket.
- Mount the meter and flow-through cell assembly at a slight angle to allow air bubbles to escape from the cell.

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- Wrap the meter/flow-through cell assembly in a cloth towel or other suitable insulating material to insulate and help stabilize potential fluctuations of temperature and other field monitoring parameters.
- Provide cover for the tubing and insulated meter/flow-through cell assembly such that it is shaded from direct sunlight at all times.
- Slowly open the valve on the regulator attached to the nitrogen cylinder until the pressure gauge reads approximately 60 pounds per square inch (PSI). Adjust the regulator on the flow controller to be as low as possible (this is critical to start from no pressure to avoid accidental surging of the well).
- Remeasure the static water level.
- Determine the minimum purge volume required for the well (see the back of the collection record for purge volumes per foot of screen).
- Start the flow controller and begin purging at the slowest rate possible.
- Note the purge start time.
- Collect all purge water in a bucket or carboy.
- Slowly increase the pressure at the controller until water begins to discharge from the well through the flow cell. The bladder pump controller should be set to allow for adequate recharge such that a maximum flow rate with no drawdown is achieved (generally 100-500 mL/min) and a smooth, even discharge flow is achieved. Reer to past sample records to obtain past flow controller intake and discharge settings for each well.
- Measure the flow rate using a graduated cylinder and time piece and monitor the water level and pumping rate. Under no circumstances should purging be interrupted until all sample volume has been collected.
- Once drawdown has stopped and an acceptable flow rate established, begin monitoring indicator parameters and continue monitoring flow rate and water level.
- Record readings every three to five minutes, or as appropriate for the flow rate and flow-through cell volume. Use the water quality meter to monitor temperature, pH, specific conductance, DO, and ORP within the flow-through cell. Use a turbidimeter to monitor turbidity outside of the flow-through cell.
- In the event that the well has extremely low recharge such that the lowest purge rate possible for the pump (typically no less than 50 - 100 mL/min) continues to dewater the well, notify the field team leader of the situation. If all efforts to avoid dewatering the well are unsuccessful, a decision may be made to allow the well to recharge to a level sufficient to allow for collection of the necessary sample volume and to sample the well immediately. Record detailed notes concerning the sampling of the well on the sample collection record.

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- Stop purging when all parameters have stabilized. Parameters are considered to have stabilized if, over three consecutive readings, the following criteria are met:
 - pH $\pm$ 10%
 - specific conductance and temperature $\pm$ 10%
 - turbidity $\pm$ 10% (down to 1 NTU), and < 5 NTU
 - DO $\pm$ 0.3 mg/L
 - ORP $\pm$ 10%
- The reporting limits presented are the lowest concentrations to which the instrument is considered linear and therefore accurate. Three consecutive readings below the reporting limits presented are considered to be stable.
- Readings should be recorded approximately every 5 minutes for flows in the range of 200 to 500 ml/min. Readings should be taken less frequently if the maximum flow rate is less than 100 ml/min because of the retention time in the flow-through cell.
- Record the time at which the required minimum volume was removed, and record the total volume removed prior to sampling.
- If parameters do not stabilize, or turbidity remains greater than 5 NTU within a reasonable purging time (30 to 45-minutes), contact the field team leader. Technical judgment will be used to determine when sampling should commence.

5.3.2 The procedure for sampling with peristaltic pumps is as follows:

Samples are frequently collected from the most-contaminated interval, as determined by previous profiling investigations, or from the lower part of the screen interval, or the midpoint of the saturated screen interval. If possible, keep the pump intake at least two feet above the bottom of the well to minimize mobilization of sediment that may be present at the bottom of the well.

Connect the necessary tubing to the pump.

- Measure a new section of 3/16-inch inner diameter (ID) silicone tubing and attach it to the peristaltic pump head. Note that the length of silicone tubing in contact with the sample should be kept to a minimum.
- Measure a new section of 3/16-inch ID polyethylene tubing to extend from the depth of the intended sampling location to the intake end of silicone tubing. To do this and avoid contamination of the tubing, it is recommended that a decontaminated water level measuring tape be used to measure the tubing as it is lowered into the well. The water level indicator may be lowered into the well with the tubing, or allowed to run onto the clean plastic on the ground outside of the well. Since the tubing is typically stored on a roll, straightening the tubing as you put it into the well will help avoid catching the tubing on any obstructions in the well, such as the top of the well screen. Once the tubing is lowered to the desired depth, immediately secure the free end of the polyethylene tubing to prevent it dropping into the well.
- Connect the electrical the pump to the battery.

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- Note that reversing the connections will typically cause the pump to run in reverse, which could push air into the well and should be avoided. Peristaltic pumps also typically have a flow direction switch. Make sure that the switch is set in the proper direction prior to turning on the pump.
- Commence purging at the slowest possible flow rate and slowly increase the speed until water begins to discharge through the flow cell. The pump rate should be set to allow for maximum flow rate (100-500 milliliters per minute) with no drawdown. Refer to historical purge information for flow rates, drawdown/recharge, etc. Under no circumstances should purging be interrupted until all sample volume has been collected.
- Collect all purge water in a bucket or carboy.
- Once the stagnant volume in the tubing has been removed (see below for volume equation), drawdown has stopped, and an acceptable flow rate has been established, begin monitoring indicator parameters and continue monitoring flow rate and water level. Record readings every three to five minutes, or as appropriate for the flow rate and flow-through cell volume. Use the water quality meter to monitor the following: temperature, pH, specific conductance, DO, and ORP within the flow-through cell. Use a turbidimeter to monitor turbidity outside of the flow-through cell.
 - Tubing radius = $r = 0.0104$ ft.
 - Volume of tubing = $r^2 \times \text{length of tubing} = V$ (in ft^3)
 - $\text{ft}^3 \times 28.316 = \text{liters}$
- In the event that the well has extremely low recharge such that the lowest purge rate possible (typically no less than 20-75 mL/min) continues to dewater the well, notify the field team leader of the situation. If all efforts to avoid dewatering the well have failed, a decision may be made to allow the well to recharge to a level sufficient to allow for collection of the necessary sample volume and to sample the well immediately.
- Record detailed notes concerning the sampling of the well.
- Stop purging when all parameters have stabilized. Parameters are considered to have stabilized if, over three consecutive readings, the following criteria are met:
 - $\text{pH} \pm 10\%$
 - specific conductance and temperature $\pm 10\%$
 - turbidity $\pm 10\%$ (down to 1 NTU), and < 5 NTU
 - $\text{DO} \pm 0.3$ mg/L
 - $\text{ORP} \pm 10\%$
- The reporting limits presented are the lowest concentrations to which the instrument is considered linear and therefore accurate. Three consecutive readings below the reporting limits presented are considered to be stable.
- Readings should be recorded approximately every 5 minutes for flows in the range of 200 to 500 mL/min. Readings should be taken less frequently if the maximum flow rate is less than 100 mL/min because of the retention time in the flow-through cell.

- If parameters do not stabilize, or turbidity remains greater than 5 NTU within a reasonable purging time (30 to 45 minutes), contact the field team leader. Technical judgment will be used to ascertain when sampling should commence.

5.4 The procedure for sampling with submersible pumps is as follows:

- Prior to placing any equipment in the well, measure and record the static water level as described in the water level measurement POP.
- Note the water level in relation to the top of the screen. If the static water level is above the top of the screen, care should be taken to prevent the water level from dropping below the top of the screen.
- Samples are frequently collected from the most-contaminated interval, as determined by previous profiling investigations, or from the lower part of the screened interval, or the midpoint of the saturated screened interval. If possible, keep the pump intake at least two feet above the bottom of the well to minimize mobilization of sediment that may be present at the bottom of the well.
- Connect the pump to the power source. Submersible pumps are driven by an external power source. If the use of a generator is required, it should be placed downwind of the sampling location to prevent exhaust from impacting the samples.
- Care must be taken in handling the generator and gasoline to preclude cross-contamination of the samples and sampling equipment.
- At a minimum, samplers must change gloves after handling the fuel or generator prior to sampling.
- Carefully lower the pump to the desired sampling depth using the suspension cable. Take care to minimize disturbance and contact with the well walls which could knock rust or other deposits into the standing water.
- Secure the pump using the suspension cable, and connect the ground from the pump.
- Connect the purge water discharge line to the water quality meter with silicone tubing.
- Connect the outflow end of the water quality meter using a short piece of silicone tubing if necessary. Attach a piece of polyethylene tubing to the discharge end sufficient in length to reach the purge water collection container. .
- Remeasure the static water level.
- Record the saturated well screen length and the saturated well screen volume on the sampling worksheet.
- Start the pump and begin purging at the slowest rate possible.
- Note the purge start time. Slowly increase the speed until discharge begins.

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- The pump should be set to allow for adequate recharge such that a maximum flow rate with no drawdown is achieved (generally 100-500 mL/min).
- Refer to the historical flow controller settings for the well to select the starting controller pressure and intake and discharge intervals.
- Collect all purge water in a bucket or carboy.
- Measure the flow rate using a graduated cylinder and time piece and monitor the water level and pumping rate during purging.
- Under no circumstances should purging be interrupted until all sample volume has been collected.
- Once drawdown has stopped and an acceptable flow rate established, begin monitoring indicator parameters and continue monitoring flow rate and water level. Record reading every three to five minutes, or as appropriate for the flow rate and flow-through cell volume.
- Use the water quality meter to monitor the following: temperature, pH, specific conductance, DO, and ORP in the flow-through cell. Use a turbidimeter to monitor turbidity outside the flow-through cell.
- In the event that the well has extremely low recharge such that the lowest purge rate possible (typically 100 ml/min or so) continues to dewater the well and notify the field team leader of the situation. If all efforts to avoid dewatering the well have failed, a decision may be made to allow the well to recharge to a level sufficient to allow for collection of the necessary sample volume and to sample the well immediately.
- Record detailed notes concerning the sampling of the well on the collection record.
- Stop purging when all parameters have stabilized. Parameters are considered to have stabilized if, over three consecutive readings, the following criteria are met:
 - pH $\pm$ 10%
 - specific conductance and temperature $\pm$ 10%
 - turbidity $\pm$ 10% (down to 1 NTU), and < 5 NTU
 - DO $\pm$ 0.3 mg/L
 - ORP $\pm$ 10%
- The reporting limits presented are the lowest concentrations to which the instrument is considered linear and therefore accurate. Three consecutive readings below the reporting limits presented are considered to be stable.
- Readings should be recorded approximately every 5 minutes for flows in the range of 200 to 500 ml/min. Readings should be taken less frequently if the maximum flow rate is less than 100 ml/min because of the retention time in the flow-through cell.

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- If parameters do not stabilize, or turbidity remains greater than 5 NTU within a reasonable purging time (30 to 45 minutes), contact the field team leader. Technical judgment will be used to ascertain when sampling should commence.

5.5 Sampling

Once purging has been completed and prior to commencement of sampling,

- Measure and record final water level, temperature, pH, specific conductance, DO, ORP, turbidity, flow rate, and final volume removed.
- Disconnect the purge tubing from the flow-through cell, and position in a manner such that sample water will be collected directly from the tubing (use a ring stand or other device to hold tubing steady to allow filling of bottles while purge water continues to discharge into bucket.
- Prior to commencing filling sample bottles, double check the flow rate to insure that it did not change when the flow cell was disconnected. This is not typically a problem when using a peristaltic, but can be when using a submersible pump, bladder or other. Re-establish the flow rate if it has changed.

In keeping with convention, samples should be collected in order of decreasing volatility and reactivity so that the most volatile or reactive samples are collected first. The following are general guidelines.

- Gases (methane/ethane/ethene/hydrogen/CO₂)
- Volatile Organic Compounds
- Semivolatile Organic Compounds
- Pesticide/PCBs
- Dioxins
- Metals
- General chemistry

During sample collection, allow the water to flow directly into and down the side of the sample container in order to minimize aeration and maintain sample integrity, without allowing the tubing to touch the inside of the sample container or lid.

In some instances the bladder pump controller pumps water out of the sample tubing in a forceful manner, such that the gases and VOC samples may be compromised. If this is the case, the non-VOC samples should be collected first. Once the non-VOC samples are collected, adjust the flow rate on the bladder pump controller so that the water is no longer being pumped out of the sample tubing in a forceful manner, and collect the samples for analysis of gases and VOCs. Record the procedure and all samples collected in this manner.

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5.6 Post-Sampling Field Activities

Preserve the samples per requirements in the work plan. Immediately label the sample containers with the sample collection date and time and place them on ice. Complete the COC forms as soon as possible. The COC will be completed in accordance with the Chain-of-Custody (POP 002).

Cease pumping and disassemble the purging and sampling equipment.

Replace the well cap and lock the outer protective casing.

Decontaminate the sampling equipment per the Decontamination of Field Equipment (POP 011).

Dispose of all purge water as per the site-specific sampling and analysis plan.

6.0 Quality Assurance / Quality Control

The tubing and lines associated with sampling pumps are typically long and awkward to handle, and careful handling is required to prevent introduction of contaminants into the well.

Duplicate measurements cannot effectively be taken using the flow-through cell, since two consecutive measurements taken are not measuring the same sample, and flow cannot be interrupted. Water quality parameters obtained should be compared to historical readings, and potential instrument issues should be considered in the event of major differences.

Pollution prevention and waste management

- Purge water volume is kept to a minimum through the use of the low-stress sampling procedures. When available, historical information on sampling rates for each well will be used in an attempt to minimize time spent determining the equilibrium flow rate and thereby minimizing purge water volume.
- Lengths of tubing remove from each roll of tubing will be tracked to maximize use and minimize waste of remaining pieces.
- Purge water will be containerized until purging and sampling activities at the well are completed. Purge water will then be disposed of in accordance with the site-specific sampling and analysis plan

7.0 Data and Records Management

All documentation will be conducted in accordance with the Recording of Field Data (POP 001).

Groundwater sampling information specific to each well will be recorded on the attached low flow groundwater sample collection record, presented in sampling and analysis plan. Activities common to

more than one well, samples collected, deviations from the sampling and analysis plan, and any other unusual occurrences will also be documented in the field logbook in accordance with Recording of Field Data (POP 001).

8.0 Personnel Qualifications and Training

The individual executing these procedures must have read, and be familiar with, the requirements of this POP.

All field samplers are required to take the 40-hour OSHA health and safety training course and annual 8-hour refresher courses prior to engaging in any field investigation activities.

Prior to implementation of this procedure, the field sampler will be instructed by a person experienced with this procedure and the collection of groundwater samples. The sampler will demonstrate to the Field Team Leader or designee an understanding of this procedure, and will have had sufficient experience conducting groundwater sampling in the field such that they are able to execute this procedure without oversight or assistance in the field.

9.0 References

U.S. Environmental Protection Agency, Region 1. Low-Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells, Revision 2, July 30, 1996.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

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Low-Flow Groundwater Collection Record (Front)



Well ID: _____

Low Flow Ground Water Sample Collection Record

Client: _____	Date: _____	Time: Start _____ am/pm
Project No: _____		Finish _____ am/pm
Site Location: _____		
Weather Conds: _____ Collector(s): _____		

1. WELL & WATER LEVEL DATA: (measured in feet from Top of Casing unless noted)

- a. Total Well Length _____ c. Screen Length _____
- b. Water Table Depth _____ d. Pump Intake _____
- e. Calculated System Purge Volume _____ (calculation on page 2)

2. WELL PURGE DATA

a. Purge Method: _____

b. Acceptance Criteria defined (see workplan)

- Temperature	3%	- D.O.	< 0.5 mg/L	- Drawdown	< 0.3 ft
- pH	+ 1.0 unit		> 0.5 mg/L within 10%	- Turbidity	< 10 NTU
- Sp. Cond.	3%	- ORP	± 10mV		> 10NTU within 10%

c. Field Testing Equipment used: Make _____ Model _____ Serial Number _____

Time (24hr)	Volume Removed		Temp. (°C)	pH	Spec. Cond. (µS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (feet)	Color/Odor
	(Liters)										

d. Acceptance criteria pass/fail

Has required volume been removed	Yes ☐	No ☐	N/A ☐
Has required turbidity been reached	☐	☐	☐
Have parameters stabilized	☐	☐	☐

(continued on back)

If no or N/A - Explain below.

3. SAMPLE COLLECTION:

Method: _____

Sample ID	Container Type	No.	Preservation	Analysis Req.	Time

Comments _____

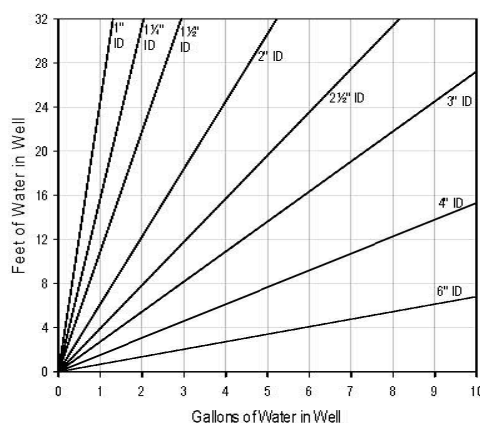
Signature _____ Date _____

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Low-Flow Groundwater Collection Record (Back)



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Volume / Linear Ft. of Pipe		
ID (in)	Gallon	Liter
0.25	0.0025	0.0097
0.375	0.0057	0.0217
0.5	0.0102	0.0386
0.75	0.0229	0.0869
1	0.0408	0.1544
1.25	0.0637	0.2413
1.5	0.0918	0.3475
2	0.1632	0.6178
2.5	0.2550	0.9653
3	0.3672	1.3900
4	0.6528	2.4711
6	1.4688	5.5600

Purge Volume Calculation

[ft (tubing length) x L/ft] + 0.275 L (flow cell vol.) = L ; L x 3 well vol. = L

(continued from front)

Volume

Time (24 hr)	Removed (Liters)	Temp (°C)	pH	Spec. Cond. (µS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (ft)	Color/Odor

[illegible]

Lockheed Martin Wilmington

Project Operating Procedure

POP-015

Field Calibration of the YSI Water Quality Meter

1.0 Scope and Applicability

The purpose of this project operating procedure (POP) is provide a framework for calibrating sondes used to measure water quality parameters for ground water and surface water. Water quality parameters include temperature, pH, dissolved oxygen (DO), conductivity/specific conductance, and oxidation reduction potential (ORP). Turbidity cannot be measured using the portable water quality meters since the method used by the YSI and other models for turbidity measurement is not approved for use by United States Environmental Agency (US^{EPA}). A separate meter which uses USEPA Method 180.1 to measure turbidity must be used.

This POP is written specifically for the YSI model 6-Series Sondes (which include the 600R, 600XL, 600XLM, 6820, 6920 and 6600 models), and the YSI 650 MDS (Multi parameter Display System) display/logger. The general calibration processes discussed herein are applicable to other manufactures sondes and displays/loggers. Consult the manufacturer's instruction manuals for specific procedures.

2.0 Health and Safety Considerations

All proper personal protection clothing and equipment is to be worn.

The standard solutions for calibrating conductivity contain iodine, potassium chloride and propanol. When using the standards, avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs, remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the Material Data Safety Sheets (MSDS) for prompt action, and in all cases seek medical attention immediately.

All standard solutions for calibration pH contain the following chemicals and warnings:

- pH 4 Solutions: potassium hydrogen phthalate, formaldehyde, water
- pH 7 Solutions: sodium phosphate (dibasic), potassium phosphate (monobasic), water
- pH 10 Solutions: potassium borate (tetra), potassium carbonate, potassium hydroxide, sodium diethylenediamine tetraacetate, water

- Avoid inhalation, skin contact, eye contact and ingestion. If skin contact occurs remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the MSDS for prompt action, and in all cases seek medical attention immediately.

Standard solutions for calibration of ORP contain the following chemicals and warnings:

- potassium ferrocyanide trihydrate
- potassium ferrocyanide
- potassium chloride
- Avoid inhalation, skin contact, eye contact, and ingestion. Avoid combining with the pH buffers and with any acids since cyanide may be released. Isolate the ORP solution. Do not dispose with other calibration solutions. If skin contact occurs, wash affected areas thoroughly with large amounts of water. Consult the Health and Safety Plan, and the MSDSs therein.

Standard solutions for calibration of DO contain sodium sulfite and cobalt chloride. Avoid inhalation, skin contact, eye contact, and ingestion. If skin contact occurs, wash affected areas thoroughly with large amounts of water. Consult the Health and Safety Plan, and the MSDSs therein.

3.0 Interferences

Each of the parameters measured with this procedure is subject to various interferences including cross-contamination, turbidity, aeration, and temperature fluctuations. Care must be taken to ensure that the instrument remains in a stable, controlled environment throughout the calibration and monitoring process; and that the conditions under which the samples are analyzed are the same as those under which calibration is conducted.

4.0 Equipment and Materials

- Thermometer (with National Institute of Standards and Technology [NIST] trace)
- pH Buffers of 4, 7, and 10
- Conductivity standards (concentration dependent upon expected field conditions)
- Zobell ORP calibration standard
- Zero DO Solution
- Deionized (DI) Ultra-Filtered (DIUF) Water

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- YSI Sonde with attached pH, Conductivity, DO, and ORP probes with clear flow-through cell
- YSI 650 Multiparameter Display System (MDS) (display logger)
- Sonde communications cable
- Ring stand or similar capable of holding the sonde and flow-through cell upright during low-flow groundwater sampling
- Kimwipes or similar disposable wipe
- Gallon-size plastic freezer bags (e.g. Ziploc) to protect the MDS and the top of the Sonde from rain

5.0 Procedures

All instrument probes must be calibrated before they are used to measure environmental samples, and the calibration should be checked at the end of the sampling day or if any anomalous readings are obtained.

Set-up

- Before performing any calibration procedure the sonde and display/logger must warm-up for at least 15 minutes.
- During the warm-up period, set the sonde up on a ring stand.
- Prior to calibration, all instrument probes on the sonde must be cleaned according to the manufacturer's instructions. Failure to perform this step can lead to erratic measurements. The probes must also be cleaned by rinsing with deionized water before and after immersing the probe in a calibration solution.
- For each of the calibration solutions, provide enough volume so that the probe and the temperature sensor are sufficiently covered. Additional detail on volume is provided under each section and in the manufacturer's instructions.
- Check the display/logger to determine the battery level in the display/logger to see if recharging is necessary.
- Set up instrument display so that the following items are displayed:
 - DO percent
 - ORP
 - DO milligrams per liter (mg/L)
 - Cond. micro Siemens per centimeter ($\mu\text{S}/\text{cm}$)
 - Sp. Cond. $\mu\text{S}/\text{cm}$
 - pH
 - Temperature

For instrument probes that rely on the temperature sensor (pH, DO/specific conductance, and ORP), the sonde temperature sensor needs to be checked for accuracy against a thermometer that is traceable to the National Institute of Standards and Technology (NIST). This accuracy check should be performed at least once a year, and the date and results of the check kept with the instrument. Temperature checks will be checked by the rental company for rented units, and by the AECOM equipment manager for AECOM-owned units. Prior to mobilizing, obtain the date and results of the check from the equipment room manager or check the outside of the case for rental units. If the check has not been performed within the past year, do not use the instrument. Document the date, results, and company that performed the check on the calibration log sheet or in the field logbook. Below is the verification procedure:

- Allow a container filled with water and the sonde to come to room temperature.
- Place a thermometer that is traceable to the NIST into the water and wait for both temperature readings to stabilize.
- Compare the two measurements. The instrument's temperature sensor must agree with the reference thermometer within the accuracy of the sensor ($\pm 0.15^{\circ}\text{C}$). If the measurements do not agree, the instrument may not be working correctly and the manufacturer should be contacted.

Dissolved Oxygen

Dissolved oxygen (DO) content in water is measured using a membrane electrode. The DO probe's membrane and electrolyte solution should be inspected for any damage or air bubbles prior to calibration. If air bubbles or damage are present, replace the membrane according to manufacturer's suggestions. After changing the membrane, it is preferable to wait 12 hours before use to allow the membrane to equilibrate. If this is not possible, note this in the calibration log. YSI 6-Series DO probe be must calibrated using the calibration cup provided with the sonde. Calibration of the DO probe requires inputting the current barometric pressure. The YSI 650 display/logger has a barometer within the unit and automatically provides this during the calibration procedure. The barometric pressure for all units onsite should be checked for agreement between units, or checking using the onsite barometer. Other display/loggers do not supply the barometric pressure, and this must be obtained from other sources. Do not use barometric pressure obtained from meteorology reports as these are usually corrected to sea level.

Calibration is performed using 100% saturated air, and checked immediately after with a solution with zero DO. The calibration check at the end of the day uses 100% saturated air.

- DO Calibration
 - Place a small amount of water (less than 1/8 inch) in the bottom of the calibration cup. Engage only one thread of the calibration cap onto the sonde so that the DO probe is readily vented to the atmosphere. Take care to avoid touching the oxygen membrane with the calibration cups and flow-cell. The DO probe and thermistor must not be in contact with the water. Keep the instrument in run mode and wait approximately 15 minutes for the air in the calibration cup to become water-saturated (100% humidity at atmospheric pressure) and the temperature to equilibrate. Set up the remaining instruments and solutions in the meantime.
 - When the temperature has stabilized, go to Calibrate mode - Calibrate DO%
 - Record the temperature on the calibration log. Check the barometric pressure reading on the YSI versus the barometer and other YSIs present. Enter the barometric pressure if correction is necessary. Record the barometric pressure on the calibration log. (Note: barometric

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pressures presented in meteorological reports are generally corrected to sea level. These are not useful for calibrating the sonde, which requires uncorrected barometric pressure).

- When the DO% and temperature readings have stabilized for at least one minute, press enter. Record the number that appears on the screen. Record also the DO mg/L value.
- Check the oxygen solubility at that pressure and temperature on the attached table and record under "Std temp/pressure correction." The instrument DO reading should be comparable with the value on the table (within +0.2 mg/L). If not, recalibrate, or replace DO membrane.
- Make up the zero DO solution by filling the calibration cap with DI water, adding approximately 1 gram of sodium sulfite to supersaturate the solution. Add a few crystals of the cobalt chloride (purple salt) and stir. There should be solids on the bottom of the cap. Screw the cap tightly onto the YSI. Water should leak out to indicate that there is no air around the probes.
- Immediately after calibration, if the DO is at or below 0.50 mg/L, record the value on the calibration log. If the number stabilizes at a value greater than 0.50 mg/L, change the DO membrane. At the end of the day, if the DO is at or above 1.0 mg/L, note the failed criteria and the readings that are impacted, and repeat the analyses at the discretion of the field team leader.
- Remove the cap, and rinse the probes well with DI water. Blot the probes dry, carefully avoiding the DO membrane.
- DO End-of-Day Check
 - Allow the DO% and temperature readings to stabilize for at least one minute. Record the number that appears on the screen. Record also the DO mg/L value.
 - Check the oxygen solubility at that pressure and temperature on the attached table and record under "Std temp/pressure correction." The instrument DO reading should be comparable with the value on the table (within ± 0.5 mg/L).

pH

The pH of a sample is determined electrometrically using a glass electrode. Choose the appropriate standards that will bracket the expected values at the sampling locations. A two or three-point calibration can be performed. Typically, a three-point calibration using standards pH 4, pH 7, and pH 10 will be required. A calibration check is performed immediately after calibration using the pH 7 standard and a criterion of ± 0.05 pH units. A calibration check is also performed at the end of the day using the pH 7 standard and a criteria of 0.3 pH units.

- pH Calibration
 - Allow the buffered samples to equilibrate to the ambient temperature.
 - Remove the calibration cap and clean all of the probes on the sonde with deionized water. Begin with pH 7.00. Wipe with Kimwipe and immerse all the probes in the 7.00 pH solution. Place enough pH 7.00 solution in the calibration cup to immerse the pH probe, reference junction, and thermistor. Return to calibration mode.
 - Scroll to pH on the calibration menu. Select 3-pt calibration.
 - Enter pH 7.00 when prompted for the first value, and press enter.

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- When value is stable for approximately 30 seconds, press enter, and record the number that appears on the screen. The display will indicate that the calibration has been accepted and will prompt the analyst to enter a second pH value.
- Remove probes from solution. Rinse with deionized (DI) water, wipe carefully, and put all probes in solution pH 4.00. Make sure that there is enough pH 4.00 buffer to immerse the pH probe, reference junction, and thermistor.
- Enter pH 4.00 when prompted for the second pH solution, press enter.
- Allow at least one minute for temperature equilibration. When value is stable for at least 30 seconds, press enter, and record the number that appears on the screen.
- Repeat steps 5, 6, and 7 for the pH 10.00 solution.
- Press enter or esc to go to calibration menu.
- Go to the run mode to perform a calibration check of the pH 7.00 solution. Rinse the probe and immerse in pH 7.00 solution. The reading should be within ± 0.05 pH units of 7.00. If not, recalibrate. Record the reading.
- pH End-of-Day Check
 - Go to the run mode to perform a calibration check of the pH 7.00 solution.
 - Rinse the probe and immerse in pH 7.00 solution. Record the reading. The reading should be within ± 0.3 pH units of 7.00.
 - If not, record on the measurements impacted that the pH calibration check criterion was not met.

Conductivity

Conductivity is used to measure the ability of an aqueous solution to carry an electrical current. Specific conductance is the conductivity value corrected to 25°C. Note that the pH buffers are highly conductive and will adversely impact calibration of conductivity. Thoroughly rinse the probes after performing pH calibration, and then pre-rinse the probe with the conductivity solution to be used.

USEPA recommends that conductivity be calibrated using standards that bracket the range of concentrations expected. Conductivities in groundwater frequently range below 1,000 $\mu\text{S}/\text{cm}$; however YSI does not recommend calibration with standards below 1,000 $\mu\text{S}/\text{cm}$ because interference with the instrument from outside electrical noise (RF) may be a factor. Since the calibration for conductivity is a 1-point calibration, and expected conductivities will generally be less than 1,000 $\mu\text{S}/\text{cm}$, calibrate with the 1,000 $\mu\text{S}/\text{cm}$ standard, and perform a check with a lower conductivity solution to bracket the range (e.g. 100 $\mu\text{S}/\text{cm}$).

- Conductivity Calibration
 - Carefully rinse the probes in DI, then in the first conductivity solution to be used.
 - Immerse all probes completely in the conductivity calibration solution. Make sure that the thermistor is immersed, and the conductivity cell is immersed past the vent hole. Gently tap the side of the calibration cup to dislodge any air bubbles trapped inside the cell.
 - Scroll to conductivity on the screen. Select calibrate to $\mu\text{S}/\text{cm}$. Check the standard solution on the temperature correction table (Table 1), or the table supplied with the bottle, and enter the corrected conductivity value. (Both should be in $\mu\text{S}/\text{cm}$.)

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Field Calibration of the YSI Water Quality Meter

- Press enter and wait for the readings to stabilize. Press enter. Record the readings for conductivity and specific conductivity in the calibration log. Do not exit conductivity.
- Do not indicate “accept” when the calibration indicates “Out of Range.” Attempt to recalibrate. If the problem persists, use another instrument. Return the instrument to the vendor or equipment room.
- Perform a check of the calibration. Remove the probes from the solution. Rinse with the next conductivity solution. Immerse all probes in the conductivity calibration solution. Allow the number to stabilize and record the values for conductivity and specific conductivity in the calibration log. If the specific conductivity result is not within 5 percent of the value on the bottle, recalibrate. Remove probes from solution and rinse with DI water. Wipe dry.
- Conductivity End-of-Day Check
 - Rinse the probes with the conductivity solution. Immerse all probes in the conductivity calibration solution.
 - Allow the number to stabilize and record the values for conductivity and specific conductivity in the calibration log. If the specific conductivity result is not within 20 percent of the value on the bottle, note on the measurements obtained that the conductivity calibration check criteria were not met.
 - Remove the probes from solution and rinse with DI water. Wipe dry.

Oxidation Reduction Potential

ORP will be checked for accuracy, and will only be field calibrated if the calibration check fails criteria.

- ORP Calibration
 - Switch to run mode. Gently mix the ORP solution and open the packet. Put all but the DO probe in the ORP solution. Allow to stabilize and record reading. If reading is not within ± 10 millivolts (mV) of the actual value corrected for temperature (Table 2), proceed to 5.6.1.2.
 - Go to Calibration mode. Scroll to ORP and press enter. Enter ORP value (corrected for temperature – Table 2) and press enter. When the number is stable for 20 seconds, press enter and record the number. If instrument says “Out of Range,” do not accept the value: Use a different instrument. If a different instrument is not available, record the number and note that it is not within limits.
- ORP End-of-Day Check
 - Switch to run mode.
 - Gently mix the ORP solution and open the packet. Put all but the DO probe in the ORP solution.
 - Allow to stabilize and record reading. If reading is not within ± 10 mV of the actual value corrected for temperature (Table 2), note on the measurements affected that the criterion for ORP check was not met.

Close up Instrument

Replace clean cap over probes.

Select run mode. Reset the parameters to the following:

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- pH
- specific conductivity
- ORP
- Temperature
- DO milligrams per liter (mg/L)

Shut off computer, and return to case.

6.0 Quality Assurance / Quality Control

Quality Control

Criteria are summarized in Table 3.

Pollution Prevention

Containers used to calibrate the probes shall be sized to use the smallest amount of standard possible but still accommodate all probes which need to be in the calibration solution such that they are adequately covered.

Conductivity and pH calibration solutions may be reused at the end of the day with caution if properly stored. However, a calibration check that reuses standard but does not meet criteria should be re-checked with fresh standard, and calibration should be conducted with fresh standards.

Waste Management

Unused calibration standards should be returned to the equipment manager for proper disposal. Do not combine ORP standards with other standards since cyanide could be released.

7.0 Data and Records Management

Calibration log sheets shall be used to document the details of instrument calibration and calibration checks.

The site logbook should be used to note when instrument calibration and instrument calibration checks were conducted, and should reference the calibration log sheets for details.

Readings measured by instruments that are subsequently found to be outside of criteria during the calibration check shall be documented on the sampling worksheet used to document the sample collection.

8.0 Personnel Qualifications and Training

The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this POP and the project-specific work plan.

The field operator is responsible for verifying that the instrument is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this POP.

9.0 References

U.S. Environmental Protection Agency Region I (USEPA-NE). 1998. *Draft Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductivity, oxidation/reduction potential [ORP], and turbidity)*. Draft. June 3.

U.S. Environmental Protection Agency Region I (USEPA-NE). 2002. *Standard Operating Procedure for Calibration and Field Measurement Procedures for the YSI Model 6-Series Sondes (Including: Temperature, pH, Specific Conductance, Turbidity, and Dissolved Oxygen)*. Revision I. May 31.

U.S. Environmental Protection Agency Region I (USEPA-NE). 2006. *Final QA Bulletin: Calibration of Dissolved Oxygen Meters*. Revision 0. February.

YSI, Inc. (YSI). 2002. YSI Calibration Procedures: Profiling and Logging, www.water-monitor.com. Dec 22.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Table 1 Conductivity Temperature Corrections

Temperature, °C	100 µs/cm	1,000 µs/cm	10,000 µs/cm
5.0	--	700	7260
10.0	--	718	7437
11.0	--	736	7614
12.00	--	754	7793
13.0	--	773	7972
14.0	--	791	8153
15.0	82	814	8615
16.0	84	833	8800
17.0	85	852	8987
18.0	87	870	9175
19.0	89	889	9364
20.0	91	908	9555
21.0	93	927	9747
22.0	94	947	9941
23.0	96	966	10136
24.0	98	985	10332
25.0	100	1004	10530
26.0	102	1024	10730
27.0	104	1043	10930
28.0	106	1062	11132
29.0	108	1082	11336
30.0	110	1102	11541
31.0	112	1121	11748
32.0	114	1141	11955
33.0	116	1161	12165
34.0	119	1181	12375
35.0	121	1201	12588

°C = degree centigrade

us/cm = microsiemens per centimeter

Table 2 ORP Check Standard Readings

Temperature, °C	100 mV Standard Solution
10	124.4
15	116.7
20	109.1
25	100
30	93.1
35	84.9
40	76.3

mV = millivolts

°C – degree centigrade

Table 3 Quality Control Criteria

Parameter	Beginning of Activities				End-of-Day	
	Calibration		Calibration Check		Calibration Check	
	Standard	Criteria	Standard	Criteria	Standard	Criteria
Temperature	NIST Thermometer	± 0.15 °C	NA	NA	NA	NA
Dissolved Oxygen	100 % Saturated	± 0.2 mg/L	0.0 mg/L	< 1.0 mg/L	100% Sat	± 0.5 mg/L
pH	Bracket anticipated (pH 7.00, 4.00, 10.00)	NA	pH 7.00	± 0.05 pH	pH 7.00	± 0.3 pH
Conductivity	Bracket anticipated (≥ 1,000 µS/cm)	NA	Bracket anticipated	± 5%	Same as for calibration	± 20%
Oxidation-Reduction Potential	Only if check fails: 100 mV Zobell solution	NA	100 mV Zobell solution	± 10mV	100 mV Zobell solution	± 10mV

NIST = National Institute of Standards and technology

°C – degree centigrade

NA = not applicable

mg/L = milligrams per liter

% = percent

Sat = saturation

µS/cm = microsiemens per centimeter

mV = millivolts

Lockheed Martin Wilmington

Project Operating Procedure

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Slug Testing

1.0 Project Scope and Applicability

This Project Operating Procedure (POP) describes the procedures for conducting in-situ rising head and falling head hydraulic conductivity tests (slug tests). Slug tests are performed to assess the hydraulic conductivity of the soil or rock surrounding the tested monitoring well.

Hydraulic conductivity values are used:

- To estimate rates and volumes of groundwater flow;
- To estimate responses of aquifers to applied stresses, such as pumping;
- To estimate the rate of movement of various chemicals in subsurface zones; and
- To construct and calibrate groundwater flow models.

In-situ tests to determine hydraulic conductivity can be conducted in open boreholes or in monitoring wells and they can be variable-head tests or constant-head tests. The change in water levels can be produced by displacing a known volume of water using a slug or using a pneumatic pump. The change in water levels during the test can be monitored using a water level tape or with electronic data loggers. Data loggers are preferred because they can collect many measurements in a short period of time, which is important for evaluating the early-time response of the aquifer to the water displacement. For the purpose of this POP, the method to perform a variable-head test in a monitoring well using electronic data logging, and either slugs or pneumatic pumps will be outlined.

1.1 General Principles

Hydraulic conductivity is a measure of the ease of flow of water through a specific porous medium. Variable-head tests are performed by causing a sudden (instantaneous) rise or drop of the static water level in a well. Water levels are monitored and recorded until the water level has returned to static conditions or sufficient data is collected to perform the hydraulic conductivity calculations.

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2.0 Health and Safety Considerations

Hydraulic conductivity testing may involve chemical hazards associated with exposure to groundwater and the testing equipment that comes in contact with the groundwater. When conducting hydraulic conductivity tests, adequate health and safety measures must be taken to protect field personnel. These measures are addressed in the project Health and Safety Plan (HASP). All work will be conducted in accordance with the HASP.

3.0 Interferences

There are many potential interferences in the performance and analysis of slug tests. For this reason, appropriately trained personnel shall perform the tests in the field and conduct the data analysis. Data and analysis will be reviewed by a qualified senior geologist or hydrogeologist.

One of the primary interferences is due to well construction. For wells screened across the water table, falling head tests may not provide accurate measures of hydraulic conductivity. Therefore, while falling head tests may be conducted in such wells, it may be inappropriate to use their results quantitatively unless the data analysis indicates that an accurate measurement of hydraulic conductivity has been obtained.

4.0 Equipment and Materials

General field supplies include the following items:

- Boring logs (if available)
- Well construction diagrams (if available)
- Well development logs (if available)
- Hydraulic Conductivity Test Log (example attached)
- Water level meter
- Slugs (if not using pneumatic methods) - diameter is dependent upon well diameter; the slug length is dependent on the length of the water column in the well but should provide a minimum of 1 foot displacement of the water column
- Pneumatic pump (if not using a slug)
- Nylon string
- Tape measure
- Pressure transducer(s) with cable/wire length sufficient to reach the target depth and to reach from the well to the field computer or handheld unit used to download the data.
- Data logger(s)

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- Computer with appropriate software
- Plastic sheeting
- Equipment decontamination supplies
- Health and safety supplies (as required by the HASP)
- Approved plans (e.g., HASP, SAP, QAPP)
- Field project logbook/pen

5.0 Procedures

5.1 General Preparation

The monitoring wells to be tested should have been previously developed and had sufficient time to equilibrate before the testing process proceeds. Well construction diagrams are necessary to determine the depth of the monitoring well and the screened interval.

The static water level in the well will be measured and recorded in the field logbook or field form. The slug diameter and length to be used in the well will be determined based on the diameter of the well and the length of the water column. In general, the larger the volume of the slug, the greater the displacement of head and the better the definition of response in the resulting data. However, *the slug must be short enough to be completely submerged beneath the static water level, and there must be room beneath the bottom of the slug for the transducer.* The slug length and diameter will be recorded in the field logbook and/or field form for use in the data analysis.

Either a pressure transducer connected to a data logger or a programmable down-hole data logger will be used to record the changes in water level during the test. The transducer must be set at a sufficient distance below the water surface so the slug does not disturb the transducer. After the water level has equilibrated to the static level, the data logger will be programmed according to manufacturer's instructions. The data logger will be programmed to record water levels at very short or logarithmically increasing intervals, because early-response data are important for the data analysis.

A measured length of nylon string will be tied to the slug. The line will be of a length that will allow the top of the slug to be submerged beneath the static water level without touching the transducer.

5.2 Falling Head Test

The slug will be lowered part way into the well so that the bottom of the slug is just above the water surface. The data logger will be started (note that data must be recorded before the slug enters the groundwater) and the slug will be simultaneously lowered into the water, so that the top of the slug is below the static water level. Care will be taken to lower the slug fast enough to produce as close to an instantaneous rise in the water level as possible, but not so fast as to produce a wave when the slug enters the water.

When the water level returns to the static level, the falling head test is complete and the rising head test can be started. The data should be saved and a new test set up on the data logger.

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If the hydraulic conductivity is low, it may take hours (or more) for the water level to return to static conditions. In this situation, the project hydrogeologist should determine a maximum duration for each test (typically 30 minutes).

The falling head test may not be accurate for wells with screens that bracket the stabilized water table. These tests may be performed in water table wells, but the results will not be used quantitatively unless the data analysis indicates that an accurate measurement of hydraulic conductivity has been obtained.

5.3 Rising Head Test

If necessary, the data logger may need to be reset following the falling head test. Then the rising head test will be started by activating the logger and simultaneously removing the slug. The slug will be quickly removed from the water so that an instantaneous drop in the water level will occur, but it will be done smoothly enough to not disturb the transducer when removing the slug. When the water has returned to a static condition or the maximum duration of time has elapsed (typically 30 minutes), the test will be terminated.

For this POP, two rising and two falling head tests will be conducted in each well being tested that is not a water table well. In the case where the well screen intersects the water table, three rising head tests will be conducted – no falling head tests will be performed in water table wells.

5.4 Pneumatic Test Procedure

Pneumatic slug tests are only to be conducted in wells that are not screened across the water table. The general steps to be performed during pneumatic slug testing are as follows:

- Static water level will be measured to the nearest 0.01 foot.
- A pressure transducer, attached to a data logger, will be placed into the well and the water level allowed to equilibrate to static conditions.
- The water column in the well will be pressurized while simultaneously measuring and recording water levels with the pressure transducer and data logger until the water level has equilibrated ("falling head test").
- The pressure in the well will then be rapidly removed and the water level will be measured and recorded ("rising head test").
- Slug testing data will be recorded on the Hydraulic Conductivity Test Log shown in Figure 5-2, or similar form.

The data from these tests will be analyzed by AQTESOLV[®] according to the Bouwer and Rice method (1989) or equivalent methods to calculate average hydraulic conductivity values for the aquifer.

5.5 Data Download

At the completion of the test(s), the data from the slug tests will be downloaded to a laptop computer or other electronic device. If feasible while in the field, this data will be plotted on a graph of time versus water level to see if it is acceptable (i.e., adequate water level displacement, sufficient number of data points, a straight-line fit to data, no extraneous fluctuations resulting from inadvertent slug

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movement and/or pressure waves). If the data are not acceptable, the test(s) will be repeated once water levels have stabilized.

5.6 Equipment Decontamination

All equipment that comes into contact with groundwater (e.g., slugs, transducer, and water level meter) will be decontaminated in accordance with POP 011 – Decontamination of Field Equipment before moving to the next location. The string should be properly discarded and disposed.

6.0 Quality Assurance / Quality Control

Quality assurance requirements typically suggest the collection of both the rising head and falling head data. Rising head data are preferred for wells screened across the water table because the hydraulic conductivity of the saturated portion of the aquifer is reflected, whereas falling head data may reflect the hydraulic conductivity of the unsaturated zone and capillary fringe.

For this POP, two rising and two falling head tests will be conducted in each well being tested that is not a water table well. In the case where the well screen intersects the water table, three rising head tests will be conducted – no falling head tests will be performed in water table wells.

For quality control purposes, the transducer data logging will be started immediately prior to lowering or removing the slug. The transducer should be activated approximately 1 second prior to ensure that the transducer is recording water level changes and that the transducer is taking readings at frequent intervals during the early part of the well response curve. Care must be taken when lowering or removing the slug to avoid splashing or generating wave effects that would obscure the early-time data.

Data from the rising and falling head tests should be inspected in graphical format to ensure that adequate water level displacement was achieved for both tests, that the data logger recorded all data from the test, and that no fluctuations exist in the data due to violent slug movement.

Both rising and falling head tests may be conducted to help draw attention to any inconsistencies in the data. If the rising and falling head results are not comparable, the data should be investigated to assess which test may more accurately reflect the hydraulic properties of the aquifer, or whether the pressure transducer recorded accurate data. Knowledge of the boring logs is essential to assessing whether the measured response is consistent with the expected response. If a consistent response is not obtained, the tests should be run again.

7.0 Data and Records Management

7.1 Data Analysis

The Monitoring Well Development Record (Figure 2) will be completed by the geologist or Several methods are available for analyzing data obtained from in-situ hydraulic conductivity tests. Most

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methods incorporate graphical techniques, such as semi-log and log-log plots, to evaluate the data and select values for the calculations.

Inherent in the analytical methods are several simplifying assumptions concerning the aquifer properties and test methods. When selecting a particular analytical method, it is important to consider the basic assumptions that underlie the mathematical expressions. In many cases, it may be advisable to evaluate the data using several methods and examine the range of hydraulic conductivity values that are obtained. For this project, it is expected that the data will be analyzed using appropriate methodologies (e.g., Bouwer and Rice, 1976; Hvorslev, 1951; Cooper, et al, 1967).

7.2 Records Management

The Hydraulic Conductivity Test Log (example attached) will be completed by the field personnel conducting the slug testing. Background information such as well diameter, depth, and screened interval will be provided from existing monitoring well construction logs. These data will be used in the calculation of hydraulic conductivity, based on the test data. The slug length, slug diameter, water level, well identification number, test type (rising or falling), file name, and time will also be recorded. The actual data of time versus water level will be recorded on the data logger and transferred to a laptop computer or other electronic device. In addition, a field project notebook should be maintained detailing any problems or unusual conditions that may have occurred during the testing process.

The records generated in this procedure will become part of the permanent record supporting the associated field work. All documentation will be retained in the project files following project completion.

8.0 Personnel Qualifications and Training

Field personnel conducting permeability tests should be experienced geologists familiar with the theory and practice of aquifer testing and analysis, as well as with all necessary equipment and software. Geologists or personnel with geologic experience should supervise hydraulic conductivity testing.

Field personnel must be health and safety certified as specified by the Occupational Safety and Health Administration (OSHA) (29 CFR 1910.120(e)(3)(i)) to work on sites where hazardous materials may be present.

It is the responsibility of the field personnel to be familiar with the hydraulic conductivity testing procedures outlined within this POP, quality assurance, and health and safety requirements outlined within the Quality Assurance Project Plan (QAPP) and the HASP. Field personnel are responsible for the proper testing procedures, decontamination of equipment, as well as proper documentation in the field logbook or field forms (if appropriate).

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9.0 References

Bouwer, H and RC Rice. 1976. A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research, Vol. 12, pp. 423-428.

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POP 011 – Decontamination of Field Equipment. Revision 0, September 2013.

10.0 Revision History

Revision	Date	Changes
0	September 2013	Original POP

Project Operating Procedure

Slug Testing



POP-016

Revision: 0

Date: September 2013

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Figure 1. Example Hydraulic Conductivity Test Log (Page 1)

Well ID: _____

HYDRAULIC CONDUCTIVITY TEST LOG

Client: _____	Date: _____	Time: Start _____ am/pm
Project No: _____		Finish _____ am/pm
Site Location: _____		
Weather Conds: _____	Tester (s): _____	

1. WELL INFORMATION

a. Ref. Point Elev. _____	e. Total Well Depth _____	i. Screen Length _____
b. Static Depth to GW _____	f. Gravel Pack Diameter _____	j. Geology of Screened Interval _____
c. Time of GW reading _____	g. Water Column Height _____ (e-b)	_____
d. Static GW Elev. (Ho) _____ (a-b)	h. Casing Diameter _____	_____

2. SLUG INFORMATION (see back for volume calculation)

a. Slug Length _____
b. Slug Diameter _____

3. DATA COLLECTION

a. Method of Data Collection: Manual _____ (see back) Electronic _____	
b. Transducer Information	c. Data Logging Information
Make _____	Make _____
Model _____	Model _____
Serial Number _____	Serial Number _____
Offset _____	Mode _____ (linear or logarithmic)
Linearity _____	Ref. Point (designation) _____ (TOC, Ground Surface, actual elev.)
Scale _____	Ref. Point value (if elev.) _____
Coefficient _____	Positive numbers indicate <u>increase</u> or <u>decrease</u> in water level
Diameter/Length _____	(circle one)

4. HYDRAULIC TEST INFORMATION

Start Time	Test Type (rising, falling)	Electronic File Name	Comments	End Time
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

5. MANUAL WATER LEVEL READINGS (as needed for control)

Time	Location	Depth to Water	Time	Location	Depth to Water
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Signature _____ Date _____

Project Operating Procedure

Slug Testing

Figure 2. Example Hydraulic Conductivity Test Log (Page 2)

6. EXPECTED WATER LEVEL DISPLACEMENT CALCULATION (optional)

- a. Diameter of Slug (in) _____
- b. Length of Slug (ft) _____
- c. Volume/Linear ft of Slug (gal/ft from chart) _____
- d. Volume of Slug (gal) _____ (b*c)
- e. Diameter of Well (in) _____
- f. Volume/Linear ft of Well (gal/ft from chart) _____
- g. Expected Change in Water Level _____ (d/f)

Volume / Linear Ft. of Pipe		
Diam. (in)	Gallon	Liter
0.25	0.0025	0.0097
0.375	0.0057	0.0217
0.5	0.0102	0.0386
0.75	0.0229	0.0869
1	0.0408	0.1544
1.25	0.0637	0.2413
1.5	0.0918	0.3475
2	0.1632	0.6178

Note: Water column height (1-g from front page) must be greater than transducer length plus length of slug.

7. MANUAL WATER LEVEL MEASUREMENTS

[illegible]

Appendix C

Stone Environmental – VOCs in Rock Core SOPs

STANDARD OPERATING PROCEDURE**SEI-10.15.10*****THE DETERMINATION OF VOLATILE ORGANIC COMPOUNDS BY GAS
CHROMATOGRAPHY / MASS SPECTROMETRY (GC/MS)
(SW846 USEPA METHOD 8260C)***

SOP Number: SEI-10.15.10

Date Issued: 08/19/04

Revision Number: 10

Date of Revision: 09/03/13

1.0 OBJECTIVE/

This method, based on SW846 USEPA Method 8260C for the analyses of volatile organic compounds, is designed to measure the concentration of specified volatile organic compounds (VOCs) in water, soil and air samples using solid phase micro-extraction (SPME) and a Gas Chromatograph equipped with a capillary column and mass spectrometer. Specific VOCs of interest are outlined in Table 1.

2.0 SUMMARY OF METHOD

This method provides gas chromatographic conditions for the detection of certain aromatic and chlorinated VOCs. Soil and water samples are prepared in 20 mL extraction vials. The SPME fiber is then exposed to the headspace above the sample for a set number of minutes while the sample is agitated via either stirring or orbital shaking. Air samples are collected in Tedlar bags and the SPME fiber is exposed directly to the sample through the syringe septum. The exposure time must be consistent for all standards and samples (typically six or eight minutes) which is accomplished using an autosampler. The absorbed analytes are thermally desorbed from the SPME fiber in the injection port of a Gas Chromatograph and transferred to a narrow bore capillary column. A temperature program is used to enhance separation as the analytes are carried through the column to the ion source of the mass spectrometer. The ionized molecules are focused and separated according to their mass/charge (m/z) ratio by a quadrupole analyzer. The signal is amplified by an electron multiplier and interpreted by the mass spectrometer data system to produce a total ion or selected ion chromatogram and mass spectra for every point on the chromatogram. The instrument's mass spectrometer can be set in scan mode or selective ion monitoring mode (SIM). SIM mode is typically used to achieve lower reporting limits for the VOAs of interest.

This method is suitable for analysis of air, and water, and soils and wastes extractable in methanol.

Soil and waste samples are collected in approximately 10-12 gram cores directly into methanol (10 mL) in 40 mL VOA vials. Subsequent to sample collection, the methanol/solid mixture is agitated to break up the solids. Following this extraction step, an aliquot of the methanol is diluted into analyte-free water and is further extracted via the headspace SPME technique. Water samples are collected in 40 mL VOA vials with

no headspace. All methanol extracted solids and water samples are analyzed as waters on the GC/MS system as required in method 8260C.

This method is based on USEPA 8260C, *Volatile Organic Compounds by Gas Chromatography Mass Spectrometry (GC/MS)* and ASTM Method D6520, *Solid Phase Micro-extraction of water and its headspace for analysis of Volatile and Semi-volatile Organic Compounds*.

3.0 DEFINITIONS

Accuracy: the degree of agreement between a measurement and true or expected value, or between the average of a number of measurements and the true or expected value.

Batch: environmental samples, which are prepared and/or analyzed together with the same process, using the same lot(s) of reagents. A preparation batch is composed of one to 20 environmental samples of a similar matrix, meeting the above-mentioned criteria.

Corrective Action: action taken to eliminate the causes of an existing non-conformance, defect or other undesirable situation in order to prevent recurrence.

Demonstration of Capability (DOC): procedure to establish the ability to generate acceptable accuracy and precision.

Instrument Blank: a blank matrix that is the same as the processed sample matrix (i.e. extract, digestate, condensate) and introduced onto the instrument for analysis. Analyzed typically as a fiber blank.

Laboratory Duplicate: Aliquots of a sample taken from the same container under laboratory conditions and processed and analyzed independently. (NELAC)

Limit of Detection (LOD): An estimate of the minimum amount of a substance that an analytical process can reliably detect. An LOD is analyte- and matrix-specific and may be laboratory-dependent. (DOD QSMV4.2)

Limit of Detection (Clarification): The smallest amount or concentration of a substance that must be present in a sample in order to be detected at a high level of confidence (99%). At the LOD, the false negative rate (Type II error) is 1%. (DOD QSMV4.2)

Limits of Quantitation (LOQ): The minimum levels, concentrations, or quantities of a target variable (e.g., target analyte) that can be reported with a specified degree of confidence. (DOD QSMV4.2)

Limit of Quantitation (Clarification): The lowest concentration that produces a quantitative result within specified limits of precision and bias. For DoD projects, the LOQ shall be set at or above the concentration of the lowest initial calibration standard.

Laboratory Control Sample (LCS): a blank matrix spiked with a known amount of analyte(s), processed simultaneously with, and under the same conditions as, samples through all steps of the analytical procedure.

Matrix: the substrate of a test sample.

Matrix Duplicate (MD): duplicate aliquot of a sample processed and analyzed independently; under the same laboratory conditions; also referred to as Sample Duplicate; Laboratory Duplicate.

Matrix Spike (MS): field sample to which a known amount of target analyte(s) is added.

Matrix Spike Duplicate (MSD): a replicate matrix spike.

Method Blank: a blank matrix processed simultaneously with, and under the same conditions as, samples through all steps of the analytical procedure.

Precision: an estimate of variability. It is an estimate of agreement among individual measurements of the same physical or chemical property, under prescribed similar conditions.

Method Detection Limit: One way to establish a Limit of Detection, defined as the minimum concentration of a substance (an analyte) that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. (DOD QSMV4.2)

Method Detection Limit (MDL) (Clarification): The MDL is one way to establish a Detection Limit, not a Limit of Detection. (DOD QSMV4.2)

Nonconformance: An indication or judgment that a product or service has not met the requirement of the relevant specifications, contract, or regulation; also the state of failing to meet the requirements. (DOD QSMV4.2)

Precision: The degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves; a data quality indicator. Precision is usually expressed as standard deviation, variance or range, in either absolute or relative terms. (NELAC)

Preservation: Refrigeration and/or reagents added at the time of sample collection (or later) to maintain the chemical and/or biological integrity of the sample. (NELAC)

Proficiency Testing: A means of evaluating a laboratory's performance under controlled conditions relative to a given set of criteria through analysis of unknown samples provided by an external source. (NELAC) [2.1]

Quality Assurance (QA): an integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

Quality Control (QC): the overall system of technical activities, the purpose of which is to measure and control the quality of a product or service.

Quality Control Sample: a control sample, generated at the laboratory or in the field, or obtained from an independent source, used to monitor a specific element in the sampling and/or testing process.

Quantitation Limit (QL): the minimum amount of a substance that can be quantitatively measured with a specified degree of confidence and within the accuracy and precision guidelines of a specific measurement system. The QL can be based on the MDL, and is generally calculated as 3-5 times the MDL, however, there are analytical techniques and methods where this relationship is not applicable. Also referred to as Practical Quantitation Level (PQL), Estimated Quantitation Level (EQL), Limit of Quantitation (LOQ).

Quantitation Range: The range of values in a calibration curve between the LOQ and the highest successfully analyzed initial calibration standard. The quantitation range lies within the calibration range. (DOD QSMV4.2)

Raw Data: Any original factual information from a measurement activity or study recorded in a laboratory notebook, worksheets, records, memoranda, notes, or exact copies thereof that are necessary for the reconstruction and evaluation of the report of the activity or study. Raw data may include photography, microfilm or microfiche copies, computer printouts, magnetic media, including dictated observations, and recorded data from automated instruments. If exact copies of raw data have been prepared (e.g., tapes which have been transcribed verbatim, data and verified accurate by signature), the exact copy or exact transcript may be submitted. (EPA-QAD)

Reporting Limit (RL): The level to which data is reported for a specific test method and/or sample. The RL is generally related to the QL. The RL must be minimally at or above the MDL.

Requirement: Denotes a mandatory specification; often designated by the term "shall". (NELAC)

Retention Time: The time between sample injection and the appearance of a solute peak at the detector. (Skoog, West, and Holler. Fundamentals of Analytical Chemistry. 1992)

Sample: Portion of material collected for analysis, identified by a single, unique alphanumeric code. A sample may consist of portions in multiple containers, if a single sample is submitted for multiple or repetitive analysis. (DOD QSMV4.2)

Sample Delivery Group: A unit within a given project that is used to identify a group of samples for delivery. An SDG is a group of samples of certain size, generally not to exceed 100 samples for the purposes of this laboratory.

Selectivity: (Analytical chemistry) The capability of a test method or instrument to respond to a target substance or constituent in the presence of non-target substances. (EPA-QAD)

Selective Ion Monitoring: A configuration of the mass spectrometer in which the intensities of several specific ion beams are recorded rather than the entire mass spectrum.

Sensitivity: The capability of a method or instrument to discriminate between measurement responses representing different levels (e.g., concentrations) of a variable of interest. (NELAC)

Shall: Denotes a requirement that is mandatory whenever the criterion for conformance with the specification requires that there be no deviation. This does not prohibit the use of alternative approaches or methods for implementing the specification so long as the requirement is fulfilled. (ANSI)

Should: Denotes a guideline or recommendation whenever noncompliance with the specification is permissible. (ANSI)

Signal to Noise Ratio: The signal carries information about the analyte, while noise is made up of extraneous information that is unwanted because it degrades the accuracy and precision of an analysis and also places a lower limit on the amount of analyte that can be detected. In most measurements, the average strength of the noise is constant and independent of the magnitude of the signal. Thus, the effect of noise on the relative error of a measurement becomes greater and greater as the quantity being measured (producing the signal) decreases in magnitude. (Skoog, Holler, and Nieman. Principles of Instrumental Analysis. 1998)

Spike: a known amount of an analyte added to a blank, sample or sub-sample.

Standard: (Document) The document describing the elements of laboratory accreditation that has been developed and established within the consensus principles of NELAC and meets the approval requirements of NELAC procedures and policies. (ASQC)

Standard: (Chemical) Standard samples are comprised of a known amount of standard reference material in the matrix undergoing analysis. A standard reference material is a certified reference material produced by the US National Institute of Standards and Technology (NIST) and characterized for absolute content, independent of analytical test method.

Standard Method: A test method issued by an organization generally recognized as competent to do so.

Standard Operating Procedure (SOP): a written document which details the method of an operation, analysis or action whose techniques and procedures are thoroughly prescribed and which is accepted as the method for performing certain routine or repetitive tasks.

SPME – Solid Phase Micro Extraction

Surrogate: A substance with properties that mimic the analyte of interest. It is unlikely to be found in environment samples and is added to them for quality control purposes. (QAMS)

Target Analytes: Analytes specifically named by a client (also called project-specific analytes). (DOD QSMV4.2)

Technical Director: Individual(s) who has overall responsibility for the technical operation of the environmental testing laboratory. (NELAC)

Tedlar Bag – Inflatable sample container, used to trap air samples for analysis, equipped with a Teflon[®]-lined syringe septum that allows a SPME fiber to come in contact with the air sample.

Traceability: The property of a result of a measurement whereby it can be related to appropriate standards, generally international or national standards, through an unbroken chain of comparisons. (VIM - 6.12)

Tuning: A check and/or adjustment of instrument performance for mass spectrometry as required by the method.). (DOD QSMV4.2)

VOC – Volatile Organic Compounds

QA/QC – Quality Assurance/Quality Control

4.0 INTERFERENCES

When analyzing for VOCs, samples can be contaminated by diffusion of volatile organics (particularly chlorofluorocarbons, acetone, toluene, and methylene chloride) through the sample container septum during

shipment and storage. A trip blank can be used as a check on this type of interference. However, a trip blank is not usually required if the analyses are being conducted onsite. A trip blank is prepared from analyte-free reagent water and carried through sampling and subsequent storage and handling. Equipment and field blanks are typically used for on-site contamination samples.

Contamination by carryover can occur whenever high-concentration and low-concentration samples are analyzed in sequence. To reduce the potential for carryover, the sample syringe or purging device must be rinsed out between samples with an appropriate solvent. Whenever an unusually concentrated sample is encountered, it should be followed by injection of a method blank or instrument blank to check for cross contamination.

Purging vessels and syringes should be adequately cleaned and flushed prior to use. All glassware must be kept scrupulously cleaned. Clean all glassware as soon as possible after use by rinsing with the last solvent used or analyte-free water. Store clean dry glassware in a clean environment.

5.0 SAFETY ISSUES

1. Laboratory personnel should take extra care when working with standards. When working with neat standards, make certain that there is adequate ventilation and that Nitrile or Latex gloves are worn and if necessary, safety glasses.
2. If necessary and appropriate, a site-specific health and safety plan shall be created for each study site and followed.
3. Field visits may involve accessing remote areas. Health and safety concerns regarding these field visits are minimal, however, hazards such as slip, trip and falls, poisonous plant and dangerous animals, as well as getting vehicles stuck in remote areas, do present considerable health and safety issues. To help ensure field staff's health and safety in remote areas, all field staff are to have daily communication with the project manager or another appropriate SEI employee.
4. All chemicals are required to be received with a Material Safety Data Sheets (MSDS). MSDSs shall be made available to all personnel involved in the sampling and testing.

6.0 EQUIPMENT AND SUPPLIES

General maintenance shall be conducted proactively to minimize the down time associated with equipment failure and to maintain the highest degree of data quality. This shall be accomplished through scheduled and symptomatic maintenance. Examples of symptomatic maintenance, in which the chromatography is monitored, include cleaning of inlet, replacement of septa and liner and mass spectrometer source cleaning. Examples of scheduled maintenance include replacement of diffusion and rough pump oils. All maintenance conducted on equipment shall be documented in the instrument maintenance logs. The primary pieces of instrumentation for the laboratory are listed below.

1. Gas Chromatograph: Analytical system complete with gas chromatograph and all required accessories, column supplies, gases, syringes and data system to determine peak areas and perform integrations. Hewlett Packard 5890 Series II.
2. Mass Spectrometer: Hewlett Packard 5971 MSD.
3. Typical Analytical Column: RTX-VMS 20m x 0.18mm ID, 1.0 μ m film or equivalent
4. SPME Autosampler: CTC Combi PAL
5. Array of micro-syringes: range 5-1000 μ L.
6. Balance: Top loading, capable of weighing accurately to 0.01 grams (soil samples only).
7. Sample introduction and preparation apparatus: SPME Fiber type 100 μ m polydimethylsiloxane (PDMS) and/or 85 μ m Carboxen/PDMS fiber, magnetic hot plate and magnetic stirrers, tube clamp and stand.
8. VOA vials: 40 mL collection containers with Teflon[®]-lined septum and either 24mL or 20mL extraction vials

7.0 REAGENTS AND STANDARDS

Reagents:

1. Analyte-free reagent water demonstrated to be free of compounds of interest (spring water, carbon filtered and/or deionized).
2. Purge and Trap Grade or equivalent grade methanol (demonstrated to be free of analytes and stored away from other solvents).

Stock standards:

Stock standards may either be prepared from pure standard materials or purchased as certified solutions. Secondary dilution standards are prepared using stock standard solutions, which contain the compounds of interest, either as single compounds or mixed together. Typically, for this method the stock standards are obtained from an approved vendor and mixed together. A certificate of analysis is retained by the laboratory and maintained on file or on file with the vendor. The aqueous standards are typically prepared at concentrations as listed in Section 9.0 and are prepared in accordance with Table 3 which is an Example of the Standard Preparation Calculation Sheet. Gas standards are purchased in mixtures of site-specific target analytes.

Calibration standards are prepared at a minimum of five to seven different concentrations levels for VOC analytes.

Stone's SOP No. SEI-4.7.n *Labeling, Preparation and Storage of Reagents, Solutions and Standards* provides procedures on properly labeling, preparing and storing of reagents and standards used in the mobile laboratory for analytical methods. This SOP should be reviewed by the analyst before labeling, preparing and storing standards within the mobile laboratory.

8.0 SAMPLE COLLECTION AND HANDLING

8.1 Sample Collection

1. Aqueous samples are collected in 40 mL Teflon[®]-lined septum VOA vials filled to ensure that no headspace is present. Upon receipt, and if multiple vials are presented for a given sample, the vials will be uniquely numerically labeled (with the numbers 1, 2, 3, etc.) and at the time of analysis this unique identifier will be recorded in the instrument's run log. If storage of these samples is expected to exceed seven days, aqueous samples should be preserved with hydrochloric acid (HCl) to a pH of < 2.
2. Soil and waste samples are collected in approximately 10-12 gram cores, and placed in 40 mL vials with 10 mL of methanol. Upon receipt, and if multiple vials are presented for a given sample, the vials will be uniquely numerically labeled (with the numbers 1, 2, 3, etc.) and at the time of analysis this unique identifier will be recorded in the instrument's run log. If required, a separate aliquot of soil from the sample location will be collected in a 40 mL vial (with no methanol preservative) for percent moisture determination.
3. Air samples are collected in Tedlar bags. Upon receipt, and if multiple bags are presented for a given sample, the bags will be uniquely numerically labeled (with the numbers 1, 2, 3, etc.) and at the time of analysis this unique identifier will be recorded in the instrument's run log. The analytes are concentrated on the SPME fiber by exposing the fiber directly to sample through the Teflon[®]-lined septum. Air samples must be analyzed within 3 days of collection.

8.2 Handling and Holding Times

1. Unpreserved water samples must be analyzed within 7 days of collection. Preserved (preserved with HCl to a pH of < 2) water samples must be analyzed within 14 days of collection. Soil samples collected in methanol must be analyzed within 14 days from collection. All samples shall be stored at < 6°C. Samples are allowed to come to room temperature just prior to analysis. All samples for this program are typically analyzed within one or two days from collection, therefore, holding times should not be a concern.
2. If samples were preserved and analyses are performed after 7 days from collection, pH determination (water samples only) should be performed. Once the sample aliquots have been taken from the VOA vial for analysis, the pH of the water sample must be determined. The purpose of the pH determination is to ensure that all VOA samples were acidified in the field. Test the pH by placing one or two drops of sample on the pH paper (do not add pH paper to the vial). Record the pH of each sample, and report these data on the runlog and in the SDG Narrative. No pH adjustment is to be performed.
3. If necessary, a separate soil sample aliquot will be collected in a 40 mL vial or equivalent for percent moisture content so that results can be adjusted for %moisture and reported as

dry weight rather than as received. Percent moisture is determined as follows: Percent Moisture Determination - Immediately after weighing the sample for analysis, weigh 5-10 g of the soil/sediment into a tared crucible. Determine the percent moisture by drying overnight at 105 °C. Monitor oven temperature daily in the Oven Temperature Log. If available, allow to cool in a desiccator before weighing. Concentrations of individual analytes will be reported relative to the dry weight of soil/sediment.

$$\text{Percent Moisture} = \frac{\text{Mass of wet sample (g)} - \text{Mass of dry sample (g)}}{\text{Mass of wet sample (g)}}$$

4. If samples are suspected to be of high concentration and are not to be immediately analyzed, they will be isolated in a separate cooler unit in the lab. If a separate cooler is not readily available in the lab, one will be purchased.

9.0 PROCEDURES

9.1 Typical GC Program

Oven Temp: 50°C (4.00 min) to 160°C at 15°C/min to 200°C at 40°C/min, hold for 1 min.

Flow Rate: Helium, 1.0 mL/min, 8 PSI, set at 45°C

Detector: MSD, SIM mode, ion masses range between 45-190 amu

Injector: 240°C, splitless (close 1.5 min)

Liner: 0.75 mm ID splitless/split injection port

9.2 GC Column

Column: RTX-VMS 20m x 0.18mm ID, 1.0 um film, equivalent

9.3 Material Preparation:

SPME: Fiber Type: 100 µm polydimethylsiloxane (PDMS).

SPME Fiber Type for low level waters or specialized project only: 85 µm Carboxen/PDMS

SPME Extraction: The SPME-absorbent polymer fiber is exposed to the headspace above a sample. The headspace is created by removing approximately 2 mLs from the 20 mL preparation vial. Salt and stir bar (if magnetic stirring is used) are added to the mixture and the sample is agitated for 6 or 8 minutes. The fiber is then retracted into the SPME holder and transferred to the GC injection port where the analytes are thermally desorbed and transferred to the head of the GC column. If used, each magnetic stirrer is rinsed three times with analyte free water prior to use. For soil samples; an aliquot of the methanol extract (typically 0.5mL but not more than 1 mL) is prepared in the 20 mL

water preparation vial, and prepared and analyzed in the same manner as a water sample above. For air samples, the SPME fiber is exposed directly to the same through the syringe septum located on the Tedlar bag. Preparation and exposure time of the fiber to the site samples is the same for all QC samples and calibration standards.

9.4 Operating Procedure

9.4.1 Tuning with 4-Bromofluorobenzene

The following ion abundances must be met before analysis of calibration standards, environmental samples and at the beginning of a 12-hour analytical sequence by analyzing BFB in a check standard, method blank or as a single injection:

BFB Key Ions and Ion Abundance Criteria	
Mass	Ion Abundance Criteria
50	15.0-40.0 percent of mass 95
75	30.0-60.0 percent of mass 95
95	base peak, 100 percent relative abundance
96	5.0-9.0 percent of mass 95
173	less than 2.0 percent of mass 174
174	>50.0 percent of mass 95
175	5.0-9.0 percent of mass 174
176	95.0-101.0 percent of mass 174
177	5.0-9.0 percent of mass 176

9.4.2 Calibration Criteria

9.4.2.1 Initial Calibration (ICAL):

1. Five to seven-point calibrations for VOC compounds using a SIM configuration is typically as follows: 2, 5, 10, 20, 50, 100, 200 ppb. (Scan calibrations are determined as needed by the client's program; options: 5, 10, 50, 150, 200 or 500) The low standard must be set at the quantitation limit (QL) or LOQ. A typical calibration range for air (ppb_{v/v}) will be similar to that of water and will be chosen on a site specific basis.
2. Calibration range must encompass the expected sample concentrations; therefore, if site samples are expected to be higher in concentration than the calibration range, adjustments to the calibration range and samples will be documented and made accordingly.
3. The linearity of the calibration curves must be assessed and are used for all quantitation. Volatile organic compounds in soil and water use an internal standard

procedure (internal standards; fluorobenzene and chlorobenzene-d5). Average response factors are used for quantitation and the average relative standard deviation (%RSD) of each compound must be $\leq 20\%$. Depending upon the field on-site program, 25% RSD may be acceptable based on the on-site data quality objectives. Linear least squares regression must be $r > 0.995$

4. Non-linear regression coefficient of determination (COD) must be $r^2 > 0.99$ (a minimum of 6 points shall be used for second order, 7 points for third order).

For DoD Projects (DOD QSM4.2, Table F-4), one of the following must be true for each analyte in the calibration:

- % RSD for each analyte must be $\leq 20\%$ as updated to Method specification for 8260C
- Linear least squares regression must be $r \geq 0.995$
- Non-linear regression coefficient of determination (COD) must be $r^2 \geq 0.99$ (a minimum of 6 points shall be used for second order, 7 points for third order).

Note: The average response factor requirements are only for 8260B and were not included in 8260C, therefore, for DOD projects the laboratory will follow the updated method. (The average response factor requirement will be ≥ 0.30 for chlorobenzene and 1,1,2,2-tetrachlorethane, and ≥ 0.1 for chloromethane, bromoform, and 1,1-dichloroethane (SPCCs). % RSD must be $\leq 30\%$ for CCCs if analyzing for 8260B only).

5. VOCs in air use an external calibration procedure. Linear regression is used for quantitation and the correlation coefficient of each compound must be greater than 0.99

9.4.2.2 Continuing Calibration (CCV):

1. A mid-point continuing calibration verification standard for VOC compounds (20 ppb or 50ppb) must be analyzed every 12 hours, prior to sample analysis in order to verify the initial calibration. A percent difference between the expected concentration and actual concentration is calculated. The percent difference (%D) values for each compound must be less than or equal to 20%.

$$\%D = \frac{\text{ExpectedConcentration} - \text{ActualConcentration}}{\text{ExpectedConcentration}}$$

The CCV may also be used to demonstrate that the BFB criteria shown in 10.4.1 have been met when operating in scan mode.

9.4.2.3 Initial Calibration Verification Standard (ICV):

A QC sample from a second (independent) source will be analyzed directly after the ICAL. The ICV sample will contain all the VOC compounds of interest at the mid-point (20-100 ppb or 5 ppb for low level waters). Recovery Limits for the ICV will be 70-130%, if compounds are determined to be poor performers then the recoveries shall be 60-140% for the ICV.

$$\% \text{Recovery} = \frac{\text{Actual Concentration}}{\text{Expected Concentration}}$$

For DoD projects, all project analytes must be within 80-120% (DoD QSM 4.2, Table F-4).

9.4.3 Retention Time Windows and Pattern Recognition

The laboratory shall identify single component target analytes by comparison of its mass spectrum to a reference spectrum. The retention time for each analyte should be within ± 0.04 minutes (DOD QSM4.2, Table F-4 allows ± 0.06 minutes) from the ICAL or daily CCV.

9.4.4 Internal Standard Response

The internal standard areas for a window shall be evaluated based on the following criteria:

- 1) CCV area for a given window is evaluated based on the value that was observed in the midpoint of calibration curve. The internal standard areas of a CCV shall be not less than $\frac{1}{2}$ nor greater than two times the area of mid point of the calibration curve.
- 2) Samples and QC samples run within this same window are evaluated against the CCV that was used to open this window. The internal standard areas shall be not less than $\frac{1}{2}$ nor greater than two times the area of the CCV.

For DoD projects (DOD QSM4.2, Table F-4) all samples (field and QC) are evaluated against the midpoint of the calibration curve.

9.4.5 Sample Preparation:

Water samples: An aliquot of sample, sufficient to get the highest concentration constituents into the upper half of the linear range, is transferred to a 20 mL extraction vial which contains approximately $\frac{1}{4}$ tsp. salt. The vial is then spiked with the surrogate (bromofluorobenzene between 4.17 and 41.67 ppb) and internal standards (fluorobenzene and chlorobenzene-d5 between 4.17 and 41.67 ppb). Invert the vial a few (approximately 3)

times and remove approximately five mLs and place the vial on the autosampler tray. The autosampler tray is then placed on the CTC autosampler and set for analysis in accordance with the CTC specifications. At that point the CTC autosampler agitates the sample and the SPME fiber is then exposed to the headspace (headspace created by removing approximately 5 mL from preparation vial) above the sample for 6 or 8 minutes while the sample is agitated. The 6 or 8 minutes is measured by the autosampler. Extraction time may be modified depending on the anticipated equilibration response of the target analytes at given concentrations (if adjusted samples and standards would be adjusted).

Soil samples: Preserved in methanol; 10-12 g core of soil is added to 10 mL of methanol containing an appropriate amount of bromofluorobenzene. Subsequent to sample collection, the methanol/soil mixture is agitated to break up the solids. The level of agitation shall be sufficient enough so that the solids are completely disaggregated as to maximize the contact between the methanol and the soil surfaces. This is typically achieved within 10 minutes using an aggressive orbital shaking procedure. Following this extraction step, an aliquot of the methanol, sufficient to get the highest concentration constituents into the upper half of the linear range but not to exceed 2 mLs, is diluted into analyte-free water and this water/methanol mixture is further extracted via the headspace SPME technique in the same manner as a water sample.

Air samples: Exposure of the SPME fiber to the air sample occurs directly through the syringe septum in the Tedlar bag. Exposure time, measured using a bench-top timer, may be modified depending on the anticipated equilibration response of the target analytes at given concentrations. There is no surrogate or internal standard for air sampling.

9.4.6 *Surrogate (SS) and Internal Standard (ISTD) Compounds for VOC compounds*

Compound	Amount Spiked
Bromofluorobenzene (SS)	Range: 4.17 to 41.67 ppb
Fluorobenzene (ISTD)	Range: 4.17 to 41.67 ppb
Chlorobenzene-d5 (ISTD)	Range: 4.17 to 41.67 ppb

9.4.7 *LCS Preparation*

Waters are spiked at around the mid-point of the calibration. Different spike amounts may also be used based on project specific needs or if LOD determinations are considered.

For the soils program, the soil LCS will be prepared in the same manner as the soil samples, an aliquot (0.5 mL or 1.0 mL) of methanol will be prepared in the SPME preparation vial, spiked with VOCs of interest, and prepared in the same manner as the soil MS/MSD assuming 10 gms of solid and 100%solid. The spike amount will be

around the mid-point of the calibration. Different spike amounts may also be used based on project specific needs

9.4.8 Matrix Spike and Matrix Spike Duplicate (MS/MSD) Compounds:

For water samples the MS in SIM configuration will be spiked at 20 ppb; the amount may change to account for the concentration of a particular analyte found in the sample being analyzed as a MS. For soil samples, an appropriate amount of the target analytes are spiked into the 10 mL of methanol. Matrix Spike Analyses contain the VOC compounds of interest in the same manner as the LCS.

9.4.9 Target Compound List

An example Target Compound List with Quantitation Limits can be found on Table 1.

10.0 CALCULATIONS

Identification of the project specific VOCs in the sample chromatogram is based on retention time and on comparison of the sample mass spectrum with characteristic ions in a reference mass spectrum. Retention times must be within ± 0.04 minutes from the ICAL. If a retention time shift is observed in the CCV or LCS, then adjustments to the daily retention time windows will be made accordingly. The relative intensities of the characteristic ions must agree within 30% of these ions in the reference spectrum. Quantification of the VOCs is determined by comparison to the internal standard and average response factor for the target ion of the analyte.

The concentration of each analyte in the sample may be calculated from response of the target ion and internal standard using the calibration curve. The calculations are as noted below.

Concentrations of Unknowns

We do not typically report TICs and in SIM mode TICs are not considered. However, Method 8260C in Scan mode does include guidelines for reporting of tentatively identified compounds (TICs). Refer to section 11.6.2 of 8260C for these guidelines if TICs are requested.

Concentrations of Calibrated Compounds (when RRF is used):

$$C_{(x)} = \frac{A_{(x)} * C_{(IS)}}{A_{(IS)} * RRF} * DF$$

Where:

$C_{(x)}$ = Concentration of compound ($\mu\text{g/L}$)

$C_{(IS)}$ = Concentration of associated internal standard ($\mu\text{g/L}$).

DF = Dilution Factor.

$A_{(IS)}$ = Area of quantitation ion for associated internal standard.

$A_{(x)}$ = Area of quantitation ion for compound.

RRF = Average Relative Response Factor from five-point initial calibration.

Note: for linear and quadratic equations see SW846 Method 8000C.

Data Reporting - Based on the mass spectra and the project specific field program, it is appropriate to report values between the MDL/Limit of detection (LOD) and the QL or LOQ. In this region, an analyte can be qualitatively detected, but not accurately quantified. Any data point reported in this region is flagged with a “J” (estimated) qualifier. Stone reports sample specific QL’s. Sample specific QL’s are derived by taking into account various sample specific data, which can include the amount of the sample subject to testing, % moisture, dilution factor, interferences and the base QL’s for the analysis.

Typical Reporting qualifiers are as follows:

B = Analyte is found in the associated method blank as well as the sample.

D = Compound is identified in an analysis at a secondary dilution factor.

E = Compound quantitation is above the instrument's calibration range for this analysis.

J = Indicates an estimated quantitation value.

Q = One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery or CCV).

U = Compound was analyzed for but not detected. Value reported is the method LOQ.

11.0 QUALITY CONTROL AND CORRECTIVE ACTION

11.1 Limit of Detection Studies

Limit of Detection (LOD) studies must be completed initially for each method, matrix and instrument and then verified quarterly for each method, lab and matrix. The initial LOD study is the same as the MDL study. LOD verifications are accomplished by running a spiked standard at a value that is greater than 1 to 4 times the LOD. Since we have a range of LODs, there will likely have to be several LOD verifications analyzed to encompass the range of anticipated LODs..

11.2 Limit of Quantitation

Limit of Detection (LOQ) studies must be completed initially for each method, matrix and instrument and then verified quarterly for each method, instrument and matrix. The initial LOQ study is conducted by running the low point of the calibration curve back through the curve once the curve is built in the data analyses software. A successful study is one where the recovery of each analyte is within the established test method acceptance criteria or client data

quality objectives for accuracy. The LOQ results must be within the limits of the DOD's limits for LCS recoveries, as stated in Table 2.

11.3 Measurement of Uncertainty

Measurement of Uncertainty studies must be completed initially for each method, matrix and instrument and then verified quarterly for each method, instrument and matrix. These are accomplished by looking at the deviation of recovery for each analyte in an LCS. For example, a recovery of 97% would have a 3% uncertainty associated with it.

11.4 Instrument Blank (SPME Fiber Blank)

To be performed once daily at the start of the analytical day. All target analyte areas detected in the instrument blank must be less than one-half the area of the analyte at the PQL value prior to continuing.

11.5 MS Tuning - 4-Bromofluorobenzene

To be performed every 12 hours, at the start of the analytical day and before beginning acquisition of a calibration curve. Criteria can be found in section 9.4.1.

11.6 Initial Calibration

See section 9.4.2.1 for the specific criteria for initial calibrations.

11.7 Continuing Calibration Verification

See section 9.4.2.2 for specific criteria for the CCV.

11.8 Method Blank

One per analytical batch (12 hours or 20 samples) directly after the calibration standard and after highly contaminated samples to demonstrate that there is no carry over into subsequent samples. All target analyte concentrations detected in the method blank must be less than one-half the PQL value prior to continuing.

For DoD projects, the method blank will be considered to be contaminated if:

- The concentration of any target analyte in the blank exceeds $\frac{1}{2}$ the reporting limit **and** is greater than $\frac{1}{10}$ the amount measured in any sample or $\frac{1}{10}$ the regulatory limit (whichever is greater);
- The concentration of any common laboratory contaminant in the blank exceeds the reporting limit **and** is greater than $\frac{1}{10}$ the amount measured in any sample or $\frac{1}{10}$ the regulatory limit (whichever is greater); or

- The blank result otherwise affects the samples results as per the test method requirements of the project-specific objectives.

If the method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the limit of detection (LOD). If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

11.9 Surrogate Standards

Surrogate recoveries should be 70-130 % in water samples and 60-140 % in soil samples. Samples with surrogate recoveries falling outside of quality control limits should be reanalyzed once. If the sample in question has associated QC (i.e. duplicate or MS/MSD), and the surrogate recoveries for these QC samples fail in a similar manner, the parent (original) sample and the associated QC samples do not have to be re analyzed for verification. If the reanalysis of the sample is also outside the quality control limits, then it will be determined that the problem may be associated with the sample matrix and noted as such.

For DoD projects, the acceptance limits for water and soil samples (for 4-Bromofluorobenzene as a surrogate are 75-120%.

11.10 Internal Standards

See section 9.4.4 for details regarding the evaluation of the internal standard.

11.11 Initial Calibration Verification Standard (ICV)

See section 9.4.2.3 for details regarding the evaluation of the initial calibration verification standard.

11.12 Laboratory Control Sample (LCS)

LCS samples shall be prepared according to section 9.4.7.

Recovery limits for the LCS for water and soils samples are 70-130% and 60-140% for poor performers and compounds not listed in Table 1. These shall be analyzed on the frequency of one per analytical batch.

For DoD projects, all target analytes must be spiked in the LCS. Recovery limits are specified in Table 2. For those compounds not listed in Table 2, the recoveries shall be 60-140% for water and soils. If outages are realized and reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) affected by the QC outage for both detections and nondetections in all samples in the associated preparatory batch.

11.13 Matrix Spike and Matrix Spike Duplicate (MS/MSD) Analysis

An MS/MSD analysis is required every set of twenty samples or as specified by the client. A sample may be chosen by the client to perform a MS/MSD analysis.

Recovery Limits for the MS/MSD are 70-130% (60-140% for poor performers) for water and soil samples. RPD for water and soils shall be 30% and 50%, respectively.

For DoD projects, MS/MSD recoveries are listed in Table 2. RPD for water and soils shall be 30%. All target analytes must be spiked in the MS/MSD samples. If a MS/MSD sample is not available for analyses within a given window, a laboratory control standard duplicate (LCSD) shall be analyzed within the batch. This LCSD shall be evaluated using the same criteria (for precision and accuracy) as that of the MS/MSD.

$$\% \text{Recovery} = \frac{\text{Sample Spiked Concentration} - \text{Un-Spiked Sample Concentration}}{\text{Spiked Concentration}}$$

11.14 CORRECTIVE ACTION

<i>Quality Control Check</i>	<i>Minimum Frequency</i>	<i>Acceptance Criteria</i>	<i>Corrective Action</i>
Initial Calibration (ICAL)	ICAL prior to sample analysis.	Minimum of five to six points for VOCs. Minimum RRF and Maximum %RSD on Table 1 or a correlation factor (R or R ²) of 0.99 for other curve types. Air calibration's linear regression should have correlation factor of 0.99. Max %RSD for DoD projects is 20% as specified in 8260C update.	Verify solution integrity and check instrument performance. Perform necessary maintenance and recalibrate instrument. Reanalyze all affected samples.
Initial Calibration Verification (ICV) and/or Laboratory Control Sample (LCS) and Laboratory Control Sample Duplicate (LCSD)	One ICV per calibration (following acceptable ICAL). One LCS per analytical batch. For DOD projects, an LCD is required if there not an MS/.MSD pair in the analytical batch.	QC limits are 70 to 130%, 60 to 140% for poor performers for target compounds in water and soil analyses. This same standard may be used as the daily LCS in which the QC limits are set to 70-130% for target compounds and 60-140% for poor performers. All analytes for air analyses should be within 60-140%. For DoD projects, the ICV Recovery Limits will be 80-120%. This sample may also be used as the laboratory control sample (LCS) if the DoD limits in Table 2 are met.	Reanalyze once; if still out verify solution integrity or ICAL solution integrity, and instrument performance. Re-prepare and reanalyze all associated samples.

Quality Control Check	Minimum Frequency	Acceptance Criteria	Corrective Action
		Note: Limits may be adjusted based on the program.	
Retention Time (RT) Window Study	Every new column installation/per ICAL	All target compounds and surrogates in all standards must fall within the established window of ± 0.04 minutes from ICAL	Perform system maintenance. Reanalyze affected samples.
Continuing Calibration Verification (CCV)	Daily before sample analysis and every 12 hours of analysis time.	See Section 9.0. $\pm 20\%D$ for VOCs in water and soils programs. $\pm 30\%D$ for VOCs in air program.	Verify solution integrity and instrument performance. Reanalyze standard once, if still out, recalibrate and reanalyze affected samples. Based on project specific objectives, marginal exceedances may be allowed. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in samples that are affected in the batch.
Method Blanks	One per preparation batch	Target Compounds < one-half reporting limit. See section 11.4 above for DOD criteria.	Investigate source of contamination. Re-prepare and reanalyze all associated samples. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.
Matrix Spike (MS) and Matrix Spike Duplicate (MSD)	One set per 20 samples of a similar matrix or as specified by the Client.	Recovery Limits for the MS/MSD are 70-130% and 60-140% for poor performers. RPD not to exceed 30% for waters and RPD not to exceed 50% for soil samples. For DoD projects, acceptable recoveries are specified in Table 2 and for compounds not in Table 2 the limits will be 60-140%. RPD not to exceed 30% for waters and soils.	Reanalyze only if recoveries indicate analytical error. If LCS or ICV are acceptable, narrate as possible matrix effect. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and put in the case narrative.
Tuning – 4-Bromofluorobenzene	every 12 hours or at the start of a new analytical batch, and before acquisition of a new	See section 9.4.1. Not applicable for air program.	Reanalyze once, if still out, MS should be retuned and adjusted to meet all criteria before continuing

Quality Control Check	Minimum Frequency	Acceptance Criteria	Corrective Action
	calibration curve		
Surrogate Recovery	Each sample	70-130% in water and 60-140% for soil samples For DOD projects 75-120% for water and soil samples	Rerun the sample once, if still out verify the solution integrity and instrument performance. Apply Q-flag or other flag to all associated analytes if acceptance criteria are not met.
Internal Standard Verification	Every field sample, standard, and QC sample.	Retention time $\pm$ 30 seconds from retention time of the midpoint standard in the ICAL; target ion area for CCV within -50% to +100% of ICAL midpoint standard. Sample and QC are evaluated against CCV using stated criteria. For DoD projects, EICP areas for all samples (FIELD AND QC) are evaluated against the midpoint of the calibration curve.	Inspect mass spectrometer and GC for malfunctions. Reanalysis of samples analyzed while system was malfunctioning is mandatory. If corrective action fails in field samples, apply Q-flag to analytes associated with the non-compliant IS. Flagging criteria are not appropriate for failed standards.

11.15 Data Review

The analyst is responsible for primary data review of data generated from the sample analysis. Analyses will be documented in the instrument run log. Maintenance is documented in the Instrument Maintenance Logbook. Instrument calibrations and recoveries of all QC samples must be within specified control limits. If instrument calibration or the recoveries of any QC sample exceed specified tolerances, then the affected sample results are evaluated and generally the samples are submitted for re-analysis. Manual integrations should be kept to a minimum and should be dated and initialed by the analyst on the QR next to the "M". Details regarding the procedures for identifying and documenting manual integrations are provided in the SOP for Manual Integrations (SEI-10.13.1manInt).

The laboratory QA/QC Checklist (see Attachment 1) is populated by the analyst and is used to indicate any problems with the referenced analytical batches and submitted to the secondary reviewer along with a Data Package Requirements checklist (Attachment 1) that informs the review team what elements of the data package have been provided. The QA/QC checklist addresses any corrective action taken in the laboratory such as dilutions and re-analyses.

To determine if analytical results are acceptable, a qualified and independent QA/QC analyst shall conduct a 100% secondary review prior to reporting of the final data package to the client. All calibrations, calculations, and transcriptions are checked for accuracy and QC sample results are evaluated against specified limits by the secondary reviewer and documented on the Secondary

Reviewer Checklist (Attachment 1). If instrument calibration and recoveries of all QC samples are within the specified criteria, then the data reports will be submitted to the Project Manager as final results with no qualifiers. If recoveries of any QC samples exceed specified limits and re-analysis is not an option, then the samples will be qualified with a Q-flag or as estimated with a “J” qualifier (J= The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.) depending on the corrective action or the QC element that failed. Data will not be reported if significant QC issues affect the batch analyses. Any qualifications or actions taken will be noted in the case narrative.

12.0 POLLUTION PREVENTION & WASTE MANAGEMENT

Pollution prevention encompasses any technique that reduces or eliminates the quantity or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in laboratory operation. The United States Environmental Protection Agency (USEPA) has established a prevention hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address their waste generation. When wastes cannot be feasibly reduced at the source, the agency recommends recycling as the next best option.

The quantity of chemical purchased should be based on expected usage during its shelf life and disposal cost of unused material. Actual reagent preparation volumes should reflect anticipated usage and reagent stability.

For information about pollution prevention that may be applicable to laboratories and research institutions, consult “Less is Better: Laboratory Chemical Management for Waste Reduction”, available from the American Chemical Society’s Department of Government Regulations and Science Policy, 1155 16th Street N.W., Washington, D.C. 20036; (202) 872-4477.

The USEPA requires that laboratory waste management practices conducted be consistent with all applicable rules and regulations. Excess reagents, samples, and method process wastes should be characterized and disposed of in an acceptable manner. The Agency urges laboratories to protect the air, water and land by minimizing and controlling all releases from hoods and bench operations, complying with the letter and spirit of any waste regulations, particularly the hazardous waste identification rules and land disposal restrictions. For further information on waste management consult the “Waste Management Manual for Laboratory Personnel”, available from the American Chemical Society.

13.0 REFERENCES

40 CFR Part 136, Appendix A, paragraphs 8.1.1 and 8.2

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Lee, Jae-Hwan, Seung Man Hwang, Dai Woon Lee, and Gwi Suk Heo, 2002, Determination of Volatile Organic Compounds (VOCs) Using Tedlar Bag/Solid-phase Microextraction/Gas Chromatography/Mass Spectrometry (SPME/GC/MS) in Ambient Workplace Air. Bull. Korean Chem. Soc., Vol 23, No. 3 pp. 488-496.

“Less is Better: Laboratory Chemical Management for Waste Reduction”, available from the American Chemical Society’s Department of Government Regulations and Science Policy, 1155 16th Street N.W., Washington, D.C. 20036; (202) 872-4477.

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14.0 TABLES, DIAGRAMS, FLOWCHARTS, AND VALIDATION DATA

Attachment 1: Sample GC Laboratory QA/QC Checklist

Table 1: Analyte Details – LOQ/QLs shown are for SIM Configuration

Analyte	CAS #	**Minimum RRF	Maximum %RSD	LOQ/QL Water (ug/L)	LOQ/QL Air (ppbv/v)	LOQ/QL Soil (ug/Kg)
Chloromethane	74-87-3	0.01	20%	5	50	120
Vinyl Chloride	75-01-4	0.01	20%	2	50	80
Chloroethane	75-00-3	0.1	20%	2	50	80
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.1	20%	2	50	80
1,1-Dichloroethene	75-35-4	0.01	20%	2	50	80
+ Carbon Disulfide	75-15-0	0.1	20%	2	50	80
+ Methylene Chloride	75-90-2	0.01	20%	2	50	80
+ t-Butyl-methyl ether	1634-04-4	0.1	20%	2	50	80
trans-1,2-Dichloroethene	156-60-5	0.1	20%	2	50	80
1,1-Dichloroethane	75-34-3	0.1	20%	2	50	80
cis-1,2-Dichloroethene	156-59-2	0.1	20%	2	50	80
* + 2-Butanone	78-93-3	0.1	20%	50	50	2000
Chloroform	67-66-3	0.1	20%	2	50	80
1,1,1-Trichloroethane	71-55-6	0.1	20%	2	50	80
Cyclohexane	110-82-7	0.1	20%	2	50	80
Carbon Tetrachloride	56-23-5	0.1	20%	2	50	80
Benzene	71-43-2	0.1	20%	2	50	80
1,2-Dichloroethane	107-06-2	0.01	20%	2	50	80
Trichloroethene	79-01-6	0.1	20%	2	50	80
Methyl Cyclohexane	108-87-2	0.1	20%	2	50	80
1,2-Dichloropropane	78-87-5	0.1	20%	2	50	80
Bromodichloromethane	75-27-4	0.1	20%	2	50	80
cis-1,3-Dichloropropene	10061-01-5	0.1	20%	2	50	80
* + 4-Methyl-2-pentanone	108-10-1	0.1	20%	50	50	2000
Toluene	108-88-3	0.1	20%	2	50	80
Trans-1,3-Dichloropropene	10061-02-6	0.1	20%	2	50	80
1,1,2-Trichloroethane	79-00-5	0.01	20%	2	50	80
Tetrachloroethene	127-18-4	0.1	20%	2	50	80
+ 2-Hexanone	591-78-6	0.1	20%	50	50	2000
Dibromochloromethane	124-48-1	0.1	20%	2	50	80
1,2-Dibromoethane	106-93-4	0.1	20%	2	50	80
Chlorobenzene	108-90-7	0.1	20%	2	50	80
Ethylbenzene	100-41-4	0.1	20%	2	50	80
M+p-Xylenes	108-38-3 106-42-3	0.1	20%	2	50	80
o-Xylene	95-47-6	0.1	20%	2	50	80

Analyte	CAS #	**Minimum RRF	Maximum %RSD	LOQ/QL Water (ug/L)	LOQ/QL Air (ppbv/v)	LOQ/QL Soil (ug/Kg)
Styrene	100-42-5	0.1	20%	2	50	80
Bromoform	75-252	0.1	20%	2	50	80
Isopropylbenzene	98-82-8	0.1	20%	2	50	80
Bromofluorobenzene	460-00-4	0.1	20%	2	50	80
1,1,2,2-Tetrachloroethane	79-34-5	0.1	20%	2	50	80
1,3-Dichlorobenzene	541-73-1	0.1	20%	2	50	80
1,4-Dichlorobenzene	106-46-7	0.1	20%	2	50	80
1,2-Dichlorobenzene	95-50-1	0.1	20%	2	50	80
+ 1,2-Dibromo-3-chloropropane	96-12-8	0.1	20%	2	50	80
1,2,4-Trichlorobenzene	120-82-1	0.1	20%	2	50	80
1,3,5-Trimethylbenzene	108-67-8	0.1	20%	2	50	80
1,2,4-Trimethylbenzene	95-63-6	0.1	20%	2	50	80
Naphthalene	91-20-3	0.1	20%	2	50	80
*Ketones or other VOC compounds not listed here may be analyzed for as verified by a successful method verification study or proficiency check sample. Method validations are performed at time of analysis when other compounds outside this list are added for a project. **Minimum response factors for a select number of compounds are lower than what is recommended in 8260C due to the fact that this method deploys solid phase microextraction as opposed to purge and trap and these minimum RFs are acceptable as demonstrated with demonstration of an acceptable LOQ standard. + - Poor Performer						

Table 2: LCS Control Limits for DoD Projects – based on DOD QSM4.2, Table G-5

Analyte	CAS #	Lower DoD Control Limit (Water), %	Upper DoD Control Limit (Water), %	Lower DoD Control Limit (Solids), %	Upper DoD Control Limit (Solids), %
Chloromethane	74-87-3	40	125	50	130
Vinyl Chloride	75-01-4	50	145	60	125
Chloroethane	75-00-3	60	135	40	155
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	NA	NA	NA	NA
1,1-Dichloroethene	75-35-4	70	130	65	135
Carbon Disulfide	75-15-0	35	160	45	160
Methylene Chloride	75-90-2	55	140	55	140
t-Butyl-methyl ether	1634-04-4	65	125	NA	NA
trans-1,2-Dichloroethene	156-60-5	60	140	65	135
1,1-Dichloroethane	75-34-3	70	135	75	125
cis-1,2-Dichloroethene	156-59-2	70	125	65	125
2-Butanone	78-93-3	30	150	30	160
Chloroform	67-66-3	65	135	70	125
1,1,1-Trichloroethane	71-55-6	65	130	70	135
Cyclohexane	110-82-7	NA	NA	NA	NA
Carbon Tetrachloride	56-23-5	65	140	65	135
Benzene	71-43-2	80	120	75	125
1,2-Dichloroethane	107-06-2	70	130	70	135
Trichloroethene	79-01-6	70	125	75	125
Methyl Cyclohexane	108-87-2	NA	NA	NA	NA
1,2-Dichloropropane	78-87-5	75	125	70	120
Bromodichloromethane	75-27-4	75	120	70	130
cis-1,3-Dichloropropene	10061-01-5	70	130	70	125
4-Methyl-2-pentanone	108-10-1	60	135	45	145
Toluene	108-88-3	75	120	70	125
Trans-1,3-Dichloropropene	10061-02-6	55	140	65	125
1,1,2-Trichloroethane	79-00-5	75	125	60	125
Tetrachloroethene	127-18-4	45	150	65	140
2-Hexanone	591-78-6	55	130	45	145
Dibromochloromethane	124-48-1	60	135	65	130
1,2-Dibromoethane	106-93-4	80	120	70	125
Chlorobenzene	108-90-7	80	120	75	125
Ethylbenzene	100-41-4	75	125	75	125
M+p-Xylenes	108-38-3 106-42-3	75	130	80	125
o-Xylene	95-47-6	80	120	75	125
Styrene	100-42-5	65	135	75	125
Bromoform	75-252	70	130	55	135
Isopropylbenzene	98-82-8	75	125	75	130
1,1,2,2-Tetrachloroethane	79-34-5	65	130	55	130
1,3-Dichlorobenzene	541-73-1	75	125	70	125
1,4-Dichlorobenzene	106-46-7	75	125	70	125

Analyte	CAS #	Lower DoD Control Limit (Water), %	Upper DoD Control Limit (Water), %	Lower DoD Control Limit (Solids), %	Upper DoD Control Limit (Solids), %
1,2-Dichlorobenzene	95-50-1	70	120	75	120
1,2-Dibromo-3-chloropropane	96-12-8	50	130	40	135
1,2,4-Trichlorobenzene	120-82-1	65	135	65	130
1,3,5-Trimethylbenzene	120-67-8	75	130	65	135
1,2,4-Trimethylbenzene	95-63-6	75	130	65	135
Naphthalene	91-20-3	55	140	40	125

If no limits are available; then 70-130% may be used.

Table 3: Example Standard Preparation Calculation Sheet

 STONE ENVIRONMENTAL INC						
<u>Gas Chromatography Laboratory</u>						
HP-5						
<u>Standard Prep Log</u>						
08/16/05-a1					dmkc	
FID WS						
100	ppm					
x: 8/31/05						
Compound	Vendor	Lot	Exp	Conc (mg/ml)	Amount	
Custom VOC	S	LB18097	8/16/2006	20	20	ul
1,1-DCA	A	B2090306	6/22/2006	20	20	ul
1,1,1-TCA	A	B3050086	6/22/2006	10	40	ul
8020 Mix	A	B1070292	8/31/2005	2	200	ul
1,1-DCE	A	B4050042	1/21/2006	20	20	ul
BFB	A	B4110093	5/17/2006	25	16	ul
MeOH	OmniSolv	44090	3/1/2008	into	3684	ul
				Total	4000	ul

15.0 AUTHORIZATION

Authored by: _____ Date: _____

David Crosby, Project Scientist

Approved by: _____ Date: _____

Seth Pitkin, Vice President

16.0 REVISIONS

Revision 1:

1. Included the analytical process to analyze air in a tedlar bag using SPME and SW846 Method 8260.

Revision 2:

1. Allow a range for the concentration of the internal standard from 8.33 to 16.67 ppb.
2. Section 9.4. Included text to allow for the BFB tune evaluation to be performed as part of a check standard prior to running calibration standards and environmental samples.
3. Table 1. Adjust chloromethane and bromomethane reporting limits to 10 ppb for waters and 120 ppb for soils.
4. Include calibration by linear regression in Section 11.9.

Revision 3:

1. Adjust frequency for continuing calibration check standard from one per 15 analytical runs to one at the beginning of each analytical day.
2. Adjustment of reporting limits to reflect latest method detection limit study.

Revision 4:

1. Add reference to SIM mode analysis on the GC/MS in Sections 2.0, 3.0, and 9.4.2., and definition under Section 3.0.
2. Change EPA to USEPA where applicable.
3. Update typical GC Program parameters in Section 9.1
4. Update QC recovery limits for LCS/ICV from 70-130% to 70-130% and 70-160% for poor performers wherever applicable (Section 11.0) and in Attachment I.
5. Update SS/IS spike concentrations to be an allowed range.
6. Add specifics regarding standard preparation procedures in Section 7.0 referencing the SEI-4.7.5 SOP

and added Table 2 Example Standard Preparation Calculation Worksheet in Section 14.0.

7. Added two new paragraphs under Section 8.2 Sample Handling for pH determinations and percent moisture determination.

Revision 5:

1. Take out reference to an LCS in section 9.4.
2. Add clarification to the LCS Section 9.4.7 regarding the preparation and analysis of soils.
3. Change Section 11.0 to read Section 11.6 ICV, Section 11.7 LCS and 11.8 MS/MSD.

Revision 6:

1. Section 6.0: add SPME Autosampler: CTC Combi PAL.
2. Section 9: Add references for DOD exceptions and references
3. Section 11: Add reference to DOD projects and blank requirements.
4. Add Table 2. Reference to DOD project limits and allowances.

Revision 7:

1. Section 8: Add text requiring unique labeling of sample vials when more than one vial is presented for a sample.

Revision 8:

1. Changed document to reflect SW846 USEPA Method 8260C from 8260B
2. Included updates for DOD exceptions.
3. Minor grammatical and typographical errors fixed.
4. Updated extractions times to include 6 minutes for faster methods.
5. Updated columns use to RTX-VMS
6. Correlation Coefficient of 0.99 is now acceptable for calibrations.
7. Added Surrogate Recovery and Internal Standard Verification to Corrective Action Table
8. Added text for IC/LCS to CA Table.
9. Removed references to CCC's and SPCC's which are not used in method 8260C

Updated QA/QC Checklist added Table 2.

Revision 9:

1. Updated section to 8.2 to include isolation protocol for suspected hot samples.
2. Added LOD, LOQ, and Measurement of Uncertainty
3. Added equipment maintenance

4. Add Secondary Data Review Checklist demonstrating 100% review of all data sets.

Revision 10:

1. Updated section 8.2.3 to include use of an oven temperature log when drying samples for percent moisture analysis.
2. Updated QA/QC checklist. Changed from ICV which is only run once after a calibration to LCS which is run in each window.
3. Updated 9.4.4 internal standard area acceptance criteria.
4. Changed section 10.0. Removed procedure for quantifying and reporting TICs.
5. Updated section 11.9. Surrogate recoveries for DoD project set to 75-120% for both soils and waters.
6. Updated section 11.13. Added criteria for RPD evaluations.
7. Updated section 11.4 – Corrective Actions Table. Changes were made to be consistent with the pertinent sections of the SOP.

Attachments

**GC/MS LABORATORY QA/QC
CHECKLIST**

**DATA PACKAGE
REQUIREMENTS**

**SECONDARY REVIEW
CHECKLIST**

GC/MS LABORATORY QA/QC CHECKLIST

Instrument: _____

QC Batch: _____

System: _____

VSTD FB Area: _____

Date: _____

VSTD CB(D5) Area: _____

<u>QC Analysis</u>	<u>Criteria</u>	<u>Filename(s):</u>
IC Calibration	%RSD $\leq$ 20%, correlation coefficient >0.99 (other)	
SPME Fiber Blank	$< 1/2$ reporting limit	
BFB Tune Check	per 8260 Method	
CC Calibration	%D $\pm 20\%$ VOCs, $\pm 30\%$ (other)	
Method Blank	$< 1/2$ reporting limit	
LCS Standard	See Table 2	
MS/MSD Analysis	See Table 2	
Surrogate Standards	70-130% waters 60-140% soils	

Note: DOD projects may require additional and/or different QC criteria then specified above, see pertinent sections of SOP for details.

Comments/Corrective Action:

Prepared By: _____

Reviewed By: _____

Data Package Requirements - Analyst Checklist

Project ID: _____ Date Range of Analyses: _____
 SDG ID: _____ Level of Reporting (I, II, III, IV?): _____
 Analyst(s): _____ DoD Project (Y/N): _____
 Lab #: _____ NY State Project (Y/N): _____

Hard Copy Components (All Projects)	Included in Data Package?	Analyst Comments
Copies of Run Logs		
Sample Login Sheets/COCs (make sure all req'd fields completed correctly for each sample, soil weights & SEI# included)		
All applicable calibrations, including:		
- Response Factor (RF) Report, including: - Cal ranges specified for each compound - RFs and datafile names for 200 ppb point (calculate and handwrite OR calculate in excel and attach to RF Report) - Plots of any linear or quadratic fits, including r^2 values written on plots. - Compound List report (shows cal fit types) - Quant reports for individual cal levels and ICV, signed and dated*		
Daily QA/QC Coversheets, indicating file IDs for each QC run and any deficiencies or other important details, signed and dated. Make sure to include any IS or SS outages and to include MS/MSD runs, where applicable.		
All Daily QC quant reports with QC Batch IDs designated, signed and dated*, including:		
- FBLK run(s) - BFB Tune check run(s) including spectra - VSTD run(s) - VBLK run(s) - LCS run(s) – Note: LCSD req'd in every window for DoD projects if no MS/MSD pair in window.		
All Sample quant reports, signed and dated*, including MS/MSD and FD runs, where applicable. Organize by hole.		
Internal Standard and Surrogate Summary Reports		

* Sign and date at bottom of quant report next to "m" for Manual Integration (MI) and include MI reason code next to each compound manually integrated.

Electronic Data Components (Basic Requirements for all projects)
**Included
in Data
Package?**
Analyst Comments

LIMS (<i>FRONT</i> and <i>DATA</i> components)		
All Data (.D) Files for project (include in comments how and where data were transferred)		
All Methods (.M) Files for project (include in comments how and where data were transferred)		

Electronic Data Components (Additional Requirements for Level III Projects)
**Included
in Data
Package?**
Analyst Comments

LIMS-generated QC Reports, including:		
• VSTD Reports		
• VBLK Reports		
• LCS/D Reports		
• MS/MSD Reports (if applicable)		
• FD Reports (if applicable)		

Additional Electronic Data Components (Additional Requirements for Level IV Projects)
**Included
in Data
Package?**
Analyst Comments

Detailed pdf Reports, post-q-edit (i.e., DEF) only		
LIMS-generated QC Reports, including:		
• VSTD Reports		
• VBLK Reports		
• LCS/D Reports		
• MS/MSD Reports		
• FD Reports		

Additional Electronic Data Components (Additional Requirements for DoD Projects)
**Included
in Data
Package?**
Analyst Comments

Detailed pdf Reports, including:		
• Pre q-edit (i.e., ABC)		
• Post-q-edit (i.e., DEF)		

Analyst Signature: _____ Date: _____

SECONDARY DATA REVIEWER CHECKLIST

Instrument: _____

Project

ID: _____

System: _____

Sample Delivery Group.

SDG Date Range: _____

(SDG): _____

Stone Project

Number: _____

<u>Action</u>	<u>Completed?</u>
COCs: Check that all COCs have been properly populated with all necessary information.	
Accuracy & Completeness: - Export and format LIMS tblSampleLogin for inclusion in lab data report, including a header that shows project and SDG info. - Check each sample on this Sample Login Summary against project COCs for accuracy and completeness. - Generate a list of samples not analyzed, including extra vials not opened, for inclusion in lab data report - Use LIMS Completeness check ("Samples Logged in/Count of Results" button) to make sure all samples have data in LIMS	
Sample Weights & Percent Moisture: If soil or rock samples are present in SDG, generate, export and format LIMS "Review Sample Weights" query for inclusion in lab data report, including a header that shows project and SDG info. This is also a handy sheet to use when reviewing results and checking calculations.	
QC Data Review: - ICAL - Check response factor calculations for ICAL (esp. those with manual integrations) and make sure all levels are represented correctly on form – add 7th level RFs if applicable. Make sure that cal ranges are correct in LIMS. - Review all QC data from each analytical batch in the SDG, making sure that all QC Data meet the requirements described on Daily QC/QC Checklist. This review should include the following: FBLK, BFB Tune (including 12-h window), ICAL, CCV, VBLK, LCS, MS/MSD, FD, ISTD and SS recoveries. Sign Daily QA/QC Checklist. - Make sure that all QC outages are documented on Analyst's Daily QA/QC Checklists. If any data qualifications are necessary based on QC outages, confirm that those qualifications have been applied to the proper samples and analytes in tblFinalResults – use filtering tool to search.	

Sample Data Review: • Make sure all results in LIMS (or on LIMS-generated Form 1 Reports) match those on chromatograms, including checking any sample weight and/or percent moisture calculations for soil/rock samples. • Make sure chromatograms say “QT reviewed” and have been signed and dated by analyst. • Check that ISTD and SS are within acceptable range for all samples in window. • Check that all results have been reported from within cal range • Check that qualifiers have been applied appropriately if necessary. • Initial and date chromatogram, as secondary reviewer	
Manual Integrations (For DoD Projects only): • Check all manual integrations by looking at before and after integrations on pdf files. • Verify that analyst has initialed and dated each manual integration. Initial and date next to analyst’s initials.	
Lab Narrative Report: • Using the Daily QC/QC Checklists, summarize in narrative any QC outages from the batches within the SDG as well as any problems encountered with samples. • Compile all necessary attachments (dependent of level of reporting). At a minimum, this would include scanned COCs, LIMS Sample Login Summary, Sample weights and percent moisture data (for soil/rock data), and sample Form 1 Reports. • Send final report to another analyst or Lab or QA Manager for review.	
EDD: • Generate EQUIS EDD (or other appropriate format) in LIMS. • Make sure that all columns are properly populated. • Make sure that EDD contains the correct number of results • Spot check results in the EDD against verified Form 1 Reports.	

Secondary Reviewer Signature: _____ Date: _____

LABORATORY and FIELD SAMPLING QUALITY SYSTEMS MANUAL

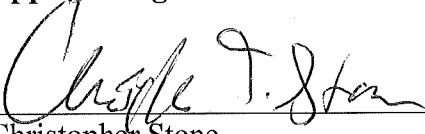


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Revision 10
EPA ID Nos. VT00974 and VT00981
Mobile Units:
Lab #1-VIN # JALE5B16067901082
Lab#2 VIN#1UK500F2541047129

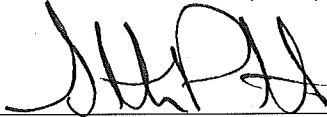
March 25, 2013

LABORATORY AND FIELD SAMPLING
QUALITY SYSTEM MANUAL
Revision 10

Approval Signatures

 3-25-13

Christopher Stone Date
Stone Environmental, Inc., President, Executive Management

 3/25/13

Seth Pitkin Date
Remediation and Investigation, Vice President, Executive Management

 3/25/13

Michael Rossi Date
Senior Scientist, Laboratory Director

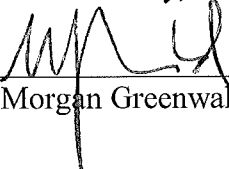
 3-25-13

Kim B. Watson Date
Quality Assurance Manager

Technical Directors:

 For 3/25/13

David Crosby, Technical Director, Analytical Chemist Date

 3/25/13

Morgan Greenwald, Technical Director, Analytical Chemist Date

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Appendix A: Facilities (Floor Plans) and Capabilities (Equipment)
Appendix B: Analytical Methodologies and Field Sampling Measurements
Appendix C: Laboratory Accreditations
Appendix D: Standard Operating Procedures Master List
Appendix E: References
Appendix F: Terms and Definitions
Appendix G: Organizational Charts
Appendix H: Forms

1.0 Introduction, Purpose, and Scope

1.1 Introduction

Stone Environmental, Inc. (Stone), located in Montpelier, Vermont was established in 1993 in response to a need for highly trained geologist, hydrogeologist and Project Managers to perform field studies in support of the Federal, Insecticide, Fungicide, and Rodenticide Act environmental studies. In addition to field measurement and sampling, on-site mobile laboratory services were developed in 1998 to support the groundwater profiling field sampling studies. Field sampling studies were being performed in support of private industry, RCRA, CERCLA and other government agencies for detailed rapid site characterizations under the Investigation and Remediation Services Division: the field sampling and measurement organization (FSMO) within Stone. Detailed Site characterization is performed using specialized technologies such as the Waterloo profiler (Waterloo^{APS TM}), the discreet fracture network approach (CORE^{DFN}) and the Membrane Interface Probe (MIP). These technologies combine real-time hydrostratigraphic data with detailed contaminant concentration distributions to provide clear insight into source zones, plume cores, and plume fate and transport.

Stone's testing capabilities include chemical analyses of a variety of matrices including aqueous, solid, waste, and air. A list of Stone's facilities (floor plans) and capabilities (laboratory and sampling equipment) is provided in Appendix A. A list of the laboratory's analytical methodologies and field sampling and measurement capabilities is provided in Appendix B.

The laboratory operates under the various state guidelines and operates under the rules and regulations of the following federal programs:

US Army Corp of Engineers, Hazardous, Toxic and Radioactive Waste
Clean Air Act
Clean Water Act
Comprehensive Environmental Response, Compensation, and Liability Act
Navy Facilities, Engineering Service Center
Department of Defense; DOD ELAP ISO 17025 QSM Standards 4.2 - Accreditation Authority
Perry Johnson Laboratory Accreditation, Inc. Troy, MI
National Pollution, Discharge, and Elimination System
Resource Conservation and Recovery Act
Toxic Substances Control Act
Federal Insecticide, Fungicide, and Rodenticide Act
TNI-National Environmental Field Activities Program
TNI-National Environmental Laboratory Accreditation Program

A list of the certifications and approvals held by the laboratory is provided in Appendix C. Original and current certificates are posted in the laboratories and available upon request from

the QA Department.

1.2 Purpose and Scope

The purpose of the quality systems manual (QSM) is to establish the framework and assign responsibilities to ensure that the staff conforms to policy. This manual outlines how that system enables all laboratory staff to meet Stone's policy, objectives, vision and mission for quality assurance. Additionally, this manual is used to inform users of the laboratory and field services of the quality practices in place. The framework on quality policies and procedures, and the Quality Systems Manual (QSM) are in accordance with the International Organization for Standardization (ISO) 17025 DOD Environmental Laboratory Accreditation Program (ELAP) QSM 4.2, The NELAC Institute (TNI)-National Environmental Laboratory Accreditation Program (NELAP), TNI-National Environmental Field Activities Program (NEFAP) Volume 2, and with Stone's Corporate Quality Management Plan (QMP). The Stone QMP describes general guidelines and minimum policies and procedures under which all Stone facilities and staff must conduct their operations. The laboratory and FSMO seeks accreditation for part of its testing, calibration and sampling activities selecting Perry Johnson Laboratory Accreditation (PJLA) Inc has their accreditation body which operates in accordance with ISO 17011.

The laboratory and FSMO has the responsibility and authority to operate in compliance with regulatory requirements in which the work is performed. If the policies and procedures given in the Stone QMP conflict with those regulatory requirements, the regulatory requirements shall hold primacy and the QSM will conform to those requirements such as required under the DOD ELAP and ISO 17025. In addition, the laboratory will operate in compliance with documented client requirements, when they do not conflict with regulatory requirements. The laboratory and FSMO will not enter into any client agreements that conflict with regulatory requirements. Where documented client agreements conflict with the policies and procedures given in this QSM but meet the regulatory requirements, the client agreement shall supersede the requirements in this QSM.

The QSM is reviewed annually for accuracy and updated as appropriate. The QSM is maintained by the QA Manager and distributed under controlled-distribution to all areas of the laboratory and MIP and Waterloo Profiler Services Team. It is the joint responsibility of the QA Manager, the Laboratory Manager and Corporate Management to ensure that all staff working in these areas familiarizes themselves with, and comply with, the procedures put forth in this QSM and associated documentation.

1.3 Scope

This QSM specifies the general requirements for the competence to carry out environmental tests, including sampling, where appropriate. Where the document uses the terms "must" and "shall", this denotes required activities. Where a practice is described, this denotes guidelines as to how those activities are generally preformed. A more detailed description of an activity or

procedure may be provided in Stone's standard operating procedures (SOPs). A master list of Stone's SOPs, controlled documents and Accreditation Authority (AA) policies is provided in Appendix D. There is a firm commitment from all members of the laboratory and field sampling team to follow a comprehensive QSM. This commitment and dedication to quality is fully supported from the analytical chemist, field sampler to senior management in order to meet the objectives of our on-site analytical laboratory, field sampling services and best serve our clients.

It is the policy of the company to discourage and reject all influence or inducements offered either by customers or suppliers which might adversely affect results or otherwise compromise the judgment or impartiality of the staff. It is the responsibility of the Laboratory Manager to inform customers and suppliers of this policy when necessary. In the event that any such influences or inducements are encountered, the staff are instructed to inform management immediately. It is the responsibility of the Executive Management to take appropriate action to prevent recurrence.

1.3.1 Stone's Vision, Mission and Values

VISION

To be sought out by decision makers around the world who require defensible and reliable scientific solutions to complex environmental challenges.

MISSION

We provide scientific tools, information, and analyses to help clients solve environmental challenges. Clients rely on us because of our integrity, expertise, and innovation. We are dedicated to a collaborative work environment that fosters personal accountability and mutual respect.

VALUES

We bring:
Scientific integrity and innovation
Respect and professionalism
A focus on client needs
We are:
Passionate about our Work
People Focused
Process Driven
Results Oriented and
Business Minded

2.0 References

See Appendix E

3.0 Terms and Definitions

See Appendix F

4.0 Organization and Management

4.1 Organizational Structure

Stone's organizational structure is provided in Appendix G, Figure 2. The laboratory and field services are under direct supervision of Senior Management who reports to Executive Management (President and Vice Presidents).

The Laboratory Manager has overall responsibility for technical operations of the laboratory, Senior Management has overall responsibility for sampling services and the Quality Assurance Manager has overall responsibility for the quality system and its implementation. In the absence of the Laboratory Manager or QA Manager, the technical director (analytical chemist), their direct supervisor will assume the responsibilities of the absent employee or delegate the responsibility to qualified personnel.

4.1.1 Roles and Responsibilities

The QA Manager oversees the Quality Assurance Program within the company, laboratory and FSMO. In this way, objectivity in the evaluation of laboratory operations and sampling are obtained. The laboratory structure provides a means for communication from the analytical chemist up to the Senior Management. This organization facilitates the generation of data, several levels of data review, and the monitoring of the overall quality of the data produced in the laboratory before it is reported to the client. Resumes of key staff, experience and educational profiles for the entire analytical staff is available at the fixed facility in the employee's training record. These records are available upon request from the QA Manager or the Administrative Assistant.

The laboratory and FSMO have specific roles and responsibilities in producing a product of known quality. All appropriate personnel are expected to have a working knowledge of the QSM. A copy of the most recent QSM is available in the laboratory, and FSMO locations, Good Laboratory Practice (GLP) standards, associated QSM and Health and Safety training is

performed for all new staff. It is expected that associates ensure that data is generated in compliance with this QSM. The responsibilities of certain key positions are detailed below.

Executive Management [President/Vice President/Executive Management] is directly and ultimately responsible for ensuring data quality and providing direction at Stone.

Responsibilities include:

- Assist in leadership and management of services.
- Participate in development of overall Stone Environmental Policies.
- Ensure that Stone QA policies are followed.
- Provide general supervision and support for Laboratory Manager and Staff.
- Monitor projects that originate from services.
- Ensure commitment to the development and implementation of the management system
- Communicate to the organization the importance of meeting customer requirements as well as statutory and regulatory requirements including requirements in the ISO 17025 standards.
- Laboratory approved results signatory

The **Laboratory Director** reports to the Executive Management and is responsible for all aspects of laboratory operation to ensure timely completion of all contractual obligations.

Responsibilities include:

- Provide overall leadership and management of laboratory.
- Assist in development of overall Stone Environmental Policies.
- Ensure that laboratory staff follows Stone policies.
- Provide general supervision and support for laboratory staff.
- Propose project assignments and staff scheduling.
- Monitor and manage workload.
- Evaluate training requests and make recommendation to Executive Management including requirements in the ISO 17025 standards.
- Communicate resource needs to Executive Management.
- Laboratory approved results signatory.

The **Laboratory Operations Manager** reports to the Executive Management and is responsible for all aspects of laboratory operation to ensure timely completion of all contractual obligations.

Responsibilities include:

- Provide overall assistant leadership and management of laboratory.
- Ensure that laboratory staff follows Stone laboratory policies.
- Provide general supervision and support for laboratory staff.
- Propose project assignments and staff scheduling.
- Monitor and manage workload.
- Evaluate training requests and make recommendation to Executive Management

- including requirements in the ISO 17025 standards.
- Communicate resource needs to Executive Management.
- Laboratory approved results signatory.

The **QA Manager** reports indirectly to the President and Vice Presidents, and is responsible for the preparation, maintenance and implementation of the QSM. Responsibilities include:

- Direct quality assurance unit (QAU) services on FIFRA projects.
- Develop and implement quality systems for other company processes both project and non-project related.
- Maintain corporate quality system under the GLP, DOD ELAP ISO 17025 and TNI/NELAC and TNI/NEFAP Standards.
- Authority for stopping, accepting or rejecting analytical data, method modifications, QA programs and QC criteria.
- Conduct internal system and data audits to monitor laboratory compliance with the QSM and SOPs.
- Provide assistance in the development of laboratory management documents including SOPs as well as control, revision and distribution thereof.
- Identify areas where corrective action is required and then ensure implementation and completion of the resulting action.
- Oversee laboratory participation in performance evaluation programs.
- Act as point of contact regarding QA matters for the laboratory and Management.
- Laboratory approved results signatory.

Project Scientists and/or Project Manager (PMs) are instrumental in assisting both the laboratory and the client during the course of a project and often fulfill the role of Project Manager or Analytical Chemists. Responsibilities include:

- Leadership role in project work and development.
- Coordination of laboratory services directly with clients.
- Understanding contractual requirements and effectively communicating client needs to laboratory personnel including requirements in the ISO 17025 standards.
- Notification of clients regarding specific non-conformance, changes or difficulties encountered within the laboratory.
- Investigation of problems with samples and shipping containers received from the field.
- Monitoring of analytical work progress.
- Lead report writing for projects managed.
- Laboratory results signatory.

Analytical Chemists/Technical Directors are responsible for the generation of data by analyzing samples according to written SOPs and state regulations. Responsibilities include but may not be limited to:

- Manage and perform analytical analysis as coordinated with the client and the project scientist or manager.
- Maintain a thorough understanding of the QSM and the SOPs associated with their specific function including requirements in the ISO 17025 standards.
- Sample Login / Sample Custodian
- Ensure that all steps related to sample analysis are documented completely and accurately.
- Perform initial review of raw data with the authority to stop, accept or reject data based on compliance with well-defined QC criteria.
- Provide prompt notification to the Laboratory Manager or QA Manager of problems or anomalies detected.
- Monitor and maintain standard laboratory equipment such as refrigerators, ovens, water systems as necessary.
- Report writing and statistical analysis of data.
- Implementation of proper sample receipt procedures and sample preservation.
- Implements, completes and/or reviews external and internal chain-of-custody, as appropriate.
- Communicates and records anomalies associated with condition upon receipt of samples to the Project Scientist or Manager.
- Assigns laboratory identification number (if applicable) to a sample and logs the sample into the Laboratory Information System.
- Secures sample storage and preservation.
- Assists Health and Safety Site Officer with sample disposal.
- Reviews storage monitoring records.
- Compiles analytical reports and provides data package and electronic deliverables according to the client request.
- Ensures that all aspects of data deliverable production, organization, contract compliance screening, archival storage, packaging and data delivery operations are performed according to the client requirements.
- With proper data review and secondary review signature, laboratory results signatory.

Health & Safety Officer is responsible for administering the Corporate Health & Safety (H&S) program in order to provide a safe, healthy working environment for all employees. The H&S Officer responsibilities include the monitoring of all work areas to detect unsafe conditions, acts, and potential hazards, enforcement of environmental, health, and safety policies and procedures and ensuring regulatory compliance with local, state, and federal laws. The H&S Officer provides safety and health recommendations to laboratory management in conjunction with the facility safety committee, develops the facility Contingency Plan, Site Specific Health and Safety Plans and task hazard forms.

5.0 Quality System

5.1 Quality System Objective

The objective of this manual is to establish the framework and assign responsibilities to ensure that the staff conforms to this quality system. The goal of the laboratory's quality system is to ensure that business and technical operations are conducted with the highest standards of professionalism and ethics in the industry. To achieve this goal, it is necessary to provide our clients with the highest quality of service available in the industry as well as scientifically sound, documented, regulatory compliant data. The laboratory's quality system is designed to minimize systematic error, encourage constructive, documented problem solving, and to provide a framework for continuous improvement within the organization.

5.2 Quality Assurance Policy

Stone's Policy Statement:

It is Stone's policy that environmental data operations will result in the collection of data of known and documented quality, suitable for its intended use, and the environmental technology field activities will perform as specified. This quality policy applies to all data collected and environmental technology field activities performed by and for Stone.

Continuous efforts toward improvement are built into every activity of the company including the laboratory. These improvements ensure that Stone maintains a high-quality, efficient mobile testing facility.

5.3 Commitment to Quality Assurance

Stone Management is committed to providing the highest quality environmental services in the industry. To ensure that the data produced and reported by Stone meet the requirements of its clients and comply with applicable municipal, state and federal regulations, Stone maintains a Quality System that is clear, effective, well communicated and supported at all levels in the company.

5.4 Ethics and Data Integrity

One of the most important aspects in assuring the highest level of data quality is a highly qualified, ethical and professional staff. Establishing and maintaining a high ethical standard is an important element of a Quality System. Each employee is trained in the prevention and detection of improper, unethical, or illegal actions in their initial orientation training program that includes a review of the ethics statement, and discussions about data integrity and repercussions that result from data misrepresentation. Stone has developed a Data Integrity Training Module which outlines all data integrity procedures, training, and documentation, as well as in-depth data monitoring. Employees are required to understand that any infractions of the laboratory data integrity procedures will result in a detailed investigation that could lead to

very serious consequences including immediate termination, debarment or civil/criminal prosecution. The initial data integrity training and the annual refresher training has a signature page which is signed and filed along with an ethics agreement, which demonstrates they have participated and that they understand their obligations related to data integrity. Specific examples of breaches of ethical behavior are discussed in the training module, including improper data manipulations, adjustments of instrument time clocks, and inappropriate changes in concentrations of standards. Data integrity training emphasizes the importance of proper documentation by the analyst in cases where analytical data are partially deficient, but may still be useful. Additionally, each employee is encouraged to discuss any fraud or unethical behavior with their Executive Management and/or the QA Manager.

Data integrity is monitored by various measures that include but are not limited to; secondary and tertiary data review, internal audits including data authenticity audits, electronic data audits and other special audits. A data integrity review is performed on all Level IV data packages during the secondary data review process. At the completion of the Level IV data review and data integrity audit, the data integrity checklist will be completed along with the secondary data review checklist. See Appendix H – “STONE ENVIRONMENTAL, INC DATA INTEGRITY AUDIT CHECKLIST”.

Violations of the ethics policy will not be tolerated. All suspected violations will be investigated by the QA Manager or a designee. Employees who violate the policy will be subject to disciplinary action up to and including termination. Criminal violations may also be referred to the government for prosecution.

5.5 Ethics Policy

In order to ensure that all personnel understand the importance the company places on maintaining high ethical standards at all times; Stone has established an Ethics Agreement (Appendix H- Forms). Each employee signs the Ethics Agreement upon initial training and annually thereafter, signifying agreed compliance with its stated purpose. Ethics is also a component of the training program.

5.6 Personnel and Training

It is the policy of the company to employ permanent and part time staff that are appropriately qualified and/or trained to perform their respective duties. Where, for commercial reasons, it is necessary to employ temporary staff, the laboratory ensures that the same criteria as those governing permanent staff apply with respect to training and qualifications. In order to ensure that employees have sufficient education and experience to perform a particular task, job descriptions are developed for all personnel.

Personnel training procedures begin with an established initial orientation program designed to familiarize the new staff with health, safety and chemical hygiene issues, the importance of

quality assurance/quality control in the analytical laboratory, Quality Management Plan (QMP) Good Laboratory Practice Standards (GLP , 40 CFR Part 160), ISO 17025 standards and company policies and benefits. The basic elements of the orientation and training program are outlined in the Orientation and Training of SEI Staff Standard Operating Procedure (SEI-1.1.n).

The level of training necessary to perform analytical tasks and sampling is determined from employee's academic background and past experience, technical courses, and on-the-job training with specific methods or instrumentation. The responsibility for formal academic training lies foremost with the individual. The responsibility for the additional specialized skills obtained through in-house training or external workshops is a shared obligation of the individual, their Group Leader, and the laboratory. An individual's academic and professional experience is kept on file including an initial statement of qualifications or resume and any additional documentation concerning subsequent training. Copies of certificates of completion, transcripts, diplomas, or other documentation may be included in the training files as appropriate.

In order to ensure that the policies and objectives of this QSM are communicated to all new personnel, the staff is required to read this QSM during the training process. This training is documented on the SEI Procedure Specific Training Log (Appendix H: Forms) and included in the training files of each staff. In addition, QSM training is provided as part of the GLP training given at Stone's initial orientation. Training records are available for inspection at the fixed facility in Montpelier, VT.

Trainees are under the supervision of experienced analysts who are responsible for showing them the analytical procedures including applicable QA/QC measures. A new analyst is not permitted to perform an analysis until the Laboratory Manager is confident that the analytical and QA/QC procedures can be carried out correctly and method proficiency is documented. Each technical employee shall also have documentation of demonstration of capability (DOC) and continued proficiency for each test method performed.

Each technical employee must complete the DOC prior to independent analysis on client samples. The DOC study may be performed by analysis of four replicate QC samples with acceptable results for precision and accuracy. Additionally, each technical employee must demonstrate continued proficiency at least once per year by one of the following:

- Acceptable performance of a blind sample;
- Another demonstration of capability;
- Successful analysis of a blind performance sample on a similar test method using the same technology.
- Analysis of at least four consecutive laboratory control samples with acceptable levels of precision and accuracy.

If the above options cannot be performed (i.e. spiking is not an option), analysis of field samples with results that are statistically indistinguishable from those obtained by another analyst may be

used to satisfy the requirement for ongoing proficiency. A DOC Certification Statement is recorded and maintained in the employee's training file. Appendix H - Forms shows an example of a DOC Certification Statement.

Stone's Vermont facility is equipped with many structural safety features. Each staff is familiar with the location, use, and capabilities of general and specialized safety features within their workplace. To protect staff from potential workplace hazards, Stone provides and requires the use of certain items of protective equipment. These include safety glasses, protective clothing, gloves, respirators, etc. For a complete description of the types of personal safety equipment available and applicable to a particular workspace, refer to the Health and Safety Manual.

Stone has a firm commitment to make sure that all analysts remain proficient in the tests that they perform. SOP's are reviewed at least every two years and analysts are required to read the latest version of the SOP and/or amendments.

5.7 Document Control

Security and control of documents is necessary to ensure that confidential information is not distributed and that all current copies of a given document are from the latest applicable revision. Unambiguous identification of a document is through a header placed on the top of each page. The header may contain the document name, revision number, revision date and number of pages.

The QA Manager controls the following documents: Quality Management Plan, Laboratory and Field Sampling Quality System Manual (QSM) and Standard Operating Procedures (SOP's). These documents require written approval by appropriate management prior to release in the company.

As approved revisions to controlled documents are prepared and distributed, outdated versions are removed and destroyed. The original copy of each revision is archived by the QA Manager for reference purposes. Documents distributed externally (to clients, etc.) are not controlled unless specifically requested.

SOP's are written procedures for standardized methods (i.e. SW-846) and are supplied primarily to document specific laboratory procedures used to satisfy the general requirements specified in the individual methods and to explain any differences between the application of the established method and the published procedure. If any difference exists between Stone's SOP and a standard method's specific procedures, method validation studies are performed to document the fact that the change does not adversely affect the applicability of the method. In general, every effort is made to adhere to the protocols of the standard method.

Standard Operating Procedures (SOP's) contain the basic procedures and practices the laboratory uses to analyze a method. These procedures provide a basis for training new associates and for

showing customers how analyses are performed. The master list of all Stone SOPs is found in Appendix D.

5.8 Request, Tender, and Contract Review

Many environmental sampling and analysis programs do not necessarily “fit” into standard laboratory service or product as noted in the TRIAD approach to environmental planning. It is the laboratory’s intent to provide standard and customized environmental testing services to our clients. To ensure project success, a thorough review is conducted by the technical staff of technical and QC requirements contained in contracts and scope of services. Contracts are reviewed for adequately defined requirements and the laboratory’s capability to meet those services. The Executive Management or his designee, with input from the Laboratory Manager, considers available resources and both current and pending workload prior to accepting new work. If the laboratory determines it has the ability to perform the work a Project Scientist is assigned and a quotation is prepared as demonstrated in the 2012 IR Services Budget Template found in Appendix H - Forms (IR Services Budget Template).

Contract review or scope of services shall include a review of the client’s requirements in terms of compound lists, test methodology requested, sensitivity, accuracy, and precision requirements. The Project Scientist or Project Manager ensures that the laboratory’s test methods are suitable to achieve these requirements and must ensure that the laboratory holds the appropriate accreditations and approvals to perform the work. The review also includes the laboratory’s capabilities in terms turnaround time, capacity, and resources to perform the work including documentation capabilities both hardcopy and electronic.

All contracts and scope of serves entered into by Stone shall be reviewed and approved by the Project Scientist and the Executive Management. Any contract requirement or amendment to a contract or scope of services communicated to the laboratory verbally must be documented and confirmed with the client in writing. Any discrepancy between the client’s requirements and the laboratory’s capability to meet those requirements is resolved in writing before acceptance of the contract. Contract amendments and scope of services adjustments initiated by the client and/or Stone, are documented in writing or in an e-mail for the benefit of both the client and the laboratory. Stone also completes an on-site laboratory startup form documenting specific project requirements such as frequency of QC and other variables such as required deliverables (See Appendix H-forms)

Any documentation between the client and Stone pertaining to the scope of services such as Quality Assurance Plans, Sampling and Analysis Plans, contract amendments, and documented communications shall become part of the permanent project record.

5.9 Subcontracting

Stone’s mobile laboratories **do not** subcontract on-site analytical services. Stone’s laboratory has

backup systems in place to ensure that samples for Stone's analytical methodologies are not subcontracted. If while on site, other analytical parameters are required, then the samplers ship the samples directly to the fixed laboratory. Stone's mobile laboratory does not take other samples into their facility and package them out for other parameters. Stone's other service groups do contract laboratory services and those services are contracted directly with the environmental laboratory. It is the responsibility of the project manager and client contracting with an environmental laboratory that the laboratory is competent to perform the tests requested at a level equivalent to the requirements of NELAP and DOD ELAP ISO 17025. All contracting and subcontracting (if requested) is arranged with the documented consent of the client. The QC guidelines specific to the client's analytical program must be transmitted to the contractor and agreed upon before shipment of samples to the contract facility. Details regarding the laboratory agreement and their SOPs are typically outlined in the site specific Quality Assurance Project Plan. Where feasible, a contractor or sub-contractor may be assessed by Stone's QA Manager either through an on-site visit or by the submission of sufficient documentation to determine the subcontractor's capabilities and qualifications. This documentation may include, but is not limited to: laboratory QSM, SOPs, recent proficiency test sample results and **relevant certifications**. Such documentation is filed with the project files or as with certain programs filed with the QA Manager and/or his or her designee.

Stone does not subcontract any samples without permission from the client. When permission is granted, samples are shipped to a subcontracting firm and the results of the analyses are transmitted back to Stone for review. These results are synthesized into a final report, documented as subcontracted and presented to the client.

5.10 Procedures for Addressing Client Complaints

This procedure provides guidance for investigation of any client or regulatory agency's technical complaint. That is, complaints concerning the validity of the laboratory's test result or test methods or the interpretation of a client's technical specification. Complaints may originate in written form or verbally. All complaints are documented and investigated by the Project Manager. The Laboratory Director is responsible for working together with the Project Manager to investigate and resolve the complaint. Dependent on the complexity and severity of the complaint, the QA Manager and Project Officers may be called upon to resolve the issue. In cases where the complaint relates to data quality or the quality system, an internal audit is conducted by the QA Manager. The SOP titled "Client Inquires, Data Revision Requests & Complaint Resolution" (SEI-8.4.n) provides approved detailed procedures to Stone's staff. In addition, all complaints and non-conformances are logged into our corrective action program and assigned a NCR number for follow-up.

5.11 Client Confidentiality and Proprietary Rights

It is Stone's policy not to release any information pertaining to projects, except to the client who submitted the samples or who is responsible for payment without the consent of the client.

Data and sample materials provided by the client or at the client's request, and the results obtained by the laboratory are held in confidence (unless such information is generally available to the public or is in the public domain or client has failed to pay Stone for all services rendered or is otherwise in breach of the terms and conditions set forth in the Stone and client contract) subject to any disclosure required by law or legal process. Laboratory reports and the data and information provided therein, are for the exclusive use and benefit of client, and are not released to a third party without written client consent. Prior to release of any information to a third party, Stone staff must obtain written consent from the original client. This release may be transmitted via facsimile, but must be on the client company letterhead.

5.12 Service to Client

Stone assigns a Project Manager (PM) to each client to ensure that the project specific and technical requirements are effectively communicated to laboratory personnel during all project phases. The PMs are available to assist any client with the project planning process in order to develop a customized analytical program. The laboratory also encourages clients to visit the facility and hold formal or informal meetings in order to become acquainted with laboratory staff and to provide an open forum for effective communication of project specific details. In order for the laboratory to produce data of known quality suitable for the intended use; communication and understanding of the project data quality objectives (DQOs) is essential.

5.12.1 Project Specific Quality Planning

Communication of contract specific technical and QC criteria is an essential activity in ensuring the success of site specific testing programs. The PM is the first point of contact for the client. It is the PM's responsibility to ensure that project specific technical and QC requirements are effectively communicated to the analytical chemist at the bench level before and during the project. Stone employs the use of the I&R Project Field Team Information Form and the Laboratory Start-up Form (See Appendix H) to communicate client specific requirements in a project including project specific quality controls and contracts.

5.12.2 Data Quality Objectives

The data quality objectives discussed below ensure that data are gathered and presented in accordance with procedures appropriate for the intended use, and that the data are of known and documented quality able to withstand scientific and legal scrutiny. The quality of the measurement data is defined in terms of precision, accuracy, representativeness, completeness, comparability, and traceability.

Precision measures the reproducibility of measurements. It is strictly defined as the degree of mutual agreement among independent measurements as the result of repeated application of the same process under similar conditions. Total precision is the measurement of the variability with the entire sampling and analysis process. It is determined by analysis of duplicate or replicate

field samples and measures variability introduced by both the laboratory and field operations. Duplicate samples and matrix spiked duplicate samples are analyzed to assess field and analytical precision, and the precision measurement is determined using the relative percent difference (RPD) between the duplicate sample results.

Accuracy is a statistical measurement of correctness and includes components of random error (variability due to imprecision) and systemic error. It therefore reflects the total uncertainty with a measurement. A measurement is accurate when the value reported does not differ from the true value or known concentration of the spike or standard. Analytical accuracy is measured by comparing the percent recovery of analytes spiked into a laboratory control sample (LCS) to a control limit. For volatile and semivolatile organic compounds, surrogate compound recoveries are also used to assess accuracy and method performance for each sample analyzed.

Representativeness is defined as the degree to which a single measurement is indicative of the characteristics of a larger sample or area. More specifically, it is the degree to which the data gathered by the project accurately and precisely represents the actual field conditions. The laboratory makes every effort to ensure a representative aliquot is removed from the sample container. Homogenization of the sample is carried out when appropriate.

Completeness is defined as the percentage of measurements that are judged to be valid measurements. Factors negatively affecting completeness include sample leakage or breakage in transit or handling and failure to meet specified holding times. Completeness can be compromised by improper handling, by improper documentation such that traceability is compromised, or by rejection of sample results due to a failure to conform to QC criteria specifications. Typically, a completeness objective of at least 90% of the data for on-site analyses or as specified by the statement of work is the goal established for most projects.

Comparability of results between current and past sampling events, and between analytical sequences of a method is achieved through Quality Assurance Project Plans (QAPP), controlled SOP's, and experienced, well trained analysts.

Traceability is the extent to which reported analytical results can be substantiated by supporting documentation. Traceability documentation exists in two essential forms: those, which link the quantitation process to authoritative standards, and those, which explicitly describe the history of each sample from collection to analysis and disposal. The traceability goal for the laboratory is 100%.

5.12.3 Estimation of Uncertainty of Measurements

The components of analytical variability (uncertainty) can be estimated when QC samples of the right type and at the appropriate frequency are incorporated into the measurement process. Stone uses numerous QC samples to obtain data for comparison to analytical DQOs and to ensure that the measurement system is working properly. The QC samples and their application as

mentioned above are based on regulatory, method or client specific requirements. As outlined in Section 12.1 QC samples for inorganic and organic analyses may include calibration blanks, instrument blanks, method blanks, laboratory control samples, calibration standards, matrix spikes and surrogate spikes.

The methods that Stone typically performs are well established and works within the published acceptance limits of the methods as recorded in the standard operating procedures. If necessary to establish uncertainty limits on non-routine methods, Stone would employ the use of statistical control charts which provide a means for long-term trend analysis as well as a tool for real time data assessment. Statistical control charts may be prepared for most routine methods and matrices analyzed by the laboratory after accumulation of at least 20 data points. The % recovery of laboratory control samples, matrix spikes and surrogates are monitored and charted only if necessary and as required by the client. The relative % difference (RPD) of laboratory duplicates is also monitored and charted as necessary.

Control limits derived from laboratory data are calculated in terms of multiple standard deviations from a mean or other reference point. Warning limits are set at ± 2 standard deviations and control limits are set at ± 3 standard deviations. Initial limits are established after a minimum of twenty data points is available. Once established, the control limits are updated at least annually. If method specified limits are available, the calculated control limits are compared to them. The laboratory adopts method-specified limits whenever available rather than use laboratory generated limits for actual evaluation of data as the laboratory limits may be too narrow for the overall site data quality objectives. This provides consistency over time, particularly for ongoing projects. In cases where acceptance limits are not specified in methodology, laboratory generated control limits are used for data evaluation if requested by the client.

In addition to control limits, control charts are used to determine if trends are occurring. Data points consistently above or below the mean or points becoming steadily high or low over time indicate the occurrences of trending or bias in the procedure. Investigation and corrective action is taken if these situations are observed.

5.13 Nonconformance and Corrective Actions

A nonconformance is typically defined as an unplanned deviation from an established protocol. An occurrence of a nonconformance may be the result of Stone's actions, which would be rendered as a deficiency, or the result of events beyond Stone's control, which would be termed an anomaly. All nonconformances or deviations are documented in an access database and numbered.

Deviations from the QSM or SOPs, deficiencies, errors, or out-of-control situations require corrective action. Documentation of the problem, identification of the cause and follow-up action to prevent recurrence is accomplished through the use of this documentation.

Any individual who detects the need for corrective action is responsible for initiating the report using the NCR Form found in Appendix H. Corrective action procedures or deviations may be initiated and are often completed at all levels of the laboratory. If the person initiating the report is uncertain as to what would constitute appropriate corrective action or is unable to resolve the situation, they identify the problem and submit the incomplete report to their Laboratory Manager, the Project Scientist/Manager or the QA Manager who is then responsible for resolution. The procedure for the corrective action at this level starts with an investigation to determine the root cause(s) of the problem.

All completed corrective action reports and/or deviations are submitted to the QA Manager within 30 days. The QA manager is responsible for review and follow up to determine if the corrective action is sufficient, effective and fully implemented with the completed corrective action performed within 90 days. Completed reports are maintained on file in the QA department. Copies of corrective action reports or deviations that are specific to a sample or set of samples will also be filed with the supportive documentation and discussed in each appropriate case narrative.

5.13.1 Correction of Erroneous Reports

The discovery that, for whatever reason, an erroneous result has been released initiates immediate corrective action to rectify the error. If the error is discovered internally then the client is immediately notified by the Project Manager to prevent use of the incorrect report for decision-making. If a client or validator has a question or finds a deficiency concerning the data submittal, the Project Scientist/Manager is responsible for communicating and implementing the corrective action in the laboratory. The analytical results and all supportive documentation in question are submitted to the appropriate section for evaluation. Should a reanalysis be necessary, it is initiated in writing.

Hard copies and revised electronic deliverables (where applicable) are given to the Project Scientist/Manager for re-submission to the client or validator. Revision of the case narrative, should it become necessary, is the responsibility of the Project Scientist/Manager. In some instances, clients request that sample handling information; recalculations or qualitative judgments are re-checked in order to ensure data integrity. In this case, resubmission of the data may not be necessary unless a problem is detected.

The Project Manager brings customer problems that persist in the laboratory to the attention of the Laboratory Manager and/or QA Manager.

5.14 Preventive Action

In order to prevent system down time, minimize corrective maintenance costs and ensure data validity, the laboratory employs a system of preventive maintenance. General preventive maintenance procedures, many of which are unique to particular instruments, are outlined in each instrument's operation manual. All routine maintenance is performed as recommended by the manufacturer. The manuals also assist in the identification of commonly needed replacement parts, so that an inventory of these parts can be maintained at the laboratory. It is the Laboratory Manager's responsibility to make sure that the most current version of the operator's manual is available in the laboratory. The on-site analytical chemist performs routine maintenance while external technicians may be called in for major repairs.

A bound maintenance and repair log notebook is kept with each instrument to record all routine and non-routine maintenance. Notation of the date and maintenance activity is recorded every time service procedures are performed. This includes routine service checks by laboratory personnel as well as factory service calls. The return to analytical control following instrument repair is also noted in laboratory maintenance logbooks. If a non-conformance resolution results in a preventive action then an NCR form is completed, logged into the access database and followed up with a preventive action.

5.15 Quality System Review by Management

A review of the quality system is conducted annually. Management, including but not limited to the Executive Management, Laboratory Managers and QA Manager, review all aspects of the laboratory's quality system. The purpose of this review is to ensure the suitability and effectiveness of Stone's program as well as provide opportunity for improvements. The review includes the following topics:

- Reports from audits by clients and regulatory agencies
- Reports from internal audits
- Results of proficiency studies
- Corrective actions from the past year and a review of their implementation
- Details of complaints from clients and their resolution
- Training goals and objectives
- Staff, facility and equipment resources
- Future plans and goals
- Monthly Operations Report to Management

In addition to this annual review, a monthly report and staff meetings occur to communicate issues and needs which arise during the course of operations.

5.16 Audits Types and Frequency

There are several different types of audits performed at Stone Environmental, Inc. Technical system audits are designed to assess the adequacy of a selected system in meeting Stone objectives.

5.16.1 System audits

System audits are technical in nature and may be performed by the QA Manager as an internal audit or by a client or regulatory agency for certification or approval. System audits cover all aspects of the laboratory, both operational and support. These audits are performed annually.

The QA Manager shall issue the audit report within 60 days of the audit. The audit report is addressed to the Laboratory Manager and Management.

Written responses are required by the Laboratory Manager within 60 days of receiving the audit report and the audit response should follow the format of the audit report, and corrective actions and time frames for their implementation are included for each deficiency. If a corrective action requires longer than sixty days to complete, the target date for the corrective action implementation is stated and evidence of the corrective action is submitted to the QA Manager in the agreed upon time frame.

5.16.2 Data Audits

Data audits are performed to assess the quality of results reported to clients. If the results of an audit (either internal or external) indicate that a client's analytical results are questionable the client is notified in writing by either the Project Scientist/Manager or the QA Manager. The laboratory then works with the client and makes every attempt to resolve the issue (i.e., by revising a report, reanalysis of the sample, etc.). Typically, the data audits are performed quarterly.

Records of the data audits are kept, and the frequency of the data audits shall be included in the QA Binder found in the QA Department.

5.16.3 Special Audits

Special Audits are conducted on an as needed basis, generally as a follow up to a specific issue such as client complaints, corrective actions, proficiency testing results, data audits, system audits, third party assessments and/or regulatory audits. Special audits are performed for a specific issue and report format distribution and timeframes are designed to address the nature of the issue.

5.16.4 External Audits

To become a participant in state and federal accreditation programs, the laboratory may be audited by representatives of regulatory agencies or an accreditation body such as PJLA. Any audit findings or non-conformances are formally documented by the QA Manager and submitted to the laboratory for corrective action. The laboratory is required to respond with corrective action to the audit findings and recommendations of the regulatory agencies before accreditation for a particular program can be granted. The Laboratory QA Manager conducts follow up audits to verify that corrective actions have been implemented. Observations made during these follow up audits are submitted to the appropriate representatives of the regulatory agency.

5.17 Proficiency Testing (PT)

The laboratory participates in internal and external laboratory check sample programs as a means for examining overall laboratory performance as well as to qualify for various federal and state certification programs. Internal or intra-laboratory check sample programs include the submission of blind samples that are carried through normal procedures. The following external or inter-laboratory check sample programs are the typical ones employed to demonstrate analytical proficiency for purposes of monitoring overall laboratory proficiency or to provide proof of acceptable performance for certification or accreditation programs by outside agencies or regulatory bodies:

National Environmental Laboratory Accreditation Program (NELAP) Semi-annual Proficiency Testing Programs.

The NELAP proficiency-testing program is an extensive and comprehensive check sample program. Private approved vendors administer the program under the direction of the EPA (WP or WS or HW designations). Participating laboratories receive reports detailing acceptability of their reported results and must provide corrective action responses to State Agencies regarding any results that are outside of the control limits. Stone participants in both the WP and HW programs and performs at least two PTs a year for the WP and HW programs. Stone must pass two PTs out of three within an eighteen month period.

5.18 Records

The laboratory retains all records related to sample analysis including raw data, calculations, derived data, calibrations and test reports. These records are maintained in a systematic manner for a minimum of seven (7) years unless other noted and outlined in the SOP, *Document Control, Record System and Archiving (SEI-7.2.n)*. Longer periods of storage may be arranged at the time of project initiation.

Mistakes are never erased, deleted or written over. They are corrected by drawing a single line through the error and entering the correction alongside. The correction is then initialed and dated

by the responsible person and if applicable the reason for the change is documented as a footnote as outlined in the SOP *Data Handling, Storage, Retrieval and Error Coding (SEI-4.3.n)*.

Each log book page or, as required, each entry is dated and initialed by the analyst at the time the record is made. Pages inserted into logbooks are stapled to a clean, bound page (if using a bound notebook). Specific information on the types of logbooks, format of entry, and other pertinent information are contained in the appropriate sectional SOPs.

The Laboratory Manager or his/her designee periodically reviews laboratory notebooks for accuracy, completeness, and compliance. If all entries on the pages are correct, then the Laboratory Manager or his/her designee initials and dates the reviewed pages. Corrective action is taken for erroneous entries before the Laboratory Manager or his/her designee signs off with their approval.

5.19 Computer, Electronic Data Security and Traceability

Access to computer systems that collect, analyze, and process raw instrumental data, and those that manage and report data must be both controlled and recorded. There are various systems at the laboratory to which this applies, which include the Laboratory Information Management System (LIMS), as well as specific systems such as a chromatography data system. System users are granted privileges that are commensurate with their experience and responsibilities. Computer access must be tracked by using unique login names and passwords for all employees that have access to the computer system. "General" or "multi-user" account access to computer systems that collect, analyze and process raw instrumental data, and those that manage and report data should not be permitted. Entries and changes are documented with the identity of the individual making the entry, and the time and date. Where a computer system is processing raw instrumental data, the instrument identification number is recorded. Many of these systems, such as the ChemStation has the capability of maintaining audit trails to track entries and changes to the data. This function shall be activated on any computer system that has that capability.

All commercially obtained software shall be verified prior to use and after version upgrade. Verification involves assessing whether the computer system accurately performs its intended function. Verification generally is accomplished by comparing the output of the program with the output of the raw data manually processed, or processed by the software being replaced. The records of the verification are required to contain the following information: software vendor, name of product, version, comparison of program output and manual output, raw data used to verify the program, date, and name of the individual performing the verification. Records of verification are retained.

Whenever possible the laboratory establishes standards for computer systems and peripheral equipment. In instances, where a vendor-provided solution is bundled with hardware and software, the vendor certifies that the proposed hardware is readily operable with existing

hardware platforms, and will provide operating and maintenance instructions. Stone staff or trained vendor technicians configure computer system hardware. Major hardware items include systems used for data collection, multi-user file servers, and multi-user printers.

Prior to release for production, use of any in-house developed software is considered under development. Software is validated prior to release. Validation of software consists of testing the output of the software based on sample input data, and comparing the output with independently calculated results.

Stone employs the use of anti-virus software to detect and remove viruses from software.

5.19.1 Archives and Record Transfer upon Facility Change or Ownership Transfer

Archives are indexed such that records are accessible on either a project or temporal basis. Archives are protected to the degree possible against fire, theft, loss, deterioration, and vermin. Electronic records are protected from deterioration caused by magnetic fields and/or electronic deterioration. Access to archives is controlled and documented by the archivist.

Stone ensures that all records are maintained as required by the regulatory guidelines and per the SOP (SEI-7.2.n) upon facility location change or ownership transfer. Stone location change, all archives are retained by Stone in accordance with the SOP. Upon ownership transfer, record retention requirements are addressed in ownership transfer agreement and the responsibility for maintaining archives for maintaining archives is clearly established.

5.19.2 Departures from Policies

Departures from laboratory Standard Operating Procedures are not permitted unless the approval of the Laboratory Manager or the QA Manager is obtained prior to implementation of the departure. These exceptions must be documented with a SOP deviation and/or highlighted in the analytical logbook, which accompanies the analytical results. If a client requests a departure from the laboratory's policies or procedures, the Project Scientist/Manager notifies the Laboratory QA Manager who then discusses the steps necessary to implement such a departure with the Laboratory Manager and appropriate laboratory analytical chemists. If necessary and appropriate method validation studies and method detection limit studies are performed as applicable.

5.19.3 Security

Because of the nature of Stone's work, adequate security of the facilities, equipment, and project files is necessary. Access to the fixed facility and typically the on-site facility is controlled through a key system. Visitors register upon entering the building and are accompanied by a staff member while visiting. The Laboratory Manager ensures that personnel are familiar with Stone's security policies.

Stone staff is familiar with and adhere to standards of confidentiality mandated by individual contracts and common sense business practices.

In addition, all of the Stone staff has been instructed on ethics reflecting our belief that the cornerstone of any business relationship is ethical behavior and data integrity. This policy is a vehicle to reinforce our commitment to quality.

6.0 Facilities

6.1 Stone Fixed Facility, On-Site Facility and Equipment

Stone has a fundamental responsibility to provide facilities, equipment, maintenance, and an organized program to make necessary improvements to ensure a safe working environment. Unless staffs fulfill their responsibilities for laboratory safety, the safety-related features of the facility and established safety programs will be ineffective. The Employee Health and Safety Manual provides a complete discussion of the safety policies enforced by the company. A copy of the Health and Safety Manual is available during his or her orientation training session. The Health and Safety Officer distributes updates as they occur.

The fixed physical layout of Stone and a typical mobile laboratory layout is provided in Appendix A. The on-site laboratory will typically be approximately 250 square feet of floor space to house the equipment and two analytical chemists. Based on the size and scope of the on-site work plan the size of the on-site laboratory will vary. The fixed facility and the mobile laboratory is compliant with all Occupational Safety and Health Administration regulations and are equipped with unique environmental controls including air flow monitoring, waste heat utilization, and security. In addition, the laboratory is outfitted with instrumentation exhibiting advanced technology and automation.

The fixed facility and the on-site laboratory facility have computer networking and centralized gas distribution to support its analytical services.

7.0 Laboratory Scope of Tests

The on-site or mobile laboratory performs USEPA standard field inorganic and USEPA standard organic analyses on various matrices including air, water, soil, and waste. Analyses follow acceptable protocols approved under applicable state and federal programs. Detailed descriptions of method procedures and reporting limits are maintained in the individual method SOP's. Appendix B of this QSM presents a summary of the laboratory and sampling methods performed by Stone's on-site facility.

7.1 Reference to Test Procedures Used

The following list includes the sources for the majority of analytical methods referenced by the laboratory:

EPA SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3rd Edition, with Update I, Update II, Update IIA and Update III, December 1996.

APHA/AWWA/WPCF, Standard Methods for the Examination of Water and Wastewater, 19th Edition.

ASTM, American Society for Testing & Materials; Annual Book of Standards, 1986 through 1993 editions.

Plumb, Russell, USEPA Corps of Engineers, Procedures for Handling and Chemical Analysis of Sediment and Water Samples, May 1991.

7.2 Method Validation and Verification Activities

Methods performed at the laboratory are validated prior to sample analysis. Method validation may involve the determination of sensitivity and linearity and reproducibility studies. This would include but are not limited to: writing appropriate method SOPs and performing method detection limit studies.

Determination of Method Selectivity

Method selectivity should be demonstrated for the analyte(s) in the specific matrix or matrices. In some cases, to achieve the required selectivity for an analyte, a confirmation analysis may be required as part of the method.

Determination of Method Sensitivity

Method sensitivity is determined by method or instrument detection limit studies. The procedure to determine the method detection limit (MDL) or limit of detection (LOD) may follow 40CFR Part 136 Appendix B (revision 1.1). The reporting limit for a given analyte may be derived from the MDL.

Determination of Limit of Quantitation (LOQ) or Reporting Limit (RL)

The MDL is the approximate limit at which an analyte can be qualitatively detected using a specific method at a 99% confidence interval. The MDL is a statistically calculated value and measures the sensitivity of an entire method and is independent of device. The Reporting Limit (RL) or Limit of Quantitation is the limit at which a compound can be qualitatively detected and quantified at a 99% confidence interval. The RLs or LOQ are also set based on specific knowledge about the analyte, project specific requirements and/or regulatory requirements. The RL is always greater than the MDL is typically set based on 3-5 times the MDL or LOD.

Stone reports results to the sample specific RL's for a set of compounds as defined in the

published methods. For most methods the low calibration standard is set at the laboratory RL to monitor method sensitivity per instrument per calibration. Sample specific RL's are derived by taking into account various sample specific data, which can include the amount of the sample subject to testing, percent moisture, dilution factors, interferences and the base RL's for the analysis.

In some cases, it is appropriate to report values between the MDL and the RL. In this region, an analyte can be qualitatively detected, but not accurately quantified. Any data point reported in this region is flagged with a "J" to indicate that it is an estimated value.

Determination of Range

Where appropriate, a determination of the applicable range of the method is performed. In most cases, range is determined and demonstrated by comparison of the response of an analyte in a curve to established and targeted criteria. The curve is used to establish the range of quantitation and the lower and upper values of the curve represent upper and lower quantitation limits. Curves are limited to linear relationships.

Determination of Interferences

A determination that the method is free from interferences in a blank matrix should be performed.

Determination of Capability

DOCs should be performed prior to method performance.

Determination of Accuracy and Precision

Accuracy and precision studies may be required as a separate determination from the DOC. Accuracy and precision studies are generally performed using four replicate analyses with the resulting percent recover and measures of reproducibility (standard deviation, relative standard deviation) calculated and measured against a set of target criteria.

Documentation of Method

The method should be formally documented in an SOP. If the method is a minor modification of a standard laboratory method that is already documented in an SOP, an SOP attachment describing the specific differences in the new method is acceptable in place of a separate SOP.

Continued Demonstration of Method Performance

Continued demonstration of method performance is addressed in the SOP by batch specific QA samples such as Laboratory control samples and method blanks.

7.3 Standard Operating Procedures (SOPs)

SOPs shall be written for all routine technical and administrative activities performed at Stone Environmental, Inc. SOPs shall describe as necessary the analytical, QA/QC and operational

protocol to be followed for each activity performed to reflect traceability of measurements. Employees must follow the procedures written in the SOP. Temporary deviations from an SOP may be necessary in order to meet the data quality objectives for a specific client or regulatory agency's request. Any department from the SOP will be documented in the project file.

Stone maintains two types of SOPs: method and procedural SOPs. Method SOPs describe a specific test method. Procedural SOPs describe function and procedures not related to a specific analytical method. SOPs, at a minimum shall undergo review every 2 years. Where a SOP is based on a published method, the laboratory shall maintain a copy of the referenced method as well. Stone's SOPs are maintained on file at the fixed facility, electronically, and pertinent laboratory SOPs are provided in each mobile laboratory and are available upon request.

8.0 Equipment Inventory

A comprehensive list of major instrumentation available, waterloo profiling and Membrane interface probe field equipment along with supporting and miscellaneous equipment can also be found in Appendix A.

8.1 Support Equipment

Equipment that are necessary to support laboratory operations but that are not the actual test instrument are maintained in proper working order and checked against an NIST traceable reference standard of measurement, when available over the range of use per the minimum frequency requirements given below:

- Refrigerator/Freezer Temperature Monitoring (Daily) when in operations
- Thermometer Calibration (based on the manufacturers expiration date) and verified against a certified thermometer annually.
- Balance Calibration Check – daily or before use with to certified weights that bracket the range of use and annually against certified weights from an outside vendor.
- Mechanic Volumetric Pipettes – Daily or prior to use

The performance criteria used to determine acceptability of use will vary based on the needs of the application for which the equipment is being used. In general, the laboratory has established tolerance ranges for analytical support equipment in accordance with the criteria established by the American Society for Testing and Materials (ASTM). Records of calibration checks and verification of support equipment are retained along with records of repair or maintenance in the equipment maintenance log.

8.2 Procedures for Calibration and Verification

Calibration of instrumentation is required to ensure that the analytical system is operating

correctly and functioning at the proper sensitivity to meet established reporting limits. Each instrument is calibrated with standard solutions appropriate to the type of instrument and the linear range established for the analytical method.

Method specific SOP's discuss in detail how each instrument is calibrated, including frequency for calibration and re-calibration, and the source or grade of the calibration materials. The range of analyses performed and instrumentation utilized is extensive and the calibration procedures are instrument specific, varying from analysis to analysis. The calibration procedures for organics usually include an initial system performance check and some type of initial calibration (with a minimum of five calibration standards for most methods) with each analytical series. On-going and closing calibration checks are also included in most analytical series. For each type of calibration standard or performance check there are specific criteria to meet before sample analyses begin. These criteria are established in the methodologies as they are written in the referenced texts or by contract specifications.

Gas Chromatography/Mass Spectrometry (GC/MS) - Prior to analysis of samples, the instrument is tuned with bromofluorobenzene (BFB) for volatile compounds and decafluorotriphenylphosphine (DFTPP) for semivolatile compounds or other tune criteria as specified by the method used. No samples are analyzed until the instrument has met the tuning criteria of the method.

In general, the instrument is then calibrated for target compounds. An initial calibration curve is produced to define the working range to establish criteria for identification. This initial calibration is evaluated on a daily basis to ensure that the system is within calibration. If the daily standard does not meet the established criteria, the system is recalibrated.

Gas Chromatography- Each chromatographic system is calibrated prior to performance of analyses. Initial calibration consists of determining the working range, establishing limits of detection, and establishing retention time windows. The calibration is checked as required to ensure that the system remains within specifications. In addition, continuing calibrations are performed at frequencies required by the method used. If the calibration checks do not meet established criteria, corrective action, which may include recalibration and reanalysis of samples, is taken.

Metals- Are typically performed in the field using HACH Kits. All applicable calibration requirements are defined in the instrument manual and as specified in the client's work plan.

Wet Chemistry - The field of classical (wet) chemistry involves a variety of instrumental and wet chemical techniques, for on-site measurements these tests are typically performed using designated kits. Calibration and standardization procedures vary depending on the system and analytical methodology required for a specific analysis. The calibration is checked on an ongoing basis to ensure that the system remains within specifications. If the ongoing calibration check does not meet established criteria, analysis is halted and corrective action is taken. The procedures include examination of instrument performance and recalibration and reanalysis of

samples back to the previous acceptable calibration check.

9.0 Purchasing Services and Supplies

Evaluation and selection of suppliers and vendors is done, in part, on the basis of the quality of their products, their ability to meet the demand for their products on continuous and short term basis, the overall quality of their services, their past history, and competitive pricing. This is achieved through evaluation of objective evidence of quality furnished by the supplier, which can include certificates of analysis, recommendations and proof of historical compliance with the similar programs for other clients. To ensure that quality critical consumables and equipment conform to specified requirements, all purchases from specific vendors are approved by a member of the management staff.

Chemical reagents, solvents, gases, glassware and general supplies are ordered as needed to maintain sufficient quantities on hand. Purchasing guidelines for all equipment and reagents effecting data quality shall meet the requirements of the specific method and testing procedure and be well documented. Similarly, performance specifications are documented for all items of equipment having an effect on data quality. This includes type, age, and acceptance status of the item. Reagents are dated upon receipt and upon opening to establish their order of use and to minimize the possibility of exceeding their shelf life. Specifications for labeling reagents, solutions and standards are outlined in SOP SEI-4.7.n Labeling Reagents, Solutions and Standards.

Requests for equipment affecting the quality of analytical data are submitted in writing to the Division and Laboratory Manager and/or Executive Management for technical approval. After approval, the requisition is submitted to the Executive Management for purchase approval.

10.0 Procedures for Traceability of Measurements

As necessary (when demonstrated by failure to calibrate), and appropriate, a technician services the company balances. This service is documented on each balance with a signed and dated calibration stamp. Balance calibrations are verified on a daily basis using traceable calibrated weights. Analytical balances are checked at multiple weights and the measured weight is recorded in a bound monitoring logbook. Any discrepancies are brought to the immediate attention of the QA Manager.

All mercury thermometers and temperature probes are purchased with certification certificates. The on-site Laboratory Manager maintains all thermometer calibrations. On a daily basis the temperature readings of the refrigerators and other temperature-controlled equipment are recorded in the monitoring logbook.

Sample storage refrigerators are typically maintained at $<6 >0^{\circ}\text{C}$.

Traceability of measurements is assured through the use of a system of documentation and analysis of testing materials. The supplier as to their accuracy certifies all standards used in the calibration of instrumentation. The laboratory maintains these certificates of analysis. The preparation of all standards is recorded in Standard Preparation Logbooks. Information to facilitate traceability is included in this documentation. All standard and reagent labels must contain the following information: solution ID, concentration, date of preparation, initials of preparer and expiration date.

The elements of the laboratories standards and reagents traceability program are outlined in the following SOP: *Labeling Reagents, Solutions and Standards (SEI-4.7.n)*.

11.0 Sampling - Procedures for Handling Test Items – Sample Custody

Sample representativeness and integrity are the foundations upon which meaningful analytical results rely. A documented and approved sampling plan reflecting data quality objectives should be in place at the sampling site. To prevent the deterioration of sample integrity, the samples should be maintained through the use of preservation techniques specified in Section 8.2 of SOP *The Determination of Volatile Organic Compounds by Gas Chromatography / Mass Spectrometry (GC/MS) (SW846 USEPA Method 8260C) (SEI-10.15.8)*. If necessary, samples should be submitted to the laboratory under standard chain-of-custody procedures as outlined in the SOP *Chain of Custody Records (SEI-4.2.n)*. Typically, for on-site laboratory work the samples are submitted directly from the field to the lab and documented in the laboratory upon receipt.

A designated analytical chemist receives samples at the laboratory. The analytical chemist removes the samples from the cooler (if applicable) and compares the sample labels with the information provided on the chain of custody form. If applicable, sample preservation, including temperature, is checked at the time of sample receipt.

Sample Acceptance Policy

Samples are considered “compromised” if the following conditions are observed upon receipt:

- Cooler and/or samples are received outside of temperature specification.
- Samples are received broken and leaking.
- Samples are received beyond holding time.
- Samples are received without appropriate preservative.
- Samples are received in inappropriate containers.
- COC does not match samples received
- COC is not properly completed or not received.
- Breakage of any Custody Seal.
- Apparent tampering with cooler and/or samples.
- Inadequate sample volume.
- Illegible, impermanent, or non-unique sample Labeling.

Any non-conformance or irregularity is noted and brought to the immediate attention of the Project Manager, and if appropriate, a Corrective Action is taken. The Project Manager takes appropriate action and documents the resolution with a phone log and attaches it to the client’s chain-of-custody.

The laboratory utilizes a custom designed database or laboratory information system to uniquely identify and track samples and analytical data throughout the mobile facility. The following information is entered into the computer: sample number (unique to this sample), client identification, date prepared (if applicable), date received, sample description (if applicable), additional comments, and notation of special handling instructions. Once logged in the samples are placed in the appropriate storage area pending analysis. Typically, all samples are analyzed on the same day that they are received so long term storage is typically not required.

11.1.1 Field Sampling Procedures

11.1.1.1 Membrane Interface Probe (MIP) Explorations

The MIP provides VOC data in the form of detector response (microvolts) for each of the detectors in a continuous vertical record at each location that it is advanced. The MIP system will be housed in a data acquisition truck equipped with a 10-kW diesel generator and lights, heat, air conditioning, water, GC, computers, printers and all the other equipment and tools necessary for efficient operation of the system. The truck will be equipped with two complete systems (MIP probe and trunkline) ready for deployment. The uphole detection system consists of a Hewlett Packard 5890 Series II gas chromatograph (GC) equipped with electron capture, photoionization and flame ionization detectors (ECD, PID and FID).

Prior to each hole, a response test will be performed. The primary purpose of the response test is to determine the travel time of the contaminant molecules from the membrane to the detectors at

the surface. The response test also provides valuable information on the condition of the membrane (and whether it needs to be replaced) as well as how well the detectors are operating. Following a successful response test, the MIP will be advanced at a rate of 1-ft/minute by pushing/hammering the probe into the ground using a GeoProbe rig. The MIP system, if continually advanced at 1-ft/minute results in “apparent drag down” or apparent smearing downward of the contamination relative to the actual concentrations in the ground after passing through highly contaminated zones. If very high detector responses are observed, driving is stopped to allow the system to “burn off” or flush out the contamination in the membrane and the carrier gas tubing. The probe temperature will be set at 120 degrees Celsius and the drive rate of 1-ft/minute ensures that the temperature does not fall significantly. Gas flow rate, pressure, temperature are monitored as the probe is advanced, along with the electrical conductivity of the soil and the response of the detectors to the gas stream.

MIP locations are located on a grid with a rough spacing of approximately 180 ft as agreed upon by the client. Areas are often designated as “floating” locations to be used to concentrate on areas believed to be likely source areas. MIP data is observed in real-time on the computer monitor. At the completion of each hole, a data plot is printed out for the use of the field team. The data files are emailed to the Stone data management team in Montpelier, VT on the wireless internet connection in the MIP truck at the completion of each hole for QA/QC review and for creation of final data plots. The MIP standard operating procedure for the MIP investigation is found in Appendix D.

11.1.2 Groundwater Investigation—WaterlooAPS-TM

Stone performs vertical groundwater profiling using the WaterlooAPS TM (Advanced Profiling System) typically at the same locations as the MIP investigations or at pre-plan investigative areas and in accordance with the standard operating procedure (SEI-10.5.3) found in Appendix D.

The WaterlooAPS-TM provides high quality, discrete depth samples for groundwater analysis. The system also provides a real-time vertically continuous record of the Index of Hydraulic Conductivity (IK) with which to assess the hydrostratigraphy at each location. The IK data are used to identify low permeability units within the flow system and sample at the interfaces of these units. High concentrations zones observed in the data can be “back projected” to source zones. Concentrations at or near the effective solubility limit for individual compounds are indicative of nearby DNAPL.

The subsurface investigation is performed along transects oriented at right angles to the groundwater flow direction. The location of the transects, the length of transects and horizontal spacing between points will be adjusted on the basis of the MIP and soil gas data. Vertical sampling depths will be targeted on the basis of MIP results and the real-time IK data.

The profiler is driven below the water table and used to collect groundwater samples. The initial assumption is that groundwater samples will be collected just below the water table and every 5 feet or 10 feet. Actual depths are based on real time IK and MIP results where applicable. In addition to the collection of groundwater samples for onsite analysis for VOCs, the system will be used to:

1. Measure a vertically continuous record of the hydrostratigraphy in the form of the Index of Hydraulic Conductivity (IK);
2. Measure the depth to the potentiometric surface at each sample depth; and
3. Measure physiochemical properties such as pH, specific conductance, dissolved oxygen, oxidation/ reduction potential, and temperature.

The profiling equipment will be calibrated prior to beginning work and at a minimum of once per week during the field program.

The WaterlooAPS-TM profiling tip is equipped with 16 ports, each with a 0.64 cm diameter. The ports are arranged in four recessed rows, resulting in an open interval approximately 6 cm (2.4 inches) in length. This configuration increases the speed of sampling and minimizes the potential for the ports to become plugged while transiting hydrostratigraphic units with a high content of fines. To further minimize the potential for plugging, the screens are flush with the outer surface of the profiling tip. This prevents high plasticity soils from entering the recessed ports and blocking inflow. In addition, each port is fitted with a double screen: a coarse outer screen and a finer inner screen.

The stainless steel profiler tip is fitted with 1/8-inch outside diameter stainless steel tubing as shown in the figure below. The tubing is added in 20-foot lengths using SwageLok couplings as the profiler is driven. The drive rod coupled to the profiling tip is custom-made heavy-duty direct push rod that has an outside diameter of 1¾ inch. This diameter is uniform along the length of the rod and profiling tip to minimize the potential for fluid movement along the rod to the tip.

The WaterlooAPS-TM data acquisition system and all necessary tools and supplies are housed in a data acquisition vehicle which provides a safe, weather insulated, high productivity work place for the field team.

Groundwater samples are collected using the WaterlooAPS-TM nitrogen gas-drive/positive displacement pump located downhole. All data are collected in a single, continuous push.

11.1.3 Index of Hydraulic Conductivity

The Index of Hydraulic Conductivity (IK) is determined by pushing analyte-free water into the formation from the profiler tip as the tool is advanced. Compressed nitrogen is used to pressurize a stainless steel vessel containing water at a fixed pressure. The flow rate and back pressure are measured using in line electronic flow meter and pressure transducer. The IK is a unique and powerful metric for assessing hydrostratigraphy in real-time. An example of Index of Hydraulic Conductivity data is shown in figure below.

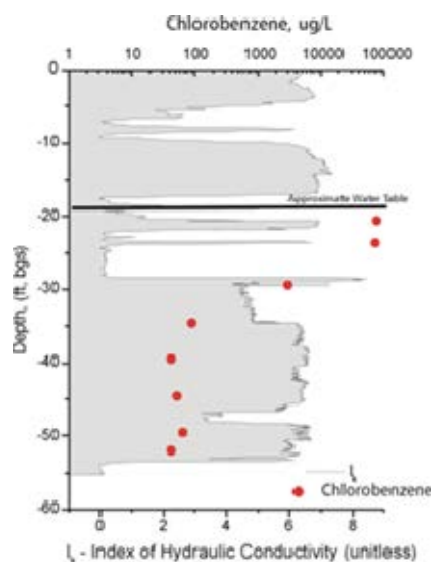


Figure 1. Example Index of Hydraulic Conductivity Data

The Index of Hydraulic Conductivity reveals five low hydraulic conductivity (K) layers (in this case, clay) with relatively high hydraulic conductivity sand between them. This is actually an extensive clay aquitard known as the Yellow Clay which happens to have significant and laterally extensive sand layers within it. These data were used in real-time to stop the advance of the Profiler and collect a groundwater sample. The plot shows that the ability to detect and sample the high-K zones allowed identification of concentrations several orders of magnitude higher than those in the rest of the profile.

The IK record allows for the identification of high-K zones during the same push in which samples are collected. As a result, no time is lost to multiple tool advances or in attempting to sample low-K, non-productive zones. Field personnel view the data in real-time and use it to target sampling to maximize the value of each profile location. The data can also be correlated between profiles and used to determine the 2 and 3-D geometry of low-K zones across the site. The solute distributions obtained from MobiLab analysis of the samples were superimposed on the stratigraphy in the lower half of the figure above. The results showed that the highest

concentration zones were either in sandy interbeds within the clay unit or immediately under the clay unit.

11.1.4 Rate of Penetration

Rate of penetration (ROP) is measured using a string potentiometer on the direct push rig. The ROP data show stratigraphic changes that may affect contaminant transport or design basis data used for remedial design.

11.1.5 Geochemical Properties

Using flow cell parameters rather than a predetermined purge volume ensures that formation water is sampled. In addition, the diversity of the flow cell parameters provides insight into the geochemical environment. A series of water quality probes in a sonde, equipped with a custom-built small volume volume flow cell, is placed in-line on the discharge side of the pump. This custom flow cell minimizes the volume of water that must be pumped to achieve equilibration of parameters. The sonde and flow cell are integrated into the data acquisition system. These data are displayed on the notebook computer screen inside the data acquisition support vehicle, protected from the weather. The sonde monitors pH, specific conductance, temperature, dissolved oxygen, and oxidation/reduction potential. These data are used to determine when sufficient purging has occurred prior to sampling. In addition, the equilibrium data can be used in assessments of fate and transport.

Data generated at each location include:

- Index of Hydraulic Conductivity with depth
- Depth to the potentiometric surface at each sample depth
- Rate of penetration
- Specific conductance at each sample depth
- pH at each sample depth
- Dissolved oxygen concentration at each sample depth
- Oxidation/reduction potential at each sample depth

The WaterlooAPS-TM provides detailed information on the hydrostratigraphy as well as samples for onsite analysis for VOCs. Concentrations near the effective solubility limit are indicative of nearby DNAPL. In some situations the profiler has recovered DNAPL from the subsurface for direct confirmation of DNAPL pools.

Very high detector responses with the MIP and concentrations of VOCs at the effective solubility limit from the WaterlooAPS-TM are indicative of nearby DNAPL. To confirm the actual presence of DNAPL, locations will be targeted for soil coring and subsampling. The subsamples from the cores will be analyzed on site for VOCs and offsite for physical properties from which phase partitioning calculations can be done to determine the presence of DNAPL. In

addition, visual methods augmented by Oil Red O (hydrophobic dye) and ultraviolet light will be used to directly observe DNAPL. The aquitard (silt and clay) materials will also be sampled and analyzed to assess the degree of diffusive flux of contaminants into the aquitard materials and the potential for these layers to act as long term sources of contamination.

11.1.6 Collection of Water Samples for Analysis

Once the sampling depth is reached, driving ceases and the outflow of water is shut off and the sampling process begins as water is purged through the sample vials and the water quality flow cell. Flow cell parameters are monitored and purging continues until the water quality parameters equilibrate. The equilibration values are recorded and the sample is collected by removing the VOA vials for the sampling jig, capping them and taking them to the onsite laboratory for analysis by Method 8260C. Typical purge volumes for the peristaltic pump approach range from 500 mL to 1000 mL.

11.2 Holding Times, Preparation and Sample Screening

Holding times for every analysis are established in the method SOPs or on a project specific basis. Typically, all samples are analyzed on the same day that they are received so holding times are not a concern. The Laboratory Manager and the Client schedules the workload to expedite the field investigations. If any holding times are not met the laboratory informs the Project Manager as soon as possible and the Project Manager notifies the client.

Samples are prepared according to performance base standardized methods. Batches are generated in the lab according to preparation method, analytical method, matrix and reporting turnaround time. In general, if necessary batches do not exceed 20 field samples of the same matrix and are defined as samples prepared at the same time.

Inorganics (Metals and Wet Chemistry) - Samples for analyses are prepared in batches containing a maximum of 20 samples of the same or similar matrix. A laboratory blank and laboratory control sample are digested with each batch. A matrix spike and replicate analyses are performed for every 20 samples of the same matrix as requested by the analytical program and available.

Organics - Samples for organics analyses are prepared in batches containing a maximum of twenty samples of the same or similar matrix and reporting turnaround time. A method blank is performed with each batch. Lab control samples are extracted with each batch for applicable methods. Matrix spike and matrix spike duplicate analyses are performed for every 20 samples of the same matrix.

Re-preparation - Re-preparation or re-analysis of a sample may be required in cases of contamination, missed dilution, low surrogate recovery, etc. If the need for reanalysis/re-preparation has been determined, the request is forwarded to the appropriate analytical chemist

Screening – If necessary and appropriate, samples for organics analyses are screened prior to analysis and/or extraction. Screening helps to prevent unnecessary re-runs and lower instrument re-calibration, re-tune and analyst labor time and may be done on the instrument and the use of a PID.

11.2.1 Sample Disposal

Stone Environmental, Inc. retains samples for up to 30 days after the project report is sent unless prior written arrangements have been made with the client or as in some cases samples require disposal on-site. Samples shall be disposed of in accordance with federal, state and local regulations. The laboratory procedures for sample disposal are further described in the laboratory SOP *On-Site Laboratory Waste Handling, Storage and Disposal* (SEI-10.14.n)

12.0 Assuring the Quality of Test Results

The quality control program implemented in the laboratory includes the analysis of method blanks, check standards, laboratory control samples, analytical spikes, and surrogate spikes. Depending upon the analysis, every analytical series includes one or more of these controls. The combination of controls used in an analysis must be completely representative of the analytical task including all aspects of sample preparation and sample analysis. This section describes routine procedures used to monitor laboratory method performance and substantiate validation of data. Controls analyzed in conjunction with samples are essential in the evaluation of the quality of the generated data. These programs may include any of the following quality controls in addition to other project specific obligations.

12.1 Quality Control Samples

Method blanks are prepared and analyzed with each analytical batch of twenty or fewer samples to identify possible sources of contamination within the analytical process. Method blanks are treated as samples (i.e., they go through each stage of the analytical process including glassware, reagents, instrumentation, and any other source of possible contamination that may affect sample results). Surrogate recoveries, and elevated levels of compounds must be evaluated for method blanks. The control limits and corrective actions for method blanks are defined in the method SOP's.

Instrument Blanks and/or Fiber Blanks are prepared as an unprocessed aliquot of reagent used to monitor the contamination of the analytical system. An instrument blank is analyzed at the start of the analytical sequence and after highly contaminated samples to confirm that the instrument is contaminate-free before continuing with sample analyses. Instrument blanks are also commonly known as *continuing calibration blanks* in inorganic analyses.

Equipment Blanks/field blanks are prepared as an unprocessed aliquot of reagent used to monitor

the contamination of the field sampling system. An equipment blank is analyzed at the start of a boring hole and after highly contaminated samples to confirm that the field equipment is contaminate-free before continuing with the boring hole.

Laboratory Control Samples (LCS) are prepared and analyzed with each batch of samples. Laboratory control samples are fortified with all compounds of interest at documented levels and when applicable with the same spiking solution as the matrix spike (MS) sample. Aqueous and solid laboratory control samples are analyzed using the same sample preparation, reagents, and analytical methods employed for the samples received. Method performance is monitored by the measure of accuracy of the results. The results of the LCS, used in conjunction with the MS samples provide an indication of whether the laboratory performed the method correctly or the sample matrix affected the results. When a laboratory control sample duplicate (LCSD) is required, a percent recovery may be calculated, as well as a relative percent difference (RPD) between the LCS and the LCSD. The control limits and corrective actions for LCS's are defined in the method SOP's.

Surrogates are non-target analyte compounds that are similar in composition and behavior to the target analytes but are not expected to be found in environmental media (often, isotopically labeled target analyses are used). Surrogates are spiked into every sample, quality control sample and method blank for organic analyses. Extractable organic analyses are spiked with surrogates at the time of extraction; and volatiles prior to analysis. Surrogates responses are used to evaluate the accuracy of the laboratory performance of the analytical method in a specific sample matrix and are expressed as percent recoveries. The control limits and corrective action for surrogate spikes are specified in the method SOP's.

Internal Standards (IS) are non-target analyte compounds that are similar to the target analytes but are not expected to be found in environmental media (generally, isotopically labeled target analytes are used) and are added to every standard, quality control sample and field sample at a known concentration prior to analysis. Internal standard area responses and retention times are evaluated in all samples and blanks according to the method of analysis. IS responses are used as the basis for quantitation of target analytes. LCS samples are also commonly known as method blank spikes. The control limits and corrective action for internal standards are specified in the method SOP's.

Matrix Spikes/Matrix Spike Duplicates (MS/MSD) are prepared and analyzed with each batch of 20 samples or less (if specified by the client) of the same matrix for organic analyses and a MS is prepared and analyzed with each batch of 20 samples of the same matrix for inorganic analyses. The MS/MSD samples are prepared by taking an aliquot of an actual site sample and fortifying it with the selected target analytes of interest. The MS/MSD samples are analyzed using the same sample preparation, reagents, and analytical methods employed as the field samples. MS and MSD responses are used to evaluate the accuracy and precision of the laboratory performance of the analytical method in a specific sample matrix. Results from site samples other than those belonging to the client will not be reported with the data package. Control limits for recoveries

of the matrix spike/matrix spike duplicate compounds are listed in the method SOP's.

Replicate analyses are prepared and analyzed for inorganic samples and for certain organic drinking water analyses with each batch of 20 samples of the same matrix. Control limits for replicate analyses are listed in the method SOP's.

Calibration Check Standards are analyzed with each analytical series at the frequencies stated in the methods. For metals, GC, and Wet Chemistry analyses calibration check standards are analyzed at a typical frequency of 10%, or after every ten samples unless otherwise noted in the site work plan. For GC/MS analyses, the frequency of the calibration check standard is every 12 hours. The tuning criteria must be met prior to analyzing blanks, standards or samples. Control limits for calibration check standards are listed in the method SOP's.

Parameter	QC type	Frequency	Control Limits	Corrective Action
Volatile/Semi-volatile Organics	method blank	1 per batch	Target analytes below RL, 10x exception for lab solvents, DOD < ½ RL	System check, reanalysis of affected samples
	surrogate spike	each sample, standard, blank	Limits listed in method	Review, reanalyze based on technical judgment
	MS/MSD	set per 20 samples per matrix	Limits listed in method	Report results
	LCS/	1 per batch	Limits listed in method	Review, reanalyze LCS and associated samples, based on technical judgment.
	ICV (independent)	After initial calibration	%Recovery 70-130, unless otherwise listed in method	Review, reanalyze ICV, check standards, recalibrate if appropriate.
Metals	lab reagent/prep blank	1 per 20 samples or batch	analyte below RL	redigest batch
	LCS	1 per batch	Soils- Limits provided by vendor; Waters - ± 20%	redigest batch
	replicates	1 per 20 samples per matrix	± 20%	flag results
	matrix spikes	1 per 20 samples per matrix	75-125%	flag results
Wet Chemistry	lab reagent/prep blank	1 per 20 samples or batch	analyte RL	system check, reanalysis of batch
	LCS	1 per batch	80-120% recovery	system check, reanalysis of batch
	replicates	1 per 20 samples per matrix	± 20%	flag results
	matrix spike	1 per 20 samples per matrix	75-125%	flag results

RL = Reporting Limit

12.2 Data Reduction

The Laboratory provides extensive data review prior to reporting results to the client. In general an analyst will process data in one of the following ways:

- Manual computation of results with manual reporting
- Computer computation of results with manual reporting
- Computer computation and reporting of results

If the analyst manually processes the data, all steps in the computation are provided for review including the source of the input parameters such as response factors, dilution factors, and calibration constants. All calculations of manually processed data are checked during secondary review.

For data that are processed using a computer and then entered into the Laboratory Information System by an analyst or data entry personnel, a hard copy of the computer-generated results is kept and uniquely identified with the sample number and any other preparation or dilution information as may be needed. The hard copy results are used for data validation and secondary review.

If computer processed data are directly acquired from the instrumentation, hard copies of the actual data are made and the analyst verifies that the following are correct before releasing instrumental data to the reporting system:

- Sample numbers
- Calibration constants/ response factors
- Output parameters such as units and compound names
- Numerical values used for detection limits
- Dilution and preparation factors

The hard copy of the results is used for data validation and review. After initial demonstration of proficiency of computerized programs computer calculations are randomly spot checked while the manual entry of every result is verified.

12.3 Data Review

The analyst is responsible for primary review of data generated from sample analysis. If the instrument calibration and recoveries of all quality control samples are within specified tolerances, then the data are presented for secondary review. If instrument calibration or the recoveries of any quality control samples exceed specified tolerances, then affected sample results are evaluated and generally the samples are submitted for re-analysis. Any manual integration that occurs are dated and signed and if appropriate, noted in the case narrative.

Secondary review (a complete technical review) is typically conducted by the designated data review personnel to determine if analytical results are acceptable. All calibrations, manual calculations and transcriptions are checked for accuracy and quality control sample results are evaluated against specified tolerances. If instrument calibration and recoveries of all quality control samples are within specified tolerances, then the data are presented to a senior analytical chemist or on-site designated deputy for final review. Periodically, during a Level IV reporting project, a complete data integrity audit will be performed during the secondary review and documented on the data integrity audit checklist.

Designated chemistry personnel perform final review of the data to determine if all analytical results of a sample(s) are consistent. Correlation of results for different parameters of a sample is evaluated at this time before the data is presented in a final report to the client. If discrepancies or deficiencies exist in the analytical results, then corrective action is taken.

Periodic data audits of final reports by the QA Manager are conducted to determine that precision, accuracy, completeness and traceability goals of the sample analysis are being conducted.

13.0 Reporting Results - Data Reports

After all analytical data have been reviewed; the final analytical report is assembled for submission to the client. The on-site laboratory can currently offer five levels for reporting analytical results.

Level I data consist of measurements taken during field analysis with the report consisting of results only.

Level II reporting consists of an analytical report with results only. Internal quality control results are retained on file at the laboratory.

Level III reporting consists of an analytical report with internal quality control results reported; these include laboratory control standards, surrogate spike recoveries, and method blank results.

Level IV data refers to data submitted in CLP-like format. Level IV is defined by the submission of QA/QC supporting material including the raw laboratory data similar to that provided with CLP Statements of Work (SOW). Submission of data in this format results in an independently validatable package. Level IV reporting includes narrative or comments of concern, analytical results, supportive documentation including all raw data and preparation sheets, and all documentation related to chain of custody. Once the document is assembled, the sections may be distinguished with colored paper with their respective titles. Copy(s) of the documentation are sent to the client, and the original document is retained in storage for a minimum of seven (7) years.

Level V data have unique requirements in compound identification, quantitation, detection limits, cleanup, or QA/QC requirements. Level V analytical procedures are generally defined as Special Analytical Services. The procedures and QA/QC are specified through these requests. The QA/QC for Level V data usually requires frequent standardization, spikes, duplicates, blanks, and strict compound identification criteria.

13.1 Project Reports

The criteria described in Section 13.1.1 apply to all Project Reports that are generated under NELAP requirements and DOD ELAP ISO 17025 requirements. The criteria described in Section 13.1.2 and 13.1.3 applies to all client reports.

13.1.1 Project Report Content

- Title
- Laboratory Name, address, telephone number, contact person and location where the test was carried out if different from the fixed laboratory address.
- Unique Laboratory Project Number
- Total number of pages (report must be paginated)
- Client Project Number (if applicable)
- Laboratory Sample Identification (if applicable)
- Client Sample Identification
- Test Method
- Matrix and/or description of sample
- Dates: sample collection, collection time, sample receipt, preparation and/or analysis date.
- Definition of data qualifiers
- Reporting units
- Solid samples: indicate dry or wet weight
- Indication by flagging where results are reported below the quantitation limit.

13.1.2 Project Narrative/Cover Letter

A Project Narrative and/or Cover Letter is included with each project report and at a minimum includes an explanation of any and all of the following occurrences:

- Non-conformances that apply to project contracts and under NELAP requirements.
- “Compromised” sample receipt
- Method Deviations
- QC criteria failures

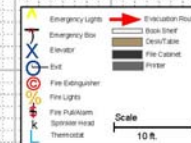
In addition, each report will include the following statement: The analytical procedures and test results in this report are in accordance with the NELAP standards and meet all NELAP requirements for parameters for which accreditation is required or available. The reports were completed according to contract specific reporting requirements. Any exceptions to the NELAP standard requirements are noted here or in the case narrative and all data has been flagged accordingly.

QSM
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Date: March 25, 2013

APPENDIX A
Facilities (Floor Plans) and
Capabilities (Equipment)



Figure 2: Typical Mobile Laboratory Layout



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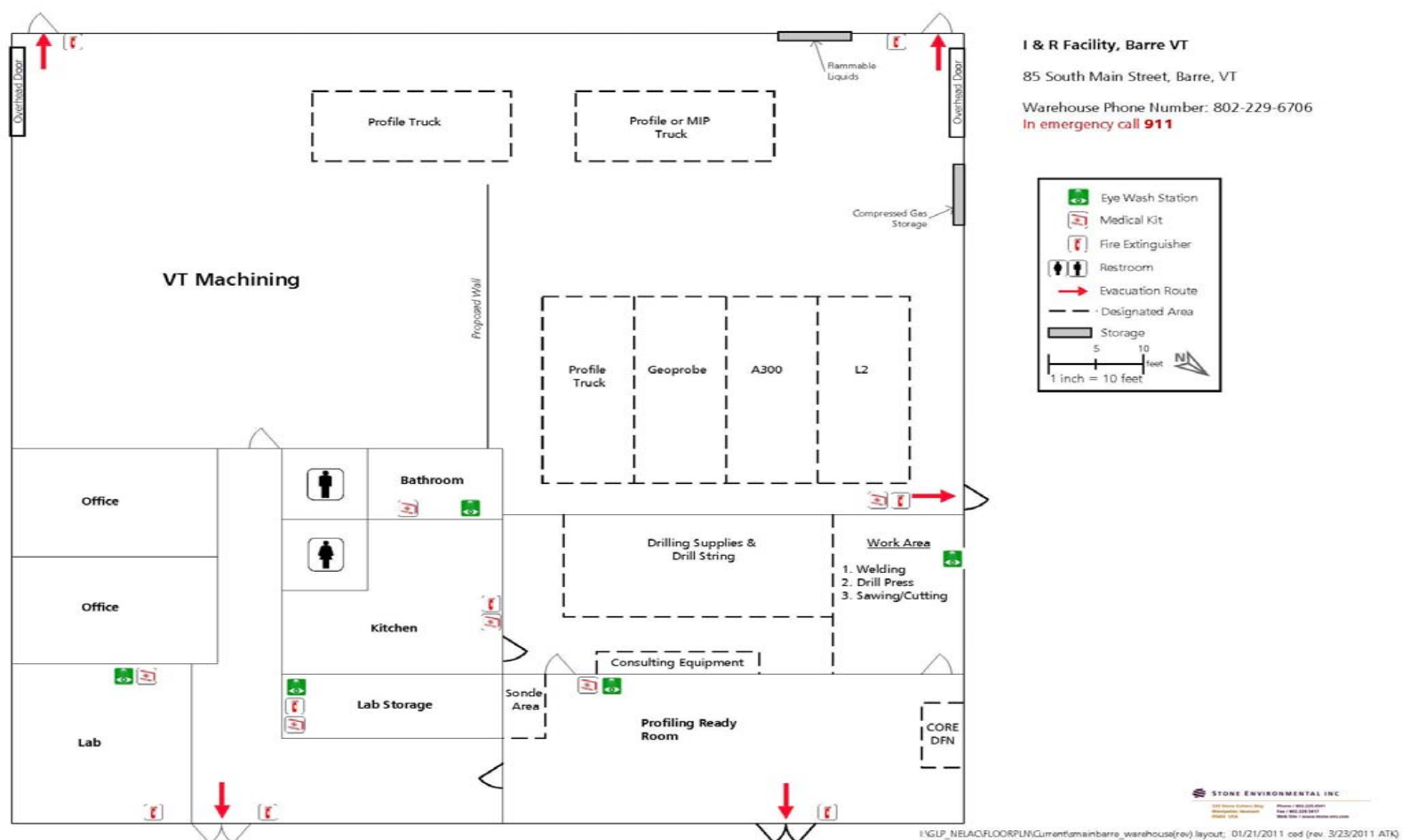


Figure 4: Fixed Lab Layout, 85 South Main Street, Barre, VT

Mobile Laboratory and Field Sampling for MIP and Profiling Equipment Inventory

The following is a comprehensive list of major instrumentation available along with supporting and miscellaneous equipment.

Mobile/Fixed Laboratory Set-Up (may include)			
Make and Model	Description	Quantity	Date Acquired
Hewlett Packard HP5890II HP5890	Gas Chromatographs equipped with dual heated injection ports, capillary inlets for split/splitless, and dual FID (flame ionization detectors). Data is collected on HP G2070AA ChemStation, Rev A.09 03[1417]	5	5/98, 2/03, 3/03, 5/03, 12/05
HP6890	Gas Chromatographs equipped with dual injection ports (split/splitless and cool-on-column) and dual micro-Electron Capture Detectors. Data is collected on HP G2070AA ChemStation, Rev A.10	1	2/08
Hewlett Packard HP5971A MSD	GC/MS System with HP5890II GC. Equipped with dual injection and dual detectors (a MS detector and FID detector). HPG1033A NIST Spectral Library, Data is collected on HP G1701AA MS ChemStation.	2	10/03 12/05
Milestone Ethos Series	Microwave oven equipped with temperature and energy control and a 12-place extraction vessel rotor.	1	02/08
Supelco	Solid Phase Micro-Extraction (SPME) preparation of Volatile and Semi-volatile analytes	4	Various
Various	Miscellaneous equipment: Hot Plates-PC-400, stir plates, pH meter, balances, syringes, laboratory support equipment, pressure regulators		Various
Trailer/ Truck/Vehicle	Mobile Lab 2 = VIN# 1UK500F2541047129 Mobile Lab 1 = VIN#JALE5B16067901082, Off job location, 85 South Main Street, Barre, VT. Truck 6 = VIN#JW6CEJ1G7SL002457		Various

Information Systems: All terminals, PC's and printers are connected on an integrated Local Area Network (LAN) via network switches, routers and wide area links. Extensive variety of software to aid in data analysis and presentation: Microsoft Office Products (Excel, Word, etc), programming environments. All lab personnel have access to the World Wide Web for additional resources. Additional equipment in the laboratories is as follows: printers, personal computers and HP GC/MS's with the HP chemstation (3) software.

Waterloo Advanced Profiling System Equipment Inventory

Waterloo Advanced Profiling System Set-Up (may include)			
Make and Model	Description	Quantity	Date Acquired
Waterloo Profiler	System comprised of a 1.5", 1.75", or 2.25" diameter tip attached to GeoProbe style rod and stainless steel sample line		Various
SEI KPRO Box	System comprised of the zero head space sample jig , valves, electronic enclosure, and peristaltic pump.	10	2002, 2003
Sonde Water Quality Monitoring Systems	Several models are used including Troll 9000, Torll 9500, YSI 600XL, HydroLab MS-5, and Hach HQ30.	10	Various
Various	Miscellaneous equipment: string potentiometers, pressure regulators, pressure vessels		Various

Information Systems: Ruggedized laptops have an extensive variety of software to aid in data analysis and presentation: Microsoft Office Products (Excel, Word, etc), programming environments, LabView and Kpro Data logging software. All sampling personnel have access to the World Wide Web for additional resources.

Membrane Interface Probe Equipment Inventory

The following is a comprehensive list of major instrumentation available along with supporting and miscellaneous equipment.

Membrane Interface Probe Set-Up (may include)			
Make and Model	Description	Quantity	Date Acquired
Geoprobe FI6000	Data Acquisition Field Instrument	1	1/11
Geoprobe MP6505	Flow Controller	1	1/11
Hewlett Packard HP5890II	Gas Chromatograph equipped with Photoionization (PID), Electron Capture (ECD) and Flame Ionization (FID) detectors.	1	1/05
Various	Miscellaneous support equipment: flow meters, multi meters, syringes, pressure regulators, MIP probes		Various
Trailer/Truck/Vehicle	Truck 5 = VIN#JALE5B16167901916		Various

Information Systems: Extensive variety of software to aid in data analysis and presentation: Microsoft Office Products (Excel, Word, etc). All lab personnel have access to the World Wide Web for additional resources. Additional equipment in the MIP laboratory is as follows: printers and personal computers.

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Revision 10
Date: March 25, 2013

APPENDIX B

Analytical Capabilities

**Stone Environmental, Inc. Mobile Laboratory
Analytical Methodologies**

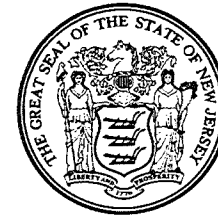
Reference	Method	Description
ASTM	D6520	Solid Phase Micro-extraction of water and its headspace for analysis of Volatile and Semi-volatile Organic Compounds
ASTM	D6520	Methanol extraction of soils (EPA 5035H, MeOH preservative) and Solid Phase Micro-extraction of soil extract and its headspace for analysis of Volatile and Semi-volatile Organic Compounds
EPA SW846	8260C	Volatile Organic Compounds by Gas Chromatography (GC)/Mass Spectrometry (GCMS) for Waters and Soils using Solid Phase Micro-extraction.
SOP SEI-10.17.1		Microwave Assisted Extraction of Volatile Organic Compounds From Rock Samples
SOP SEI-10.18.1		The Determination of Volatile Organic Compounds By Gas Chromatography/Dual ECD Detectors in Rock Samples (Using Cool On-Column Injection and Split Method Injection).
EPA SW-846	Modified 8015	Field TPH- Gasoline and Diesel
EPA SW-846	Modified 8021	Field GC Aromatic and Halogenated Volatile Organics
EPA SW-846	Modified 8082	Field Determination of Polychlorinated Biphenyls (PCBs) by Gas Chromatography with an Electron Capture Detector (ECD)
EPA SW8015	Modified 8015	Field Direct injection of Gas Chromatograph – Select Compounds
EPA SW-846	6200	Field Portable XRF Spectroscopy for the Determination of Elemental Concentrations in Soil and Sediment
EPA SW-846	4020	Screening for PCBs by Immunoassay
EPA SW-846	4035	Screening for PAHs by Immunoassay
Standard Methods	3500FE	Ferrous Iron (Phenanthroline Method)
Standard Methods	4500 CIG	Chlorine
HACH Kit	Various	Nitrate, Hexavalent Chromium

QSM
Revision 10
Date: March 25, 2013

APPENDIX C

Laboratory Accreditation

State of New Jersey
Department of Environmental Protection
Certifies That



Stone Environmental, Inc.

Laboratory Certification ID # VT001

is hereby approved as a

Nationally Accredited Environmental Laboratory
*to perform the analyses as indicated on the Annual Certified Parameter List
which must accompany this certificate to be valid*

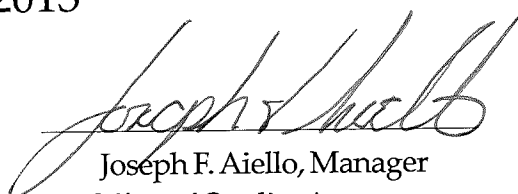
having duly met the requirements of the
Regulations Governing The Certification Of
Laboratories And Environmental Measurements N.J.A.C. 7:18 et. seq.
and

having been found compliant with the 2009 TNI Standard approved by the
The NELAC Institute

Expiration Date June 30, 2013



NJDEP is a NELAP Recognized Accreditation Body


Joseph F. Aiello, Manager
Office of Quality Assurance

This certificate is to be conspicuously displayed at the laboratory with the annual certified parameter list in a location on the premises visible to the public.
Consumers are urged to verify the laboratory's current accreditation status with the State of NJ, NELAP.

New Jersey Department of Environmental Protection
National Environmental Laboratory Accreditation Program
ANNUAL CERTIFIED PARAMETER LIST AND CURRENT STATUS
Effective as of 07/01/2012 until 06/30/2013



Laboratory Name: STONE ENVIRONMENTAL, INC. Laboratory Number: VT001 Activity ID: NLC120001
535 STONE CUTTERS WAY
MONTPELIER, VT 05602

Category: SHW05 -- Organic Parameters, Prep. / Screening

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Certified	Yes	NJ	SHW05.05230	NPW, SCM	Solid Phase Microextraction	[ASTM D6520]	Organics

Category: SHW07 -- Organic Parameters, Chromatography/MS

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Certified	Yes	NJ	SHW07.04010	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Benzene
Certified	Yes	NJ	SHW07.04020	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chlorobenzene
Certified	Yes	NJ	SHW07.04030	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichlorobenzene (1,2-)
Certified	Yes	NJ	SHW07.04040	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichlorobenzene (1,3-)
Certified	Yes	NJ	SHW07.04050	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichlorobenzene (1,4-)
Certified	Yes	NJ	SHW07.04060	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Ethylbenzene
Certified	Yes	NJ	SHW07.04065	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Isopropylbenzene
Certified	Yes	NJ	SHW07.04070	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Toluene
Certified	Yes	NJ	SHW07.04073	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trimethylbenzene (1,2,4-)
Certified	Yes	NJ	SHW07.04074	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trimethylbenzene (1,3,5-)
Certified	Yes	NJ	SHW07.04080	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylenes (total)
Certified	Yes	NJ	SHW07.04081	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylene (m-)
Certified	Yes	NJ	SHW07.04082	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylene (o-)
Certified	Yes	NJ	SHW07.04083	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylene (p-)
Certified	Yes	NJ	SHW07.04090	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Bromodichloromethane
Certified	Yes	NJ	SHW07.04100	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Bromoform
Dropped	No	NJ	SHW07.04111	NPW, SCM	GC/MS, P&T, or Direct Injection, Capillary	[SW-846 8260B]	Cyclohexane
Certified	Yes	NJ	SHW07.04120	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Carbon tetrachloride
Certified	Yes	NJ	SHW07.04130	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chloroethane
Certified	Yes	NJ	SHW07.04150	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chloroform
Certified	Yes	NJ	SHW07.04160	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chloromethane
Certified	Yes	NJ	SHW07.04170	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropene (trans-1,3-)
Certified	Yes	NJ	SHW07.04180	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dibromochloromethane
Certified	Yes	NJ	SHW07.04185	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dibromoethane (1,2-) (EDB)
Certified	Yes	NJ	SHW07.04187	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dibromo-3-chloropropane (1,2-)

KEY: AE = Air and Emissions, BT = Biological Tissues, DW = Drinking Water, NPW = Non-Potable Water, SCM = Solid and Chemical Materials

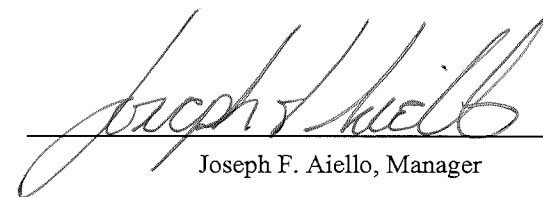
New Jersey Department of Environmental Protection
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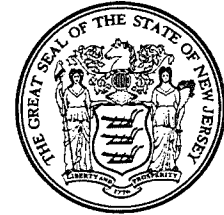
Category: SHW07 – Organic Parameters, Chromatography/MS

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Certified	Yes	NJ	SHW07.04200	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethane (1,1-)
Certified	Yes	NJ	SHW07.04210	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethane (1,2-)
Certified	Yes	NJ	SHW07.04220	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethene (1,1-)
Certified	Yes	NJ	SHW07.04230	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethene (trans-1,2-)
Certified	Yes	NJ	SHW07.04235	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethene (cis-1,2-)
Certified	Yes	NJ	SHW07.04240	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropane (1,2-)
Certified	Yes	NJ	SHW07.04250	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropene (cis-1,3-)
Certified	Yes	NJ	SHW07.04260	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Methylene chloride (Dichloromethane)
Certified	Yes	NJ	SHW07.04270	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Tetrachloroethane (1,1,2,2-)
Certified	Yes	NJ	SHW07.04280	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Tetrachloroethene
Certified	Yes	NJ	SHW07.04290	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloroethane (1,1,1-)
Certified	Yes	NJ	SHW07.04300	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloroethane (1,1,2-)
Certified	Yes	NJ	SHW07.04310	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloroethene
Certified	Yes	NJ	SHW07.04322	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloro (1,1,2-) trifluoroethane (1,2,2-)
Certified	Yes	NJ	SHW07.04330	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Vinyl chloride
Certified	Yes	NJ	SHW07.04350	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Carbon disulfide
Certified	Yes	NJ	SHW07.04390	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Methyl tert-butyl ether
Dropped	No	NJ	SHW07.04535	NPW, SCM	GC/MS, P&T, or Direct Injection, Capillary	[SW-846 8260B]	Methylcyclohexane
Certified	Yes	NJ	SHW07.04540	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Naphthalene
Certified	Yes	NJ	SHW07.04550	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Styrene
Dropped	No	NJ	SHW07.04560	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Tetrachloroethane (1,1,1,2-)
Certified	Yes	NJ	SHW07.04570	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichlorobenzene (1,2,4-)


Joseph F. Aiello, Manager

KEY: AE = Air and Emissions, BT = Biological Tissues, DW = Drinking Water, NPW = Non-Potable Water, SCM = Solid and Chemical Materials

State of New Jersey
Department of Environmental Protection



Certifies That

Stone Environmental, Inc.

Laboratory Certification ID # VT002

is hereby approved as a

Nationally Accredited Environmental Laboratory

to perform the analyses as indicated on the Annual Certified Parameter List

which must accompany this certificate to be valid

having duly met the requirements of the

Regulations Governing The Certification Of

Laboratories And Environmental Measurements N.J.A.C. 7:18 et. seq.

and

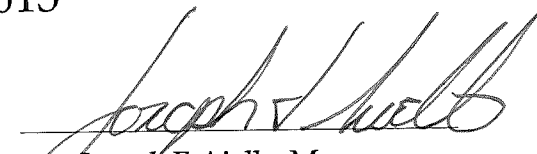
having been found compliant with the 2009 TNI Standard approved by the

The NELAC Institute

Expiration Date June 30, 2013



NJDEP is a NELAP Recognized Accreditation Body


Joseph F. Aiello, Manager
Office of Quality Assurance

This certificate is to be conspicuously displayed at the laboratory with the annual certified parameter list in a location on the premises visible to the public.
Consumers are urged to verify the laboratory's current accreditation status with the State of NJ, NELAP.

New Jersey Department of Environmental Protection
National Environmental Laboratory Accreditation Program
ANNUAL CERTIFIED PARAMETER LIST AND CURRENT STATUS
Effective as of 07/01/2012 until 06/30/2013



Laboratory Name: STONE ENVIRONMENTAL INC Laboratory Number: VT002 Activity ID: NLC120001
535 STONE CUTTERS WAY
MONTPELIER, VT 05602

Category: SHW05 – Organic Parameters, Prep. / Screening

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Applied	No	NJ	SHW05.05230	NPW, SCM	Solid Phase Microextraction	[ASTM D6520]	Organics

Category: SHW07 – Organic Parameters, Chromatography/MS

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Certified	Yes	NJ	SHW07.04010	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Benzene
Certified	Yes	NJ	SHW07.04020	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chlorobenzene
Certified	Yes	NJ	SHW07.04030	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichlorobenzene (1,2-)
Certified	Yes	NJ	SHW07.04040	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichlorobenzene (1,3-)
Certified	Yes	NJ	SHW07.04050	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichlorobenzene (1,4-)
Certified	Yes	NJ	SHW07.04060	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Ethylbenzene
Certified	Yes	NJ	SHW07.04065	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Isopropylbenzene
Certified	Yes	NJ	SHW07.04070	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Toluene
Certified	Yes	NJ	SHW07.04073	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trimethylbenzene (1,2,4-)
Certified	Yes	NJ	SHW07.04074	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trimethylbenzene (1,3,5-)
Certified	Yes	NJ	SHW07.04080	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylenes (total)
Certified	Yes	NJ	SHW07.04081	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylene (m-)
Certified	Yes	NJ	SHW07.04082	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylene (o-)
Certified	Yes	NJ	SHW07.04083	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Xylene (p-)
Certified	Yes	NJ	SHW07.04090	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Bromodichloromethane
Certified	Yes	NJ	SHW07.04100	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Bromoform
Dropped	No	NJ	SHW07.04111	NPW, SCM	GC/MS, P&T, or Direct Injection, Capillary	[SW-846 8260B]	Cyclohexane
Certified	Yes	NJ	SHW07.04120	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Carbon tetrachloride
Certified	Yes	NJ	SHW07.04130	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chloroethane
Certified	Yes	NJ	SHW07.04150	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chloroform
Certified	Yes	NJ	SHW07.04160	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Chloromethane
Certified	Yes	NJ	SHW07.04170	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropene (trans-1,3-)
Certified	Yes	NJ	SHW07.04180	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dibromochloromethane
Certified	Yes	NJ	SHW07.04185	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dibromoethane (1,2-) (EDB)
Certified	Yes	NJ	SHW07.04187	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dibromo-3-chloropropane (1,2-)

KEY: AE = Air and Emissions, BT = Biological Tissues, DW = Drinking Water, NPW = Non-Potable Water, SCM = Solid and Chemical Materials

New Jersey Department of Environmental Protection
National Environmental Laboratory Accreditation Program
ANNUAL CERTIFIED PARAMETER LIST AND CURRENT STATUS
Effective as of 07/01/2012 until 06/30/2013



Laboratory Name: STONE ENVIRONMENTAL INC **Laboratory Number:** VT002 **Activity ID:** NLC120001
535 STONE CUTTERS WAY
MONTPELIER, VT 05602

Category: SHW07 – Organic Parameters, Chromatography/MS

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Certified	Yes	NJ	SHW07.04200	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethane (1,1-)
Certified	Yes	NJ	SHW07.04210	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethane (1,2-)
Certified	Yes	NJ	SHW07.04220	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethene (1,1-)
Certified	Yes	NJ	SHW07.04230	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethene (trans-1,2-)
Certified	Yes	NJ	SHW07.04235	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloroethene (cis-1,2-)
Certified	Yes	NJ	SHW07.04240	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropane (1,2-)
Dropped	No	NJ	SHW07.04241	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropane (1,3-)
Certified	Yes	NJ	SHW07.04250	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Dichloropropene (cis-1,3-)
Certified	Yes	NJ	SHW07.04260	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Methylene chloride (Dichloromethane)
Certified	Yes	NJ	SHW07.04270	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Tetrachloroethane (1,1,2,2-)
Certified	Yes	NJ	SHW07.04280	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Tetrachloroethene
Certified	Yes	NJ	SHW07.04290	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloroethane (1,1,1-)
Certified	Yes	NJ	SHW07.04300	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloroethane (1,1,2-)
Certified	Yes	NJ	SHW07.04310	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloroethene
Certified	Yes	NJ	SHW07.04322	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichloro (1,1,2-) trifluoroethane (1,2,2-)
Certified	Yes	NJ	SHW07.04330	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Vinyl chloride
Certified	Yes	NJ	SHW07.04350	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Carbon disulfide
Certified	Yes	NJ	SHW07.04390	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Methyl tert-butyl ether
Dropped	No	NJ	SHW07.04535	NPW, SCM	GC/MS, P&T, or Direct Injection, Capillary	[SW-846 8260B]	Methylcyclohexane
Certified	Yes	NJ	SHW07.04540	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Naphthalene
Certified	Yes	NJ	SHW07.04550	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Styrene
Dropped	No	NJ	SHW07.04560	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Tetrachloroethane (1,1,1,2-)

KEY: AE = Air and Emissions, BT = Biological Tissues, DW = Drinking Water, NPW = Non-Potable Water, SCM = Solid and Chemical Materials

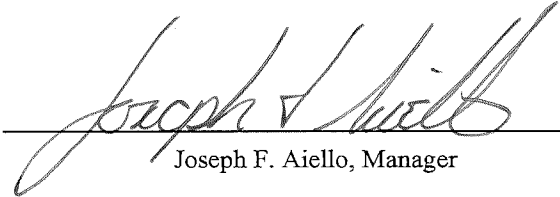
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Laboratory Name: STONE ENVIRONMENTAL INC Laboratory Number: VT002 Activity ID: NLC120001
535 STONE CUTTERS WAY
MONTPELIER, VT 05602

Category: SHW07 – Organic Parameters, Chromatography/MS

Status	Eligible to Report NJ Data	State	Code	Matrix	Technique Description	Approved Method	Parameter Description
Certified	Yes	NJ	SHW07.04570	NPW, SCM	GC/MS, P & T or Direct Injection, Capillary	[SW-846 8260B]	Trichlorobenzene (1,2,4-)


Joseph F. Aiello, Manager

KEY: AE = Air and Emissions, BT = Biological Tissues, DW = Drinking Water, NPW = Non-Potable Water, SCM = Solid and Chemical Materials

QSM
Revision 10
Date: March 25, 2013

APPENDIX D
Standard Operating Procedures Master List
SOP SEI-10.15.9
SOP SEI-6.43.3
SOP SEI-10.12.2

CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX

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Controlled Documents and PJLA Policies

		ISSUED	REVISED	REVIEWED
SEI-LQSMR8	Laboratory Quality Systems Manual (previously Laboratory Quality Manual)	03/05/04	1/12/12	1/12/12
SEI- QMP-1.0	Quality Management Plan	9/7/12	NA	NA
NCR Formv1	NCR Form 2012	9/7/12		
H&S Manual2012	Health and Safety Management Program	3/2004	1/26/12	1/26/12
Employee Policy Manual2012	Employee Policy Manual	06/02	3/13/2012	3/13/2012
PJLA PL-1	Perry Johnson Laboratory Accreditation, Inc. Proficiency Testing Requirements	12/00	10/11	10/12
PJLA PL-2	Perry Johnson Laboratory Accreditation, Inc. Measurement Traceability Policy	12/00	10/11	10/12
PJLA PL-3	Perry Johnson Laboratory Accreditation, Inc. Policy on Measurement Uncertainty	12/00	10/11	10/12
PJLA PL-4	Perry Johnson Laboratory Accreditation, Inc. Calibration Scopes of Accreditation	11/08	10/11	10/12
ISO 17025	General requirements for the competence of testing and calibration laboratories	05/15/2005		
TNI-NELAC	Management and Technical Requirements for Laboratories Performing Environmental Analysis	7/1/11		



CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX

TNI-NEFAP Field Sampling and Measurement Organization Sector
Volume 1 General Requirements For Field Sampling and
Measurement Organizations

5/1/2007

Chapter 1 ADMINISTRATION

		ISSUED	REVISED	REVIEWED
SEI-1.1.12	Orientation and Training of Stone Environmental, Inc. (Stone) Employees	11/22/93	08/24/12	8/24/12
SEI-1.2.5	General Procedures For Regulatory Agency Inspections, Sponsors Audits, or Third Party Inspections	11/22/93	05/15/12	05/15/12
SEI-1.3.4	Assignment of Internal Study Numbers and/or Project Numbers	04/14/94	05/15/12	05/15/12
SEI-1.4.11	Curriculum Vitae	05/12/93	06/30/05	02/04/11
SEI-1.5.5	Filing Procedures for Project/Study Records	06/20/94	01/18/02	08/03/12
SEI-1.6.3	Backing up the Corporate Network File System	01/17/01	01/18/08	01/18/12
SEI-1.7.3	Archiving Project Folders from the Corporate Network	01/17/01	01/18/08	01/18/12
SEI-1.8.1	Data Recovery Procedure	08/03/05	01/18/08	01/18/12

Chapter 2 PROTOCOLS AND REPORTS

		ISSUED	REVISED	REVIEWED
SEI-2.1.6	Protocol Preparation Requirements	09/02/93	05/11/12	05/11/12
SEI-2.2.6	Final Report Requirements	09/02/93	05/15/12	05/15/12
SEI-2.3.2	Interim, Progress, and Quarterly Reporting	07/29/99	05/15/12	05/15/12

Chapter 3 STANDARD OPERATING PROCEDURES

		ISSUED	REVISED	REVIEWED
SEI-3.1.9	Creating and Revising Standard Operating Procedures	04/09/93	05/15/12	05/15/12
SEI-3.2.7	Documentation, Revision, Distribution, Review and Retirement of Standard Operating Procedures	11/16/93	05/15/12	05/15/12



CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX

SEI-3.4.3	<i>Retirement of Standard Operating Procedures- See SOP 3.2.7</i>	03/14/97	na	08/22/12
SEI-3.5.2	Creating and Revising Study Specific Procedures	03/14/97	01/15/02	02/04/11
Chapter 4	DOCUMENTATION			
		ISSUED	REVISED	REVIEWED
SEI-4.1.6	Documentation of Amendments or Deviations from Protocols and Standard Operating Procedures	04/12/93	05/10/12	05/10/12
SEI-4.2.7	Chain of Custody Records	04/09/93	05/10/12	05/10/12
SEI-4.4.4	Documentation of Project Specific Phone Conversations and Correspondence	09/02/93	03/15/02	10/17/07
SEI-4.5.11	Data Handling, Storage, Retrieval and Error Coding	09/02/93	05/10/12	05/10/12
SEI-4.6.7	Significant Figures, Rounding Procedures and Use of Conversion Factors	12/08/93	08/24/12	08/24/12
SEI-4.7.5	Labeling Reagents, Solutions and Standards	04/18/94	08/24/12	08/24/12
SEI-4.8.3	Documentation and Reconstruction of Pesticide Use History	04/14/94	02/19/03	08/23/12
SEI-4.10.3	Computer Software Verification	04/21/94	04/04/03	08/23/12
SEI-4.14.2	Quality Control Check on Transcribed Data, Data Calculations, Figures, and Tables	07/29/99	03/06/03	08/23/12
SEI-4.15.2	Construction of Maps to Illustrate Groundwater Elevation and Depth to Groundwater Contours	07/19/99	03/06/03	08/23/12
SEI-4.17.1	Receipt, Storage, and Documentation of Test Substances	03/03/00	12/17/01	08/23/12
SEI-4.18.1	Data Collection and Analysis Practices for the Campbell Scientific, Incorporated, Data Loggers and Related Hardware	05/05/00	03/06/03	08/23/12
SEI-4.19.1	Receipt and Storage of Electronic Data	12/13/00	02/28/03	08/23/12

CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX

Chapter 5	FIELD WORK AND EQUIPMENT	ISSUED	REVISED	REVIEWED
SEI-5.1.5	Maintenance and Decontamination of Field Equipment	04/09/93	02/20/04	04/17/08
SEI-5.3.4	Use of Borrowed and Rented Equipment	04/18/94	02/20/04	04/11/08
SEI-5.6.4	Maintenance of Bailers	11/22/93	02/20/04	04/11/08
SEI-5.11.2	Maintenance and Calibration of the Oakton ORP Tester (Oxidation and Reduction Potential (ORP) Meter)	02/16/96	02/20/04	04/9/08
SEI-5.14.2	Use, Maintenance and Calibration of Electronic Balances Model GL1002R, OHAUS CT-200 Top Loading, Adam Equipment 2T200 and/or Other Similar Models	06/17/97	02/20/04	04/9/08
SEI-5.19.2	Maintenance, and Calibration of the Cole Parmer Model DspH3 and 1484-44 and Similar Type pH and Conductivity Meters	06/17/97	02/24/04	04/17/08
SEI-5.20.2	Maintenance, and Calibration of the Cole Parmer Model 19815-00 Conductivity Meter	03/10/98	02/24/04	04/17/08
SEI-5.21.2	Maintenance, and Calibration of the Cole Parmer Model 59000-25 pH Tester	03/10/98	02/24/04	04/17/08
SEI-5.22.2	Maintenance, and Calibration of the Troll SP4000 Datalogger	05/14/99	02/24/04	04/17/08
SEI-5.23.3	Maintenance, and Calibration of the pH/CON 10 Meter	05/14/99	02/24/04	04/14/08
SEI-5.24.2	Maintenance, and Calibration of the GPI Industrial Grade Flow Meter	06/08/99	05/15/03	04/17/08
SEI-5.25.1	Use, Maintenance, and Calibration of the Multi-Parameter Troll 9000 and 9500	04/18/08	07/12/12	07/12/12
SEI-5.26.0	Use, Maintenance, and Calibration of the Lamotte Model 2020e Turbidity Meter	06/23/05	na	04/14/08
SEI-5.27.1	Use, Maintenance, and Calibration of the Hydrolab MS5 Water Quality Multiprobes	04/17/08	07/12/12	07/12/12
SEI-5.28.0	Use, Maintenance and Calibration of the HACH LDO Portable Dissolved Oxygen Meters (HACH Models HQ10 and HQ30d)	02/04/2011	na	02/04/2011



CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX

SEI-5.29.0	Use, Maintenance, and Calibration of the MultiRAE IR Multi-Gas Monitor (PGM-54)	02/04/2011	na	02/04/2011
SEI-5.30.0	Use, Calibration, and Maintenance of The YSI Model 699xl Multi-parameter Water Quality Monitoring System(Temperature, Specific Conductance, Ph, Redox Potential, Dissolved Oxygen)	8/13/02	7/12/12	7/12/12
Chapter 6	FIELD WORK AND PROFILING			
		ISSUED	REVISED	REVIEWED
SEI-6.1.6	Collection of Soil Samples for Preliminary Site Selection	10/26/92	11/18/05	04/2/08
SEI-6.2.6	Water Level measurement, Use, Maintenance and Calibration of Electronic Water Level Indicators	04/09/93	02/20/04	04/2/08
SEI-6.3.4	Surface Water Sampling	04/09/93	02/24/04	04/2/08
SEI-6.4.5	Installation, Development and Decommissioning of Monitoring Wells and Observation Wells	04/09/93	08/01/07	04/10/08
SEI-6.6.9	Installation and Testing of Bladder Pumps for Sampling of Monitoring Wells	04/09/93	03/31/04	05/02/08
SEI-6.8.5	Guelph Permeameter Testing, Use, Maintenance and Calibration of the Guelph Permeameter	04/12/93	02/20/04	05/02/08
SEI-6.10.4	Soil Characterization Study	04/09/93	03/31/04	04/15/08
SEI-6.11.8	Slug Tests	04/12/93	03/02/06	05/02/08
SEI-6.12.9	Porous Cup Lysimeter Installation, Testing, and Sampling	05/17/93	04/16/04	11/17/05
SEI-6.13.8	<i>Porous Cup Lysimeter Sampling (Included in SOP 6.12.9)</i>	06/02/93	<i>Retired</i>	<i>Retired</i>
SEI-6.14.3	Test System Preparation, Care and Observations	04/18/94	04/16/04	05/02/08
SEI-6.16.4	Handling, Collection and Transportation of Samples	11/22/93	04/16/04	04/14/08
SEI-6.17.4	Evaluation of Soil Texture, Moisture Content, and Mottling, Using the USDA Soil Classification Scheme	11/15/94	04/16/04	05/02/08
SEI-6.18.2	<i>Installation and Reading of Irometer "Watermark" Soilmoisture Sensors</i>	05/19/95	<i>Retired</i>	<i>Retired</i>
	Use, Maintenance and Calibration of the IonScience		02/04/2011	02/04/2011



CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX

SEI-6.19.2	PhoCheck 1000+ Photo Ionization Detector (PID)	07/19/99		
SEI-6.20.3	Undisturbed Soil Sample Collection Using a Thin Walled (Shelby) Tube	02/16/96	11/18/05	04/17/08
SEI-6.23.1	Observation and Monitoring Well Surveying	07/19/99	11/29/05	04/15/08
SEI-6.24.1	Locating Soil Sampling Points in a Sampling Area	07/19/99	11/18/05	04/14/08
SEI-6.25.3	Operation and Maintenance of the Concord Model Ss4804 Soil Sampler	06/17/97	11/18/05	05/02/08
SEI-6.26.2	Spray Tank Sample Collection	06/17/97	11/18/05	04/17/08
SEI-6.27.3	Groundwater Sampling of Monitoring Wells	03/03/00	11/18/05	04/16/08
SEI-6.34.0	Procedure for Sampling Groundwater Monitoring Wells Using Low Stress (Low Flow) Technique	01/21/05	01/21/05	04/16/08
SEI-6.35.0	Passive Collection of Pore Water Samples Using Passive Diffusion Bags	06/22/07	na	05/02/08
SEI-6.36.1	Procedure For Collection of Soil Gas Samples for VOC Analysis	6/22/07	3/6/13	3/6/13
SEI-6.37.1	Field Methods for Retrieval, Collection, Handling, and Preservation of Rock Samples to be Analyzed for VOCs and Physical Properties	7/01/08	12/17/12	12/17/12
SEI-6.38.0	Optical Brightener Testing	9/10/08	na	09/10/08
SEI-6.39.1	Surface Sediment Sampling Using an Ekman Grab Sampler	08/21/12	10/16/12	10/16/12
SEI-6.40.0	Sediment Porewater Sampling using a (Henry's) Push Point Sampler	08/21/12	na	08/21/12
SEI-6.41.0	Hydrophobic Dye Testing for Light or Dense Non-Aqueous Phase Liquids (NAPL) Contamination	08/21/12	na	08/21/12
SEI-6.42.2	Geologic Description of Unconsolidated Deposits	01/18/02	10/16/12	10/16/12
SEI-6.43.3	Groundwater Profiling and K-Pro Testing	08/13/02	08/23/12	08/23/12
SEI-6.44.0	Procedure for Sample Collection From Residences and Commercial (Potable) Drinking Water Supplies	10/15/12	na	10/15/12
SEI-6.45.0	Collection, Handling, and Preservation of Discrete Soil	10/15/12	na	10/15/12



CONTROLLED DOCUMENTS AND STANDARD OPERATING PROCEDURES MASTER INDEX**Samples**

SEI-6.46.0	Geologic Description of Unconsolidated Deposits Using the Unified Soil classification System (USCS)	10/15/12	na	10/15/12
SEI-6.47.0	Non-Aqueous Phase Liquid (NAPL) Sampling	10/16/12	na	10/16/12

Chapter 7 ARCHIVES

		ISSUED	REVISED	REVIEWED
SEI-7.1.4	Transfer of Raw Data to the Sponsor or Client	09/02/93	02/18/03	08/24/12
SEI-7.2.6	Document Control, Record System and Archiving	11/16/93	03/04/03	08/24/12
SEI-7.3.3	Procedures to be Followed when Terminating a Study	04/18/94	02/20/03	08/24/12

Chapter 8 MANAGEMENT

		ISSUED	REVISED	REVIEWED
SEI-8.1.5	Duties and Responsibilities of the Study Director	09/02/93	03/18/03	02/04/2011
SEI-8.2.4	Duties and Responsibilities of Principal Investigator and/or Project Manager	09/02/93	03/18/03	02/04/2011
SEI-8.3.6	Duties and Responsibilities of Test Facility Management	11/22/93	02/18/03	02/04/2011
SEI-8.4.0	Client Inquiries, Data Revision Requests & Complaint Resolution	10/20/05	na	02/04/2011

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		ISSUED	REVISED	REVIEWED
SEI-9.1.1	Use of Contract Quality Assurance	07/19/99	2/18/03	04/18/08
SEI-9.3.1	Construction and Maintenance of the Master Schedule	07/19/99	2/18/03	04/18/08
SEI-9.4.2	Duties and Responsibilities of SEI Quality Assurance Personnel	03/28/97	2/18/03	04/18/08

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Chapter 10 ENVIRONMENTAL MOBILE LABORATORY		ISSUED	REVISED	REVIEWED
SEI-10.1.6	Determination of Aromatic and Chlorinated Volatile Organics and Light Weight Petroleum Hydrocarbon Compounds Using Solid Phase Microextraction (SPME) and A Gas Chromatograph in Soil and Water Samples (Modified SW846 Methods 8021/8015 & ASTM D6520)	02/21/03	05/26/09	05/26/09
SEI-10.2.0	Determination of Polychlorinated Biphenyl (PCB) by Gas Chromatography with an Electron Capture Detector (ECD) in Sediment and Soil Samples	08/17/04	na	02/15/08
SEI-10.5.2	<i>Renumbered See SOP SEI-6.43.3</i>			
SEI-10.7.1	<i>Renumbered See SOP SEI-5.30.2</i>			
SEI-10.11.0	<i>Renumbered See SOP SEI-6.42.1</i>			
SEI-10.12.2	Use, Calibration, and Maintenance of the Membrane Interface Probe (MIP)	08/4/04	5/18/12	05/18/12
SEI-10.13.0	Policy Requirements for Manual Integration of Chromatographic Peaks	08/05/04	na	05/02/08
SEI-10.14.0	On-Site Laboratory Waste Handling, Storage and Disposal	10/20/04	na	05/02/08
SEI-10.15.9	<i>The Determination of Volatile Organic Compounds By GC/MS (SW846 USEPA METHOD 8260C)</i>	08/19/04	11/7/12	11/7/12
SEI-10.16.0	Determination of Selected Elements in Soil and Sediment Samples Using Field Portable X-Ray Fluorescence Spectrum Analyzers, SW846 6200	10/22/04	na	08/22/12
SEI-10.17.1	Microwave Assisted Extraction of Volatile Organic Compounds From Rock Samples	07/2/08	5/21/12	5/21/12

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SEI-10.18.1	The Determination of Volatile Organic Compounds By Gas Chromatography/Dual ECD Detectors in Rock Samples (Using Cool On-Column Injection and Split Method Injection)	07/02/08	5/21/12	5/21/12
Chapter 11	HEALTH AND SAFETY			
		ISSUED	REVISED	REVIEWED
SEI-11.1.2	Preparing and Amending a Site Health and Safety Plan (HASP)	12/13/00	11/29/05	10/17/07
Chapter 12	GEOGRAPHIC INFORMATION SYSTEMS (GIS)			
		ISSUED	REVISED	REVIEWED
<i>SEI-12.1.0</i>	<i>Managing Paths in ArcView Project Files</i>	<i>draft</i>	na	na
Chapter 13	SURFACE DRINKING WATER STUDIES			
		ISSUED	REVISED	REVIEWED
SEI-13.1.1	Watershed Estimation Process for Surface Drinking Water Studies	05/30/01	03/18/03	08/22/12
SEI-13.2.1	Training of Sampling Personnel for Surface Water Drinking Studies	12/13/00	01/15/02	08/22/12
SEI-13.3.1	Community Water System Visit and On-Site Data Collection for Surface Drinking Water Studies	12/13/00	03/18/03	08/22/12
SEI-13.4.2	Collection of Samples for Surface Drinking Water Studies	12/13/00	04/04/03	08/22/12
SEI-13.5.1	Assigning System Identification Numbers for Surface Drinking Water Studies	12/13/00	05/08/02	08/22/12
SEI-13.6.0	Composition of Watershed Shapefiles in Preparation For Community Water system Watershed Characterization	04/04/03	na	08/22/12
SEI-13.7.0	Composition of Community Water System Intake Shapefiles For Watershed Characterization	04/04/03	na	08/22/12

N.B. - italicized SOPs have been retired or are still in draft form
 Retired SOPs will be removed from the list after one year.
 na – not applicable



STANDARD OPERATING PROCEDURE**SEI-10.15.9*****THE DETERMINATION OF VOLATILE ORGANIC COMPOUNDS BY GAS
CHROMATOGRAPHY / MASS SPECTROMETRY (GC/MS)
(SW846 USEPA METHOD 8260C)***

SOP Number: SEI-10.15.9

Date Issued: 08/19/04

Revision Number: 9

Date of Revision: 11/7/12

1.0 OBJECTIVE/

This method, based on SW846 USEPA Method 8260C for the analyses of volatile organic compounds, is designed to measure the concentration of specified volatile organic compounds (VOCs) in water, soil and air samples using solid phase micro-extraction (SPME) and a Gas Chromatograph equipped with a capillary column and mass spectrometer. Specific VOCs of interest are outlined in Table 1.

2.0 SUMMARY OF METHOD

This method provides gas chromatographic conditions for the detection of certain aromatic and chlorinated VOCs. Soil and water samples are prepared in 20 mL extraction vials. The SPME fiber is then exposed to the headspace above the sample for a set number of minutes while the sample is agitated via either stirring or orbital shaking. Air samples are collected in Tedlar bags and the SPME fiber is exposed directly to the sample through the syringe septum. The exposure time must be consistent for all standards and samples (typically six or eight minutes). The absorbed analytes are thermally desorbed from the SPME fiber in the injection port of a Gas Chromatograph and transferred to a narrow bore capillary column. A temperature program is used to enhance separation as the analytes are carried through the column to the ion source of the mass spectrometer. The ionized molecules are focused and separated according to their mass/charge (m/z) ratio by a quadrupole analyzer. The signal is amplified by an electron multiplier and interpreted by the mass spectrometer data system to produce a total ion or selected ion chromatogram and mass spectra for every point on the chromatogram. The instrument's mass spectrometer can be set in scan mode or selective ion monitoring mode (SIM). SIM mode is typically used to achieve lower reporting limits.

This method is suitable for analysis of air, water, soils, and wastes extractable in methanol.

Soil and waste samples are collected in approximately 10-12 gram cores directly into methanol (10 mL) in 40 mL VOA vials. Subsequent to sample collection, the methanol/solid mixture is agitated to break up the solids. Following this extraction step, an aliquot of the methanol is diluted into analyte-free water and is further extracted via the headspace SPME technique. Water samples are collected in 40 mL VOA vials with no headspace. All soil and water samples are analyzed as waters on the GC/MS.

This method is based on USEPA 8260C, *Volatile Organic Compounds by Gas Chromatography Mass Spectrometry (GC/MS)* and ASTM Method D6520, *Solid Phase Micro-extraction of water and its headspace for analysis of Volatile and Semi-volatile Organic Compounds*.

3.0 DEFINITIONS

Accuracy: the degree of agreement between a measurement and true or expected value, or between the average of a number of measurements and the true or expected value.

Batch: environmental samples, which are prepared and/or analyzed together with the same process, using the same lot(s) of reagents. A preparation batch is composed of one to 20 environmental samples of a similar matrix, meeting the above-mentioned criteria.

Corrective Action: action taken to eliminate the causes of an existing non-conformance, defect or other undesirable situation in order to prevent recurrence.

Demonstration of Capability (DOC): procedure to establish the ability to generate acceptable accuracy and precision.

Instrument Blank: a blank matrix that is the same as the processed sample matrix (i.e. extract, digestate, condensate) and introduced onto the instrument for analysis. Analyzed typically as a fiber blank.

Laboratory Duplicate: Aliquots of a sample taken from the same container under laboratory conditions and processed and analyzed independently. (NELAC)

Limit of Detection (LOD): An estimate of the minimum amount of a substance that an analytical process can reliably detect. An LOD is analyte- and matrix-specific and may be laboratory-dependent. (DOD QSMV4.2)

Limit of Detection (Clarification): The smallest amount or concentration of a substance that must be present in a sample in order to be detected at a high level of confidence (99%). At the LOD, the false negative rate (Type II error) is 1%. (DOD QSMV4.2)

Limits of Quantitation (LOQ): The minimum levels, concentrations, or quantities of a target variable (e.g., target analyte) that can be reported with a specified degree of confidence. (DOD QSMV4.2)

Limit of Quantitation (Clarification): The lowest concentration that produces a quantitative result within specified limits of precision and bias. For DoD projects, the LOQ shall be set at or above the concentration of the lowest initial calibration standard.

Laboratory Control Sample (LCS): a blank matrix spiked with a known amount of analyte(s), processed simultaneously with, and under the same conditions as, samples through all steps of the analytical procedure.

Matrix: the substrate of a test sample.

Matrix Duplicate (MD): duplicate aliquot of a sample processed and analyzed independently; under the same laboratory conditions; also referred to as Sample Duplicate; Laboratory Duplicate.

Matrix Spike (MS): field sample to which a known amount of target analyte(s) is added.

Matrix Spike Duplicate (MSD): a replicate matrix spike.

Method Blank: a blank matrix processed simultaneously with, and under the same conditions as, samples through all steps of the analytical procedure.

Precision: an estimate of variability. It is an estimate of agreement among individual measurements of the same physical or chemical property, under prescribed similar conditions.

Method Detection Limit: One way to establish a Limit of Detection, defined as the minimum concentration of a substance (an analyte) that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. (DOD QSMV4.2)

Method Detection Limit (MDL) (Clarification): The MDL is one way to establish a Detection Limit, not a Limit of Detection. (DOD QSMV4.2)

Nonconformance: An indication or judgment that a product or service has not met the requirement of the relevant specifications, contract, or regulation; also the state of failing to meet the requirements. (DOD QSMV4.2)

Precision: The degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves; a data quality indicator. Precision is usually expressed as standard deviation, variance or range, in either absolute or relative terms. (NELAC)

Preservation: Refrigeration and/or reagents added at the time of sample collection (or later) to maintain the chemical and/or biological integrity of the sample. (NELAC)

Proficiency Testing: A means of evaluating a laboratory's performance under controlled conditions relative to a given set of criteria through analysis of unknown samples provided by an external source. (NELAC) [2.1]

Quality Assurance (QA): an integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

Quality Control (QC): the overall system of technical activities, the purpose of which is to measure and control the quality of a product or service.

Quality Control Sample: a control sample, generated at the laboratory or in the field, or obtained from an independent source, used to monitor a specific element in the sampling and/or testing process.

Quantitation Limit (QL): the minimum amount of a substance that can be quantitatively measured with a specified degree of confidence and within the accuracy and precision guidelines of a specific measurement system. The QL can be based on the MDL, and is generally calculated as 3-5 times the MDL, however, there are analytical techniques and methods where this relationship is not applicable. Also referred to as Practical Quantitation Level (PQL), Estimated Quantitation Level (EQL), Limit of Quantitation (LOQ).

Quantitation Range: The range of values in a calibration curve between the LOQ and the highest successfully analyzed initial calibration standard. The quantitation range lies within the calibration range. (DOD QSMV4.2)

Raw Data: Any original factual information from a measurement activity or study recorded in a laboratory notebook, worksheets, records, memoranda, notes, or exact copies thereof that are necessary for the reconstruction and evaluation of the report of the activity or study. Raw data may include photography, microfilm or microfiche copies, computer printouts, magnetic media, including dictated observations, and recorded data from automated instruments. If exact copies of raw data have been prepared (e.g., tapes which have been transcribed verbatim, data and verified accurate by signature), the exact copy or exact transcript may be submitted. (EPA-QAD)

Reporting Limit (RL): The level to which data is reported for a specific test method and/or sample. The RL is generally related to the QL. The RL must be minimally at or above the MDL.

Requirement: Denotes a mandatory specification; often designated by the term "shall". (NELAC)

Retention Time: The time between sample injection and the appearance of a solute peak at the detector. (Skoog, West, and Holler. Fundamentals of Analytical Chemistry. 1992)

Sample: Portion of material collected for analysis, identified by a single, unique alphanumeric code. A sample may consist of portions in multiple containers, if a single sample is submitted for multiple or repetitive analysis. (DOD QSMV4.2)

Selectivity: (Analytical chemistry) The capability of a test method or instrument to respond to a target substance or constituent in the presence of non-target substances. (EPA-QAD)

Selective Ion Monitoring: A configuration of the mass spectrometer in which the intensities of several specific ion beams are recorded rather than the entire mass spectrum.

Sensitivity: The capability of a method or instrument to discriminate between measurement responses representing different levels (e.g., concentrations) of a variable of interest. (NELAC)

Shall: Denotes a requirement that is mandatory whenever the criterion for conformance with the specification requires that there be no deviation. This does not prohibit the use of alternative approaches or methods for implementing the specification so long as the requirement is fulfilled. (ANSI)

Should: Denotes a guideline or recommendation whenever noncompliance with the specification is permissible. (ANSI)

Signal to Noise Ratio: The signal carries information about the analyte, while noise is made up of extraneous information that is unwanted because it degrades the accuracy and precision of an analysis and also places a lower limit on the amount of analyte that can be detected. In most measurements, the average strength of the noise is constant and independent of the magnitude of the signal. Thus, the effect of noise on the relative error of a measurement becomes greater and greater as the quantity being measured (producing the signal) decreases in magnitude. (Skoog, Holler, and Nieman. Principles of Instrumental Analysis. 1998)

Spike: a known amount of an analyte added to a blank, sample or sub-sample.

Standard: (Document) The document describing the elements of laboratory accreditation that has been developed and established within the consensus principles of NELAC and meets the approval requirements of NELAC procedures and policies. (ASQC)

Standard: (Chemical) Standard samples are comprised of a known amount of standard reference material in the matrix undergoing analysis. A standard reference material is a certified reference material produced by the US National Institute of Standards and Technology (NIST) and characterized for absolute content, independent of analytical test method.

Standard Method: A test method issued by an organization generally recognized as competent to do so.

Standard Operating Procedure (SOP): a written document which details the method of an operation, analysis or action whose techniques and procedures are thoroughly prescribed and which is accepted as the method for performing certain routine or repetitive tasks.

SPME – Solid Phase Micro Extraction

Surrogate: A substance with properties that mimic the analyte of interest. It is unlikely to be found in environment samples and is added to them for quality control purposes. (QAMS)

Target Analytes: Analytes specifically named by a client (also called project-specific analytes). (DOD QSMV4.2)

Technical Director: Individual(s) who has overall responsibility for the technical operation of the environmental testing laboratory. (NELAC)

Tedlar Bag – Inflatable sample container, used to trap air samples for analysis, equipped with a Teflon[®]-lined syringe septum that allows a SPME fiber to come in contact with the air sample.

Traceability: The property of a result of a measurement whereby it can be related to appropriate standards, generally international or national standards, through an unbroken chain of comparisons. (VIM - 6.12)

Tuning: A check and/or adjustment of instrument performance for mass spectrometry as required by the method.). (DOD QSMV4.2)

VOC – Volatile Organic Compounds

QA/QC – Quality Assurance/Quality Control

4.0 INTERFERENCES

When analyzing for VOCs, samples can be contaminated by diffusion of volatile organics (particularly chlorofluorocarbons and methylene chloride) through the sample container septum during shipment and storage. A trip blank can be used as a check on this type of interference however, a trip blank is not usually required if the analyses are being conducted onsite. A trip blank is prepared from analyte-free reagent water and carried through sampling and subsequent storage and handling.

Contamination by carryover can occur whenever high-concentration and low-concentration samples are analyzed in sequence. To reduce the potential for carryover, the sample syringe or purging device must be

rinsed out between samples with an appropriate solvent. Whenever an unusually concentrated sample is encountered, it should be followed by injection of a method blank to check for cross contamination.

Purging vessels and syringes should be adequately cleaned and flushed prior to use. All glassware must be kept scrupulously cleaned. Clean all glassware as soon as possible after use by rinsing with the last solvent used or analyte-free water. Store clean dry glassware in a clean environment.

5.0 SAFETY ISSUES

1. Laboratory personnel should take extra care when working with standards. When working with neat standards, make certain that there is adequate ventilation and that Nitrile or Latex gloves are worn and if necessary, safety glasses.
2. If necessary and appropriate, a site-specific health and safety plan shall be created for each study site and followed.
3. Field visits may involve accessing remote areas. Health and safety concerns regarding these field visits are minimal, however, hazards such as slip, trip and falls, poisonous plant and dangerous animals, as well as getting vehicles stuck in remote areas, do present considerable health and safety issues. To help ensure field staff's health and safety in remote areas, all field staff are to have daily communication with the project manager or another appropriate SEI employee.
4. All chemicals are required to be received with a Material Safety Data Sheets (MSDS). MSDSs shall be made available to all personnel involved in the sampling and testing.

6.0 EQUIPMENT AND SUPPLIES

General maintenance shall be conducted proactively to minimize the down time associated with equipment failure and to maintain the highest degree of data quality. This shall be accomplished through scheduled and symptomatic maintenance. Examples of symptomatic maintenance, in which the chromatography is monitored, include cleaning of inlet, replacement of septa and liner and mass spectrometer source cleaning. Examples of scheduled maintenance include replacement of diffusion and rough pump oils. All maintenance conducted on equipment shall be documented in the instrument maintenance logs. The primary pieces of instrumentation for the laboratory are listed below.

1. Gas Chromatograph: Analytical system complete with gas chromatograph and all required accessories, column supplies, gases, syringes and data system to determine peak areas and perform integrations. Hewlett Packard 5890 Series II.
2. Mass Spectrometer: Hewlett Packard 5971 MSD.
3. Typical Analytical Column: RTX-VMS 20m x 0.18mm ID, 1.0 um film or equivalent
4. SPME Autosampler: CTC Combi PAL

5. Array of micro-syringes: range 5-1000 uL.
6. Balance: Top loading, capable of weighing accurately to 0.01 grams (soil samples only).
7. Sample introduction and preparation apparatus: SPME Fiber type 100 µm polydimethylsiloxane (PDMS) and/or 85 µm Carboxen/PDMS fiber, magnetic hot plate and magnetic stirrers, tube clamp and stand.
8. VOA vials: 40 mL collection containers with Teflon®-lined septum and either 24mL or 20mL extraction vials

7.0 REAGENTS AND STANDARDS

Reagents:

1. Analyte-free reagent water demonstrated to be free of compounds of interest (spring water, carbon filtered and/or deionized).
2. Purge and Trap Grade or equivalent grade methanol (demonstrated to be free of analytes and stored away from other solvents).

Stock standards:

Stock standards may either be prepared from pure standard materials or purchased as certified solutions. Secondary dilution standards are prepared using stock standard solutions, which contain the compounds of interest, either as single compounds or mixed together. Typically, for this method the stock standards are obtained from an approved vendor and mixed together. A certificate of analysis is retained by the laboratory and maintained on file or on file with the vendor. The aqueous standards are typically prepared at concentrations as listed in Section 9.0 and are prepared in accordance with Table 3 which is an Example of the Standard Preparation Calculation Sheet. Gas standards are purchased in mixtures of site-specific target analytes.

Calibration standards are prepared at a minimum of five to seven different concentrations levels for VOC analytes.

Stone's SOP No. SEI-4.7.n *Labeling, Preparation and Storage of Reagents, Solutions and Standards* provides procedures on properly labeling, preparing and storing of reagents and standards used in the mobile laboratory for analytical methods. This SOP should be reviewed by the analyst before labeling, preparing and storing standards within the mobile laboratory.

8.0 SAMPLE COLLECTION AND HANDLING

8.1 Sample Collection

1. Aqueous samples are collected in 40 mL Teflon®-lined septum VOA vials filled to ensure that no headspace is present. Upon receipt, and if multiple vials are presented for a given sample, the vials will be uniquely numerically labeled (with the numbers 1, 2, 3, etc.) and

at the time of analysis this unique identifier will be recorded in the instrument's run log. If storage of these samples is expected to exceed seven days, aqueous samples should be preserved with hydrochloric acid (HCl) to a pH of < 2.

2. Soil and waste samples are collected in approximately 10-12 gram cores, and placed in 40 mL vials with 10 mL of methanol. Upon receipt, and if multiple vials are presented for a given sample, the vials will be uniquely numerically labeled (with the numbers 1, 2, 3, etc.) and at the time of analysis this unique identifier will be recorded in the instrument's run log. If required, a separate aliquot of soil from the sample location will be collected in a 40 mL vial (with no methanol preservative) for percent moisture determination.
3. Air samples are collected in Tedlar bags. Upon receipt, and if multiple bags are presented for a given sample, the bags will be uniquely numerically labeled (with the numbers 1, 2, 3, etc.) and at the time of analysis this unique identifier will be recorded in the instrument's run log. The analytes are concentrated on the SPME fiber by exposing the fiber directly to sample through the Teflon[®]-lined septum. Air samples must be analyzed within 3 days of collection.

8.2 Handling and Holding Times

1. Unpreserved water samples must be analyzed within 7 days of collection. Preserved (preserved with HCl to a pH of < 2) water samples must be analyzed within 14 days of collection. Soil samples collected in methanol must be analyzed within 14 days from collection. All samples shall be stored at < 6°C. Samples are allowed to come to room temperature just prior to analysis. All samples for this program are typically analyzed within one or two days from collection, therefore, holding times should not be a concern.
2. If samples were preserved and analyses are performed after 7 days from collection, pH determination (water samples only) should be performed. Once the sample aliquots have been taken from the VOA vial for analysis, the pH of the water sample must be determined. The purpose of the pH determination is to ensure that all VOA samples were acidified in the field. Test the pH by placing one or two drops of sample on the pH paper (do not add pH paper to the vial). Record the pH of each sample, and report these data on the runlog and in the SDG Narrative. No pH adjustment is to be performed.
3. If necessary, a separate soil sample aliquot will be collected in a 40 mL vial or equivalent for percent moisture content so that results can be adjusted for %moisture and reported as dry weight rather than as received. Percent moisture is determined as follows: Percent Moisture Determination - Immediately after weighing the sample for analysis, weigh 5-10 g of the soil/sediment into a tared crucible. Determine the percent moisture by drying overnight at 105 °C. If available, allow to cool in a desiccator before weighing. Concentrations of individual analytes will be reported relative to the dry weight of soil/sediment.

$$\text{Percent Moisture} = \frac{\text{Mass of wet sample (g)} - \text{Mass of dry sample (g)}}{\text{Mass of wet sample (g)}}$$

4. If samples are suspected to be of high concentration and are not to be immediately analyzed, they will be isolated in a separate cooler unit in the lab. If a separate cooler is not readily available in the lab, one will be purchased.

9.0 PROCEDURES

9.1 Typical GC Program

Oven Temp: 50°C (4.00 min) to 160°C at 15°C/min to 200°C at 40°C/min, hold for 1 min.

Flow Rate: Helium, 1.0 mL/min, 8 PSI, set at 45°C

Detector: MSD, SIM mode, ion masses range between 45-190 amu

Injector: 240°C, splitless (close 1.5 min)

Liner: 0.75 mm ID splitless/split injection port

9.2 GC Column

Column: RTX-VMS 20m x 0.18mm ID, 1.0 um film, equivalent

9.3 Material Preparation:

SPME: Fiber Type: 100 µm polydimethylsiloxane (PDMS).

SPME Fiber Type for low level waters or specialized project only: 85 µm Carboxen/PDMS

SPME Extraction: The SPME-absorbent polymer fiber is exposed to the headspace above a sample. The headspace is created by removing approximately 2 mLs from the 20 mL preparation vial. Salt and stir bar (if stirring is used) are added to the mixture and the sample is agitated for 6 or 8 minutes. The fiber is then retracted into the SPME holder and transferred to the GC injection port where the analytes are thermally desorbed and transferred to the head of the GC column. If used, each magnetic stirrer is rinsed three times with analyte free water prior to use. For soil samples; an aliquot of the methanol extract (typically 0.5mL but not more than 1 mL) is prepared in the 20 mL water preparation vial, and prepared and analyzed in the same manner as a water sample above. For air samples, the SPME fiber is exposed directly to the same through the syringe septum located on the Tedlar bag. Preparation and exposure time of the fiber to the site samples is the same for all QC samples and calibration standards.

9.4 Operating Procedure

9.4.1 Tuning with 4-Bromofluorobenzene

The following ion abundances must be met before analysis of calibration standards, environmental samples and at the beginning of a 12-hour analytical sequence by analyzing BFB in a check standard, method blank or as a single injection:

BFB Key Ions and Ion Abundance Criteria	
Mass	Ion Abundance Criteria
50	15.0-40.0 percent of mass 95
75	30.0-60.0 percent of mass 95
95	base peak, 100 percent relative abundance
96	5.0-9.0 percent of mass 95
173	less than 2.0 percent of mass 174
174	>50.0 percent of mass 95
175	5.0-9.0 percent of mass 174
176	95.0-101.0 percent of mass 174
177	5.0-9.0 percent of mass 176

9.4.2 Calibration Criteria

9.4.2.1 Initial Calibration (ICAL):

1. Five to seven-point calibrations for VOC compounds using a SIM configuration is as follows: 2, 5, 10, 20, 50, 100, 200 ppb. (Scan calibrations are determined as needed by the client's program) The low standard must be set at the quantitation limit (QL) or LOQ. A typical calibration range for air (ppb^{v/v}) will be similar to that of water and will be chosen on a site specific basis.
2. Calibration range must encompass the expected sample concentrations; therefore, if site samples are expected to be higher in concentration than the calibration range, adjustments to the calibration range and samples will be documented and made accordingly.
3. The linearity of the calibration curves must be assessed and are used for all quantitation. Volatile organic compounds in soil and water use an internal standard procedure (internal standards; fluorobenzene and chlorobenzene-d5). Average response factors are used for quantitation and the average relative standard deviation (%RSD) of each compound must be $\leq 20\%$. Linear least squares regression must be $r > 0.995$
4. Non-linear regression coefficient of determination (COD) must be $r^2 > 0.99$ (6 points shall be used for second order, 7 points shall be used for third order). Depending upon

the field on-site program, 25% RSD may be acceptable based on the on-site data quality objectives.

For DoD Projects (DOD QSM4.2, Table F-4), one of the following must be true for each analyte in the calibration:

- % RSD for each analyte must be $\leq 15\%$ (method requirement $\leq 20\%$).
- Linear least squares regression must be $r \geq 0.995$
- Non-linear regression coefficient of determination (COD) must be $r^2 \geq 0.99$ (6 points shall be used for second order, 7 points shall be used for third order).

Note: The average response factor requirements are only for 8260B and were not included in 8260C, therefore, for DOD projects the laboratory will follow the updated method. (The average response factor requirement will be ≥ 0.30 for chlorobenzene and 1,1,2,2-tetrachlorethane, and ≥ 0.1 for chloromethane, bromoform, and 1,1-dichloroethane (SPCCs). % RSD must be $\leq 30\%$ for CCCs if analyzing for 8260B only).

5. VOCs in air use an external calibration procedure. Linear regression is used for quantitation and the correlation coefficient of each compound must be greater than 0.99

9.4.2.2 Continuing Calibration (CCV):

1. A mid-point continuing calibration verification standard for VOC compounds (20 ppb or 50ppb) must be analyzed every 12 hours, prior to sample analysis in order to verify the initial calibration. A percent difference between the expected concentration and actual concentration is calculated. The percent difference (%D) values for each compound must be less than or equal to 20%.

$$\%D = \frac{\text{ExpectedConcentration} - \text{ActualConcentration}}{\text{ExpectedConcentration}}$$

The CCV may also be used to demonstrate that the BFB criteria shown in 10.4.1 have been met when operating in scan mode.

9.4.2.3 Initial Calibration Verification Standard (ICV):

A QC sample from a second (independent) source will be analyzed directly after the ICAL. The ICV sample will contain all the VOC compounds of interest at the mid-point (20-100 ppb or 5 ppb for low level waters). Recovery Limits for the ICV will be 70-130%, if compounds are determined to be poor performers then the recoveries shall be 60-140% for the ICV.

For DoD projects, all project analytes must be within tolerances listed in Table 2.

$$\% \text{Recovery} = \frac{\text{Actual Concentration}}{\text{Expected Concentration}}$$

9.4.3 Retention Time Windows and Pattern Recognition

The laboratory shall identify single component target analytes by comparison of its mass spectrum to a reference spectrum. The retention time for each analyte should be within ± 0.04 minutes (DOD QSM4.2, Table F-4 allows ± 0.06 minutes) from the ICAL or daily CCV.

9.4.4 Internal Standard Response

Internal standard areas shall be evaluated based on the value that was observed in the midpoint of calibration curve. The internal standard areas shall be less than $\frac{1}{2}$ or greater than two times the area found in the midpoint of the curve.

9.4.5 Sample Preparation:

Water samples: An aliquot of sample, sufficient to get the highest concentration constituents into the upper half of the linear range, is transferred to a 20 mL extraction vial which contains approximately $\frac{1}{4}$ tsp. salt. The vial is then spiked with the surrogate (bromofluorobenzene between 4.17 and 41.67 ppb) and internal standard (fluorobenzene between 4.17 and 41.67 ppb). Invert the vial a few (approximately 3) times and remove approximately five mLs and place the vial on the autosampler tray. The autosampler tray is then placed on the CTC autosampler and set for analysis in accordance with the CTC specifications. At that point the CTC autosampler agitates the sample and the SPME fiber is then exposed to the headspace (headspace created by removing approximately 5 mL from preparation vial) above the sample for 6 or 8 minutes while the sample is agitated. The 6 or 8 minutes is measured by either the autosampler. Extraction time may be modified depending on the anticipated equilibration response of the target analytes at given concentrations (if adjusted samples and standards would be adjusted).

Soil samples: Preserved in methanol; 10-12 g core of soil is added to 10 mL of methanol containing an appropriate amount of bromofluorobenzene. Subsequent to sample collection, the methanol/soil mixture is agitated to break up the solids. The level of agitation shall be sufficient enough so that the solids are completely disaggregated as to maximize the contact between the methanol and the soil surfaces. This is typically achieved within 10 minutes using an aggressive orbital shaking procedure. Following this extraction step, an aliquot of the methanol, sufficient to get the highest concentration constituents into the upper half of the linear range but not to exceed 2 mLs, is diluted into analyte-free water and this water/methanol mixture is further extracted via the headspace SPME technique in the same manner as a water sample.

Air samples: Exposure of the SPME fiber to the air sample occurs directly through the syringe septum in the Tedlar bag. Exposure time, measured using a bench-top timer, may be modified depending on the anticipated equilibration response of the target analytes at given concentrations. There is no surrogate or internal standard for air sampling.

9.4.6 Analysis of Samples:

Analysis of samples is performed using SPME followed by analysis on a GC equipped with a narrow bore capillary column and a MSD. For this program the fiber is exposed to the headspace above the sample in the CTC autosampler. A small portion of sample is discarded from the 20 ml vial prior to exposure to generate headspace (approximately 5 mLs). The exposure time needs to be consistent (typically 6 to 8 minutes for this method). To facilitate the release of the analytes from their respective media, the sample is agitated throughout the extraction process (fiber exposure). Following extraction, the fiber adsorbed analytes are thermally desorbed within the injection port of the GC and are transferred to the capillary column.

9.4.7 Surrogate (SS) and Internal Standard (ISTD) Compounds for VOC compounds

Compound	Amount Spiked
Bromofluorobenzene (SS)	Range: 4.17 to 41.67 ppb
Fluorobenzene (ISTD)	Range: 4.17 to 41.67 ppb
Chlorobenzene-d5 (ISTD)	Range: 4.17 to 41.67 ppb

9.4.8 LCS Preparation

Compounds and spike amounts are on Table 1. For a waters program, compounds and spike amounts are specified according to project specific needs. Waters are spiked at around the mid-point of the calibration.

For the soils program, the soil LCS will be prepared in the same manner as the soil samples, an aliquot (0.5 mL or 1.0 mL) of methanol will be prepared in the SPME preparation vial, spiked with VOCs of interest, and prepared in the same manner as the soil MS/MSD.

9.4.9 Matrix Spike and Matrix Spike Duplicate (MS/MSD) Compounds:

For water samples the MS in SIM configuration will be spiked at 20 ppb; the amount may change to account for the concentration of a particular analyte found in the sample being analyzed as a MS. For soil samples, an appropriate amount of the target analytes are spiked

into the 10 mL of methanol. Matrix Spike Analyses contains the VOC compounds of interest in the same manner as the LCS.

9.4.10 Target Compound List Compounds

A Target Compound List with Quantitation Limits can be found on Table 1.

10.0 CALCULATIONS

Identification of the project specific VOCs in the sample chromatogram is based on retention time and on comparison of the sample mass spectrum with characteristic ions in a reference mass spectrum. Retention times must be within ± 0.04 minutes from the ICAL. If a retention time shift is observed in the CCV or daily ICV, then adjustments to the daily retention time windows will be made accordingly. The relative intensities of the characteristic ions must agree within 30% of these ions in the reference spectrum. Quantification of the VOCs is determined by comparison to the internal standard and average response factor for the target ion of the analyte.

The concentration of each analyte in the sample may be determined by calculating the amount of standard injected, from the target ion peak response, using the calibration curve. The calculations are as noted below.

Concentrations of Unknowns

Method 8260B does not include reporting of tentatively identified compounds (TIC). However, reporting of up to 10 TIC's whose peak heights are $\geq 10\%$ of the nearest internal standard may be requested or $\geq 40\%$ of the nearest internal standard may be requested for low concentration analyses only when the laboratory has analyzed the samples in Scan Mode. Concentrations are calculated using the following formula using an assumed response factor (RF) of 1:

$$C_{(x)} = \frac{C_{(IS)} * A_{(x)} * DF}{A_{(IS)}}$$

Where:

$C_{(x)}$ = Concentration of Unknown ($\mu\text{g/L}$).

$C_{(IS)}$ = Concentration of internal standard ($\mu\text{g/L}$).

DF = Dilution Factor

$A_{(x)}$ = Area of Unknown (from the total ion chromatogram)

$A_{(IS)}$ = Area of associated internal standard (from the total ion chromatogram).

Concentrations of Calibrated Compounds (when RRF is used):

$$C_{(x)} = \frac{A_{(x)} * C_{(IS)}}{A_{(IS)} * RRF} * DF$$

Where:

$C_{(x)}$ = Concentration of compound (µg/L)

$C_{(IS)}$ = Concentration of associated internal standard (µg/L).

DF = Dilution Factor.

$A_{(IS)}$ = Area of quantitation ion for associated internal standard.

$A_{(x)}$ = Area of quantitation ion for compound.

RRF = Average Relative Response Factor from five-point initial calibration.

Note: for linear and quadratic equations see SW846 Method 8000C.

Data Reporting - Based on the mass spectra and the project specific field program, it is appropriate to report values between the MDL/Limit of detection (LOD) and the QL or LOQ. In this region, an analyte can be qualitatively detected, but not accurately quantified. Any data point reported in this region is flagged with a “J” (estimated) qualifier. Stone reports sample specific QL’s. Sample specific QL’s are derived by taking into account various sample specific data, which can include the amount of the sample subject to testing, % moisture, dilution factor, interferences and the base QL’s for the analysis.

Typical Reporting qualifiers are as follows:

B = Analyte is found in the associated method blank as well as the sample.

D = Compound is identified in an analysis at a secondary dilution factor.

E = Compound quantitation is above the instrument's calibration range for this analysis.

J = Indicates an estimated quantitation value.

Q = One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery or CCV).

U = Compound was analyzed for but not detected. Value reported is the method LOQ.

11.0 QUALITY CONTROL AND CORRECTIVE ACTION

11.1 Limit of Detection Studies

Limit of Detection (LOD) studies must be completed initially for each method, matrix and instrument and then verified quarterly for each method, lab and matrix. The initial LOD study is the same as the MDL study. LOD verifications are accomplished by running a spiked standard at a value that is greater than 1 to 4 times the LOD. Since we have a range of LODs, we will likely have to run several LOD verifications.

11.2 Limit of Quantitation

Limit of Detection (LOQ) studies must be completed initially for each method, matrix and instrument and then verified quarterly for each method, instrument and matrix. The initial LOQ study is conducted by running the low point of the calibration curve back through the curve once the curve is built in the data analyses software. A successful study is one where the recovery of each analyte is within the established test method acceptance criteria or client data quality objectives for accuracy. The LOQ results must be within the limits of the DOD's limits for LCS recoveries, as stated in Table 2.

11.3 Measurement of Uncertainty

Measurement of Uncertainty studies must be completed initially for each method, matrix and instrument and then verified quarterly for each method, instrument and matrix. These are accomplished by looking at the deviation of recovery for each analyte in an LCS. For example, a recovery of 97% would have a 3% uncertainty associated with it.

11.4 Instrument Blank (SPME Fiber Blank)

To be performed once daily at the start of the analytical day. All target analyte areas detected in the instrument blank must be less than one-half the area of the analyte at the PQL value prior to continuing.

11.5 MS Tuning - 4-Bromofluorobenzene

To be performed every 12 hours, at the start of the analytical day and before beginning acquisition of a calibration curve. Criteria can be found in section 9.4.1.

11.6 Initial Calibration

Prior to the analysis of any samples or QC samples an initial calibration curve for the quantification of analytes of interest is established using criteria as noted in Section 9.0. Minimum of 5 calibration standards with the lowest standard concentration at or below the RL. %RSD for all analytes $\leq 20\%$ RSD. Least squares regression $r \geq 0.995$; non-linear regression—coefficient of determination (COD) $r^2 \geq 0.99$ (6 points shall be used for second order, 7 points shall be used for third order). If this criteria is not met, then correct problem then repeat ICAL.

Calibration range must encompass the expected sample concentrations; therefore, if site samples are expected to be higher in concentration than the calibration range, adjustments to the calibration range and samples will be documented and made accordingly.

11.7 Continuing Calibration Verification

To be performed every 12 hours, at the start of the analytical day. Percent differences or percent drift must be less than or equal to $\leq 20\%$.

11.8 Method Blank

One per analytical batch (12 hours or 20 samples) directly after the calibration standard and after highly contaminated samples to demonstrate that there is no carry over into subsequent samples. All target analyte concentrations detected in the method blank must be less than one-half the PQL value prior to continuing.

For DoD projects, the method blank will be considered to be contaminated if:

- The concentration of any target analyte in the blank exceeds $\frac{1}{2}$ the reporting limit **and** is greater than $\frac{1}{10}$ the amount measured in any sample or $\frac{1}{10}$ the regulatory limit (whichever is greater);
- The concentration of any common laboratory contaminant in the blank exceeds the reporting limit **and** is greater than $\frac{1}{10}$ the amount measured in any sample or $\frac{1}{10}$ the regulatory limit (whichever is greater); or
- The blank result otherwise affects the samples results as per the test method requirements of the project-specific objectives.

If the method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the limit of detection (LOD). If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

11.9 Surrogate Standards

Surrogate recoveries should be 70-130 % in water samples and 60-140 % in soil samples. Samples with surrogate recoveries falling outside of quality control limits should be reanalyzed once. If the reanalysis of the sample is also outside the quality control limits, then it will be determined that the problem may be associated with the sample matrix and noted as such.

For DoD projects, the acceptance limits for 4-Bromofluorobenzene as a surrogate are 75-120%.

11.10 Internal Standards

Internal standard areas shall be evaluated based on the value that was observed in the midpoint of calibration curve. If the internal standard area is less than $\frac{1}{2}$ or greater than two times the area found in the midpoint of the curve, the affected sample(s) should be rerun to confirm a possible matrix affect.

11.11 Initial Calibration Verification Standard (ICV)

A QC sample from a second source independent of the initial calibration will be analyzed directly after the ICAL or CCV. The ICV sample will contain all the VOC compounds of interest at mid point of the calibration curve. Recovery Limits for the ICV will be 70-130% and 40-160% for poor performers. For DoD projects, the ICV Recovery Limits will be 80-120%. This sample may also be used as the laboratory control sample (LCS).

11.12 Laboratory Control Sample (LCS)

For a waters program, compounds and spike amounts are specified according to project specific needs. Waters will be spiked at around the mid-point of the calibration. For the soils program, the soil LCS will be prepared in the same manner as the soil samples, an aliquot (0.5 mL) of methanol will be prepared in the SPME preparation vial, spiked with VOCs of interest, and prepared in the same manner as the soil MS/MSD. Recovery Limits for the LCS are as specified in Table 2 (DOD LCS Limits) and for compounds not in Table 2 the limits will be 60-140%. These shall be analyzed on the frequency of one per analytical batch. For DoD projects, all target analytes must be spiked in the LCS. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.

11.13 Matrix Spike and Matrix Spike Duplicate (MS/MSD) Analysis

An MS/MSD analysis is required every set of twenty samples or as specified by the client. A sample may be chosen by the client to perform a MS/MSD analysis.

Recovery Limits for the MS/MSD are as specified in Table 2 (DOD LCS Limits) and for compounds not in Table 2 the limits will be 60-140%. For DoD projects, all target analytes must be spiked in the MS/MSD samples.

$$\% \text{Recovery} = \frac{\text{Sample Spiked Concentration} - \text{Un-Spiked Sample Concentration}}{\text{Spiked Concentration}}$$

11.14 CORRECTIVE ACTION

Quality Control Check	Minimum Frequency	Acceptance Criteria	Corrective Action
Initial Calibration (ICAL)	ICAL prior to sample analysis.	Minimum of five to six points for VOCs. Minimum RRF and Maximum %RSD on Table 1 or a correlation factor (R or R^2) of 0.99 for other curve types. Air calibration's linear regression should have correlation factor of 0.99.	Verify solution integrity and check instrument performance. Perform necessary maintenance and recalibrate instrument. Reanalyze all affected samples.
Initial Calibration Verification (ICV) and/or Laboratory Control Sample (LCS)	One ICV per calibration (following acceptable ICAL). One LCS per analytical batch.	QC limits are 70 to 130% for target compounds in water and soil analyses. This same standard may be used as the daily LCS in which the QC limits are set to 70-130% for target compounds and 60-140% for poor performers. All analytes for air analyses should be within 60-140%. For DoD projects, the ICV Recovery Limits will be 80-120%. This sample may also be used as the laboratory control sample (LCS) Note: Limits may be adjusted based on the program.	Reanalyze once; if still out verify solution integrity or ICAL solution integrity, and instrument performance. Re-prepare and reanalyze all associated samples.
Retention Time (RT) Window Study	Every new column installation/per ICAL	All target compounds and surrogates in all standards must fall within the established window of ± 0.04 minutes from ICAL	Perform system maintenance. Reanalyze affected samples.
Continuing Calibration Verification (CCV)	Daily before sample analysis and every 12 hours of analysis time.	See Section 9.0. $\pm 20\%D$ for VOCs in water and soils programs. $\pm 30\%D$ for VOCs in air program.	Verify solution integrity and instrument performance. Reanalyze standard once, if still out, recalibrate and reanalyze affected samples. Based on project specific objectives, marginal exceedances may be allowed. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable CCV.

Quality Control Check	Minimum Frequency	Acceptance Criteria	Corrective Action
Method Blanks	One per preparation batch	Target Compounds < one-half reporting limit. See section 11.4 above for DOD criteria.	Investigate source of contamination. Re-prepare and reanalyze all associated samples. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.
Matrix Spike (MS) and Matrix Spike Duplicate (MSD)	One set per 20 samples of a similar matrix or as specified by the Client.	Recovery Limits for the MS/MSD are as specified in Table 2 (DOD LCS Limits) and for compounds not in Table 2 the limits will be 60-140%. RPD not to exceed 30% for waters RPD not to exceed 50% for soil samples.	Reanalyze only if recoveries indicate analytical error. If LCS or ICV are acceptable, narrate as possible matrix effect. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and put in the case narrative.
Tuning – 4-Bromofluorobenzene	every 12 hours or at the start of a new analytical day, and before acquisition of a new calibration curve	See section 9.4.1. Not applicable for air program.	Reanalyze once, if still out, MS should be retuned and adjusted to meet all criteria before continuing
Surrogate Recovery	Each sample	70-130% in water and 60-140% for soil samples For DOD projects 75-125% for water and soil samples	Rerun the sample once, if still out verify the solution integrity and instrument performance. Apply Q-flag or other flag to all associated analytes if acceptance criteria are not met.
Internal Standard Verification	Every field sample, standard, and QC sample.	Retention time $\pm$ 30 seconds from retention time of the midpoint standard in the ICAL; EICP area within -50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions. Reanalysis of samples analyzed while system was malfunctioning is mandatory. If corrective action fails in field samples, apply Q-flag to analytes associated with the non-compliant IS. Flagging criteria are not appropriate for failed standards.

11.15 Data Review

The analyst is responsible for primary data review of data generated from the sample analysis. Analyses will be documented in the instrument run log. Maintenance is documented in the Instrument Maintenance Logbook. Instrument calibrations and recoveries of all QC samples must be within specified control limits. If instrument calibration or the recoveries of any QC sample exceed specified tolerances, then the affected sample results are evaluated and generally the samples are

submitted for re-analysis. Manual integrations should be kept to a minimum and should be dated and initialed by the analyst. To determine if analytical results are acceptable, a qualified and independent QA/QC analyst shall conduct a 100% secondary review prior to reporting of the final data package to the client. The laboratory QA/QC Checklist (Attachment 1) is used to indicate any problems with the referenced analytical batches and submitted to the secondary reviewer. The QA/QC checklist addresses any corrective action taken in the laboratory such as dilutions and reanalyses. All calibrations, calculations, and transcriptions are checked for accuracy and QC sample results are evaluated against specified limits by the secondary reviewer and documented on the Secondary Reviewer Checklist (Attachment I). If instrument calibration and recoveries of all QC samples are within the specified criteria, then the data reports will be submitted to the Project Manager as final results with no qualifiers. If recoveries of any QC samples exceed specified limits and re-analysis is not an option, then the samples will be qualified with a Q-flag or as estimated with a "J" qualifier (J= The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.) depending on the corrective action or the QC element that failed. Data will not be reported if significant QC issues affect the batch analyses. Any qualifications or actions taken will be noted in the case narrative.

12.0 POLLUTION PREVENTION & WASTE MANAGEMENT

Pollution prevention encompasses any technique that reduces or eliminates the quantity or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in laboratory operation. The United States Environmental Protection Agency (USEPA) has established a prevention hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address their waste generation. When wastes cannot be feasibly reduced at the source, the agency recommends recycling as the next best option.

The quantity of chemical purchased should be based on expected usage during its shelf life and disposal cost of unused material. Actual reagent preparation volumes should reflect anticipated usage and reagent stability.

For information about pollution prevention that may be applicable to laboratories and research institutions, consult "Less is Better: Laboratory Chemical Management for Waste Reduction", available from the American Chemical Society's Department of Government Regulations and Science Policy, 1155 16th Street N.W., Washington, D.C. 20036; (202) 872-4477.

The USEPA requires that laboratory waste management practices conducted be consistent with all applicable rules and regulations. Excess reagents, samples, and method process wastes should be characterized and disposed of in an acceptable manner. The Agency urges laboratories to protect the air, water and land by minimizing and controlling all releases from hoods and bench operations, complying with the letter and spirit of any waste regulations, particularly the hazardous waste identification rules and land disposal restrictions. For further information on waste management consult the "Waste Management Manual for Laboratory Personnel", available from the American Chemical Society.

13.0 REFERENCES

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14.0 TABLES, DIAGRAMS, FLOWCHARTS, AND VALIDATION DATA

Attachment 1: Sample GC Laboratory QA/QC Checklist

Table 1: Analyte Details – LOQ/QLs and MS/MSD Spike values shown are for SIM Configuration

Analyte	CAS #	**Minimum RRF	Maximum %RSD	LOQ/QL Water (ug/L)	LOQ/QL Air (ppbv/v)	LOQ/QL Soil (ug/Kg)
Chloromethane	74-87-3	0.01	20%	5	1-50	120
Vinyl Chloride	75-01-4	0.01	20%	2	1-50	80
Chloroethane	75-00-3	0.1	20%	2	1-50	80
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.1	20%	2	1-50	80
1,1-Dichloroethene	75-35-4	0.01	20%	2	1-50	80
+ Carbon Disulfide	75-15-0	0.1	20%	2	1-50	80
+ Methylene Chloride	75-90-2	0.01	20%	2	1-50	80
+ t-Butyl-methyl ether	1634-04-4	0.1	20%	2	1-50	80
trans-1,2-Dichloroethene	156-60-5	0.1	20%	2	1-50	80
1,1-Dichloroethane	75-34-3	0.1	20%	2	1-50	80
cis-1,2-Dichloroethene	156-59-2	0.1	20%	2	1-50	80
* + 2-Butanone	78-93-3	0.1	20%	50	1-50	2000
Chloroform	67-66-3	0.1	20%	2	1-50	80
1,1,1-Trichloroethane	71-55-6	0.1	20%	2	1-50	80
Cyclohexane	110-82-7	0.1	20%	2	1-50	80
Carbon Tetrachloride	56-23-5	0.1	20%	2	1-50	80
Benzene	71-43-2	0.1	20%	2	1-50	80
1,2-Dichloroethane	107-06-2	0.01	20%	2	1-50	80
Trichloroethene	79-01-6	0.1	20%	2	1-50	80
Methyl Cyclohexane	108-87-2	0.1	20%	2	1-50	80
1,2-Dichloropropane	78-87-5	0.1	20%	2	1-50	80
Bromodichloromethane	75-27-4	0.1	20%	2	1-50	80
cis-1,3-Dichloropropene	10061-01-5	0.1	20%	2	1-50	80
* + 4-Methyl-2-pentanone	108-10-1	0.1	20%	50	1-50	2000
Toluene	108-88-3	0.1	20%	2	1-50	80
Trans-1,3-Dichloropropene	10061-02-6	0.1	20%	2	1-50	80
1,1,2-Trichloroethane	79-00-5	0.1	20%	2	1-50	80
Tetrachloroethene	127-18-4	0.1	20%	2	1-50	80
+ 2-Hexanone	591-78-6	0.1	20%	50	1-50	2000
Dibromochloromethane	124-48-1	0.1	20%	2	1-50	80
1,2-Dibromoethane	106-93-4	0.1	20%	2	1-50	80
Chlorobenzene	108-90-7	0.1	20%	2	1-50	80
Ethylbenzene	100-41-4	0.1	20%	2	1-50	80
M+p-Xylenes	108-38-3 106-42-3	0.1	20%	2	1-50	80
o-Xylene	95-47-6	0.1	20%	2	1-50	80

Analyte	CAS #	**Minimum RRF	Maximum %RSD	LOQ/QL Water (ug/L)	LOQ/QL Air (ppbv/v)	LOQ/QL Soil (ug/Kg)
Styrene	100-42-5	0.1	20%	2	1-50	80
Bromoform	75-252	0.1	20%	2	1-50	80
Isopropylbenzene	98-82-8	0.1	20%	2	1-50	80
Bromofluorobenzene	460-00-4	0.1	20%	2	1-50	80
1,1,2,2-Tetrachloroethane	79-34-5	0.1	20%	2	1-50	80
1,3-Dichlorobenzene	541-73-1	0.1	20%	2	1-50	80
1,4-Dichlorobenzene	106-46-7	0.1	20%	2	1-50	80
1,2-Dichlorobenzene	95-50-1	0.1	20%	2	1-50	80
+ 1,2-Dibromo-3-chloropropane	96-12-8	0.1	20%	2	1-50	80
1,2,4-Trichlorobenzene	120-82-1	0.1	20%	2	1-50	80
1,3,5-Trimethylbenzene	108-67-8	0.1	20%	2	1-50	80
1,2,4-Trimethylbenzene	95-63-6	0.1	20%	2	1-50	80
Naphthalene	91-20-3	0.1	20%	2	1-50	80
*Ketones or other VOC compounds not listed here may be analyzed for as verified by a successful method verification study. Method validations are performed at time of analysis when other compounds outside this list are added for a project. **Minimum response factors for a select number of compounds are lower than what is recommended in 8260C due to the fact that this method deploys solid phase microextraction as opposed to purge and trap and these minimum RFs are acceptable as demonstrated with demonstration of an acceptable LOQ standard.						
+- Poor Performer						

Table 2: LCS Control Limits for DoD Projects (presented in terms of percent recovery)

Analyte	CAS #	Lower DoD Control Limit (Water)	Upper DoD Control Limit (Water)	Lower DoD Control Limit (Solids)	Upper DoD Control Limit (Solids)
Chloromethane	74-87-3	40	125	50	130
Vinyl Chloride	75-01-4	50	145	60	125
Chloroethane	75-00-3	60	135	40	155
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	NA	NA	NA	NA
1,1-Dichloroethene	75-35-4	70	130	65	135
Carbon Disulfide	75-15-0	35	160	45	160
Methylene Chloride	75-90-2	55	140	55	140
t-Butyl-methyl ether	1634-04-4	65	125	NA	NA
trans-1,2-Dichloroethene	156-60-5	60	140	65	135
1,1-Dichloroethane	75-34-3	70	135	75	125
cis-1,2-Dichloroethene	156-59-2	70	125	65	125
2-Butanone	78-93-3	30	150	30	160
Chloroform	67-66-3	65	135	70	125
1,1,1-Trichloroethane	71-55-6	65	130	70	135
Cyclohexane	110-82-7	NA	NA	NA	NA
Carbon Tetrachloride	56-23-5	65	140	65	135
Benzene	71-43-2	80	120	75	125
1,2-Dichloroethane	107-06-2	70	130	70	135
Trichloroethene	79-01-6	70	125	75	125
Methyl Cyclohexane	108-87-2	NA	NA	NA	NA
1,2-Dichloropropane	78-87-5	75	125	70	120
Bromodichloromethane	75-27-4	75	120	70	130
cis-1,3-Dichloropropene	10061-01-5	70	130	70	125
4-Methyl-2-pentanone	108-10-1	60	135	45	145
Toluene	108-88-3	75	120	70	125
Trans-1,3-Dichloropropene	10061-02-6	55	140	65	125
1,1,2-Trichloroethane	79-00-5	75	125	60	125
Tetrachloroethene	127-18-4	45	150	65	140
2-Hexanone	591-78-6	55	130	45	145
Dibromochloromethane	124-48-1	60	135	65	130
1,2-Dibromoethane	106-93-4	80	120	70	125
Chlorobenzene	108-90-7	80	120	75	125
Ethylbenzene	100-41-4	75	125	75	125
M+p-Xylenes	108-38-3 106-42-3	75	130	80	125
o-Xylene	95-47-6	80	120	75	125
Styrene	100-42-5	65	135	75	125
Bromoform	75-252	70	130	55	135
Isopropylbenzene	98-82-8	75	125	75	130
1,1,2,2-Tetrachloroethane	79-34-5	65	130	55	130
1,3-Dichlorobenzene	541-73-1	75	125	70	125
1,4-Dichlorobenzene	106-46-7	75	125	70	125

Analyte	CAS #	Lower DoD Control Limit (Water)	Upper DoD Control Limit (Water)	Lower DoD Control Limit (Solids)	Upper DoD Control Limit (Solids)
1,2-Dichlorobenzene	95-50-1	70	120	75	120
1,2-Dibromo-3-chloropropane	96-12-8	50	130	40	135
1,2,4-Trichlorobenzene	120-82-1	65	135	65	130

Table 3: Example Standard Preparation Calculation Sheet

 STONE ENVIRONMENTAL INC						
<u>Gas Chromatography Laboratory</u>						
HP-5						
<u>Standard Prep Log</u>						
08/16/05-a1					dmkc	
FID WS						
100	ppm					
x: 8/31/05						
Compound	Vendor	Lot	Exp	Conc (mg/ml)	Amount	
Custom VOC	S	LB18097	8/16/2006	20	20	ul
1,1-DCA	A	B2090306	6/22/2006	20	20	ul
1,1,1-TCA	A	B3050086	6/22/2006	10	40	ul
8020 Mix	A	B1070292	8/31/2005	2	200	ul
1,1-DCE	A	B4050042	1/21/2006	20	20	ul
BFB	A	B4110093	5/17/2006	25	16	ul
MeOH	OmniSolv	44090	3/1/2008	into	3684	ul
				Total	4000	ul

15.0 AUTHORIZATION

Authored by: Kim Watson for Date: 11-7-12
David Crosby, Project Scientist

Approved by: Seth Pitkin Date: 11-7-12
Seth Pitkin, Vice President

16.0 REVISIONS**Revision 1:**

1. Included the analytical process to analyze air in a tedlar bag using SPME and SW846 Method 8260.

Revision 2:

1. Allow a range for the concentration of the internal standard from 8.33 to 16.67 ppb.
2. Section 9.4. Included text to allow for the BFB tune evaluation to be performed as part of a check standard prior to running calibration standards and environmental samples.
3. Table 1. Adjust chloromethane and bromomethane reporting limits to 10 ppb for waters and 120 ppb for soils.
4. Include calibration by linear regression in Section 11.9.

Revision 3:

1. Adjust frequency for continuing calibration check standard from one per 15 analytical runs to one at the beginning of each analytical day.
2. Adjustment of reporting limits to reflect latest method detection limit study.

Revision 4:

1. Add reference to SIM mode analysis on the GC/MS in Sections 2.0, 3.0, and 9.4.2., and definition under Section 3.0.
2. Change EPA to USEPA were applicable.
3. Update typical GC Program parameters in Section 9.1
4. Update QC recovery limits for LCS/ICV from 70-130% to 70-130% and 70-160% for poor performers wherever applicable (Section 11.0) and in Attachment I.
5. Update SS/IS spike concentrations to be an allowed range.
6. Add specifics regarding standard preparation procedures in Section 7.0 referencing the SEI-4.7.5 SOP

and added Table 2 Example Standard Preparation Calculation Worksheet in Section 14.0.

7. Added two new paragraphs under Section 8.2 Sample Handling for pH determinations and percent moisture determination.

Revision 5:

1. Take out reference to an LCS in section 9.4.
2. Add clarification to the LCS Section 9.4.7 regarding the preparation and analysis of soils.
3. Change Section 11.0 to read Section 11.6 ICV, Section 11.7 LCS and 11.8 MS/MSD.

Revision 6:

1. Section 6.0: add SPME Autosampler: CTC Combi PAL.
2. Section 9: Add references for DOD exceptions and references
3. Section 11: Add reference to DOD projects and blank requirements.
4. Add Table 2. Reference to DOD project limits and allowances.

Revision 7:

1. Section 8: Add text requiring unique labeling of sample vials when more than one vial is presented for a sample.

Revision 8:

1. Changed document to reflect SW846 USEPA Method 8260C from 8260B
2. Included updates for DOD exceptions.
3. Minor grammatical and typographical errors fixed.
4. Updated extractions times to include 6 minutes for faster methods.
5. Updated columns use to RTX-VMS
6. Correlation Coefficient of 0.99 is now acceptable for calibrations.
7. Added Surrogate Recovery and Internal Standard Verification to Corrective Action Table
8. Added text for IC/LCS to CA Table.
9. Removed references to CCC's and SPCC's which are not used in method 8260C

Updated QA/QC Checklist added Table 2.

Revision 9:

1. Updated section to 8.2 to include isolation protocol for suspected hot samples.
2. Added LOD, LOQ, and Measurement of Uncertainty
3. Added equipment maintenance

4. Add Secondary Data Review Checklist demonstrating 100% review of all data sets.

Attachment I

SAMPLE GC LABORATORY QA/QC CHECKLIST AND SECONDARY REVIEW CHECKLIST

GC/MS LABORATORY QA/QC CHECKLIST

Instrument: _____

QC Batch: _____

System: _____

VSTD FB Area: _____

Date: _____

VSTD CB(D5) Area: _____

<u>QC Analysis</u>	<u>Criteria</u>	<u>Filename(s):</u>
IC Calibration	%RSD $\leq$ 20%, correlation coefficient >0.99 (other)	
SPME Fiber Blank	$< 1/2$ reporting limit	
BFB Tune Check	per 8260 Method	
CC Calibration	%D $\pm 20\%$ VOCs, $\pm 30\%$ (other)	
Method Blank	$< 1/2$ reporting limit	
ICV Standard	See Table 2	
MS/MSD Analysis	See Table 2	
Surrogate Standards	70-130% waters 60-140% soils	

Note: DOD projects may require additional and/or different QC criteria then specified above, see pertinent sections of SOP for details.

Comments/Corrective Action:

Prepared By: _____

Reviewed By: _____

SECONDARY DATA REVIEWER CHECKLIST

Instrument: _____

Project

ID: _____

System: _____

Sample Delivery Group.

SDG Date Range: _____

(SDG): _____

Stone Project

Number: _____

<u>Action</u>	<u>Completed?</u>
COCs: Check that all COCs have been properly populated with all necessary information.	
Accuracy & Completeness: - Export and format LIMS tblSampleLogin for inclusion in lab data report, including a header that shows project and SDG info. - Check each sample on this Sample Login Summary against project COCs for accuracy and completeness. - Generate a list of samples not analyzed, including extra vials not opened, for inclusion in lab data report - Use LIMS Completeness check ("Samples Logged in/Count of Results" button) to make sure all samples have data in LIMS	
Sample Weights & Percent Moisture: If soil or rock samples are present in SDG, generate, export and format LIMS "Review Sample Weights" query for inclusion in lab data report, including a header that shows project and SDG info. This is also a handy sheet to use when reviewing results and checking calculations.	
QC Data Review: - ICAL - Check response factor calculations for ICAL (esp. those with manual integrations) and make sure all levels are represented correctly on form – add 7th level RFs if applicable. Make sure that cal ranges are correct in LIMS. - Review all QC data from each analytical batch in the SDG, making sure that all QC Data meet the requirements described on Daily QC/QC Checklist. This review should include the following: FBLK, BFB Tune (including 12-h window), ICAL, CCV, VBLK, LCS, MS/MSD, FD, ISTD and SS recoveries. Sign Daily QA/QC Checklist. - Make sure that all QC outages are documented on Analyst's Daily QA/QC Checklists. If any data qualifications are necessary based on QC outages, confirm that those qualifications have been applied to the proper samples and analytes in tblFinalResults – use filtering tool to search.	

Sample Data Review: • Make sure all results in LIMS (or on LIMS-generated Form 1 Reports) match those on chromatograms, including checking any sample weight and/or percent moisture calculations for soil/rock samples. • Make sure chromatograms say “QT reviewed” and have been signed and dated by analyst. • Check that ISTD and SS are within acceptable range for all samples in window. • Check that all results have been reported from within cal range • Check that qualifiers have been applied appropriately if necessary. • Initial and date chromatogram, as secondary reviewer	
Manual Integrations (For DoD Projects only): • Check all manual integrations by looking at before and after integrations on pdf files. • Verify that analyst has initialed and dated each manual integration. Initial and date next to analyst’s initials.	
Lab Narrative Report: • Using the Daily QC/QC Checklists, summarize in narrative any QC outages from the batches within the SDG as well as any problems encountered with samples. • Compile all necessary attachments (dependent of level of reporting). At a minimum, this would include scanned COCs, LIMS Sample Login Summary, Sample weights and percent moisture data (for soil/rock data), and sample Form 1 Reports. • Send final report to another analyst or Lab or QA Manager for review.	
EDD: • Generate EQUIS EDD (or other appropriate format) in LIMS. • Make sure that all columns are properly populated. • Make sure that EDD contains the correct number of results • Spot check results in the EDD against verified Form 1 Reports.	

Secondary Reviewer Signature: _____ Date: _____

STANDARD OPERATING PROCEDURE

SEI-6.43.3

GROUNDWATER PROFILING AND KPRO TESTING

SOP Number: SEI-6.43.3

Date Issued: 08/13/02

Revision Number: 3

Date of Revision: 8/22/12

1.0 OBJECTIVE

Groundwater profiling is conducted to assess the distribution of contaminants and hydrogeologic conditions of a given aquifer at a scale much smaller (several centimeters) than the conventional monitoring well system. This method uses the Waterloo^{APS} (Advanced Profiling System) to collect groundwater samples at multiple discrete depths as the profiler is advanced vertically through unconsolidated, saturated porous media at a given location. The Waterloo^{APS} is a direct push tool used to collect samples and other data at multiple depths within a single hole without withdrawing and decontaminating the tool between samples. The profiling system can generate the following data in addition to the collection of groundwater samples for analysis:

- 1) Index of hydraulic conductivity (I_k)
- 2) Depth to potentiometric surface (water table)
- 3) Specific conductance
- 4) pH
- 5) Dissolved oxygen
- 6) Oxidation/reduction potential
- 7) Temperature

The index of hydraulic conductivity provides a real-time indication of the relative changes in hydraulic conductivity which allows for decisions to be made on depths to stop driving the profiler and collect samples as well as to assess the hydro-stratigraphy across the site.

There are two types of profiler configurations: 1) a peristaltic pump configuration with a single downhole tube and 2) a gas drive pump configuration with three downhole tubes.

The peristaltic pump can be used when the depth to water is less than the suction limit (typically around 25 feet below ground surface). The gas drive pump system must be used when the depth to water is greater than 25 feet below ground surface (bgs).

2.0 POLICIES

An experienced, qualified SEI staff member will train all SEI staff using this SOP.

SEI staff will read the most current version of this SOP and other appropriate SOPs prior to starting fieldwork.

3.0 SAFETY ISSUES

The corporate Health and Safety Plan and the Site Health and Safety Plan specify the procedures to be followed and equipment to be used during site activities. The following is a brief and general overview of safety issues.

- Potential Safety Issues include:
 - Noise Levels
 - Heavy equipment (drill rigs or direct push rigs) hazards
 - Overhead utility hazards
 - Underground utility hazards
 - Traffic/ motor vehicle hazards
 - Hazards associated with exposure to various chemicals
 - Slip, trip and fall hazards
 - Pinch point hazards
 - Compressed gas hazards
 - Fire hazards from hot work (e.g., grinding)
 - Gasoline hazards (filling generator)
- SEI staff and others under contract with SEI that may be present on-site will wear a hardhat whenever overhead hazards are present.
- Appropriate eye protection should be worn
- Hearing protection shall be worn whenever the drill rig is actively advancing profiling equipment.
- Steel toed boots will be worn.
- SEI staff will read the site health and safety plan (HASP) prior to beginning a project.
- Additional personal protective equipment shall be worn in accordance to the health and safety document.

4.0 PROCEDURE

4.1 Equipment

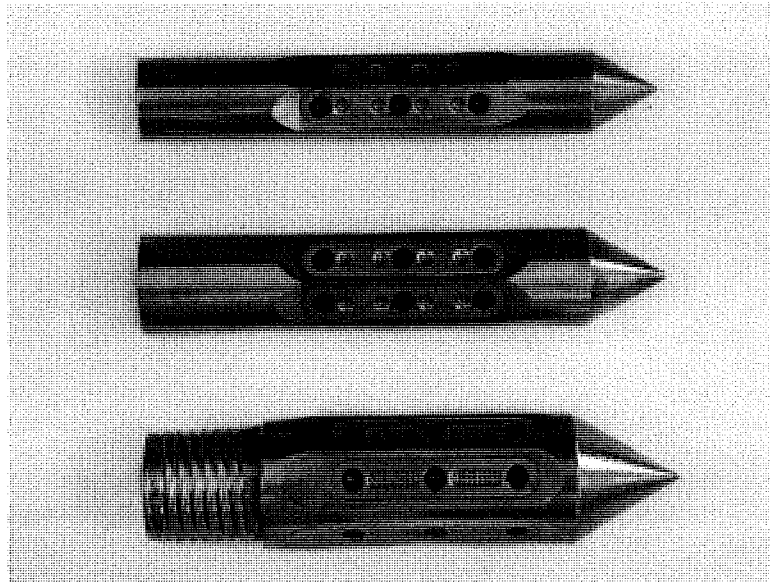
An equipment list is presented in Attachment 1. This list includes the equipment used for the peristaltic pump configuration and the gas drive pump configuration.

4.1.1 Drive Platform and Related Equipment

Any device that vibrates, hammers, or pushes drill tools can be used to advance the profiler. The type of drive platform selected is a function of the type of material to be sampled and the depth to which the profiler needs to be advanced. Typical drive platforms include GeoProbe 66 series probe rigs or similar rigs as well as larger conventional auger drill rigs with a breaker hammer mounted on the rig. A Geoprobe 8 series or equivalent is recommended to drive the 2.25" tip and rods. Field staff must ensure that the proper adaptors and subassemblies are provided for the particular drive platform to be used prior to taking to the field.

4.1.2 The Waterloo Profiler

This system is comprised of a 1.5, 1.75 or 2.25 -inch diameter profiling tip that is attached to 1.5 or 2.25-inch GeoProbe style rod or a quick thread style 1.75-inch diameter drill rod. The 1.5 and 2.25-inch drill rod is provided by others. The 1.75 inch rod is the standard rod size that Stone uses for profiling.



1.5, 1.75 and 2.25" Profiling Tips

The 1.5 and 1.75-inch profiling tips contain 4 removable plates, each with 4 screened sampling ports (16 total) that allow for the groundwater to pass into the tip. The 2.25-inch

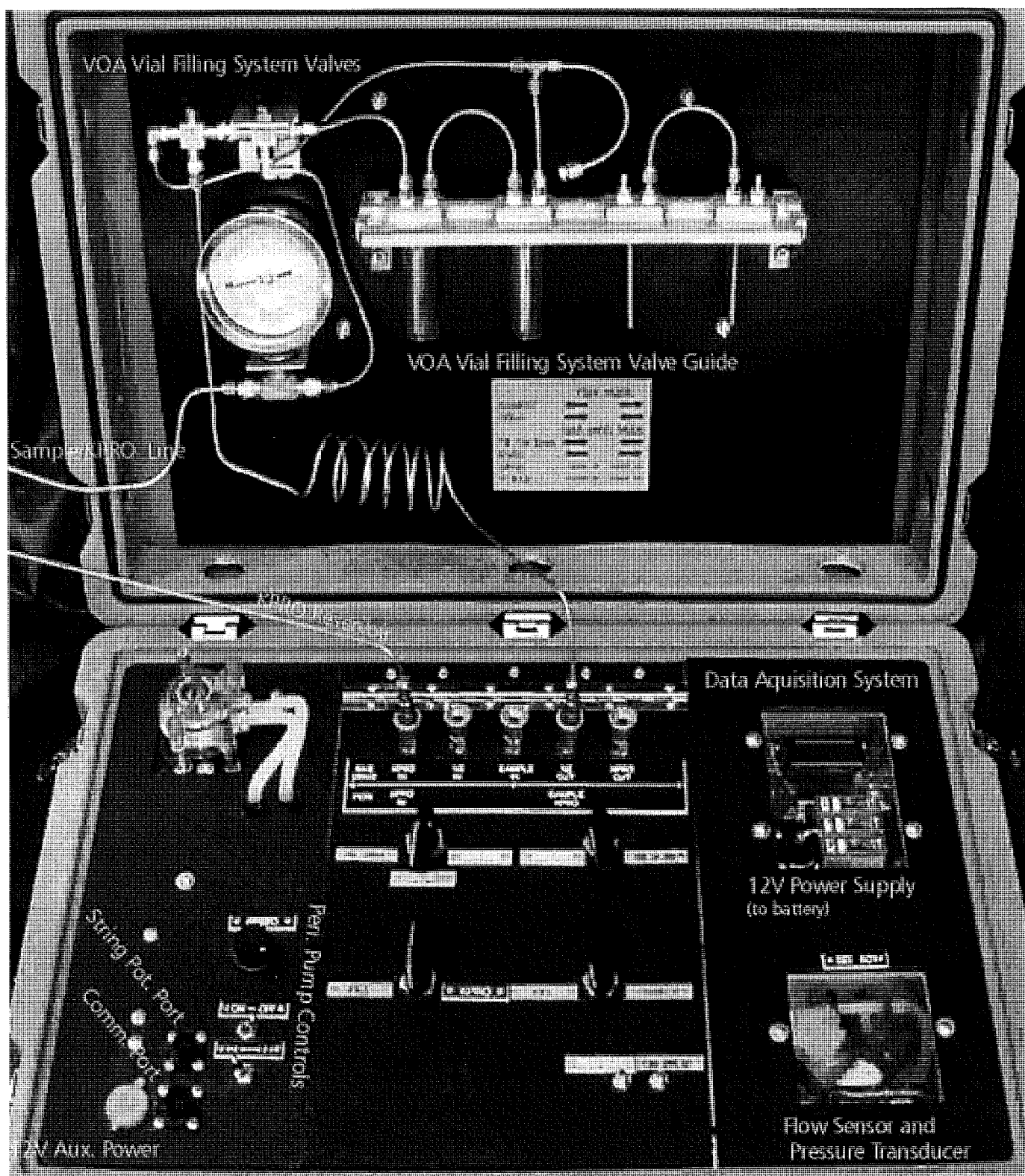
tip contains 6 plates. The plates have a slightly different design than the smaller tips in that the entire plate is more or less a sampling port. The groundwater is obtained using either a peristaltic pump or a gas-drive system (see Figure 4.1 for a schematic of these two profiler configurations).

4.1.3 Volatile Organic Analysis (VOA) Vial Filling System

The system contains as many as four vials connected in-series using stainless steel tubing and specially designed vial holders. The system is designed to mitigate losses of the volatile organic compounds (VOC) by ensuring that no exposure to the atmosphere occurs while the sample is collected. The bottle holders can accommodate up to four 40-mL VOA or 250-mL vials. The vial filling system has been incorporated into the SEI KPRO box. Although the KPRO box utilizes a peristaltic pump, the sample vials are located on the *down hole side of the pump* so that groundwater is pumped through the vials before going through the head of the pump.

4.1.4 KPRO Measurement and Data Acquisition System

The KPRO box consists of four valves, electronic enclosure, peristaltic pump and vial filling system (referred to as the sample jig). The valves can be oriented in a variety of ways in order to send water down and out of the profiling tip or to collect a groundwater sample in both peristaltic and gas drive modes. The following photo illustrates the box setup in peristaltic mode:

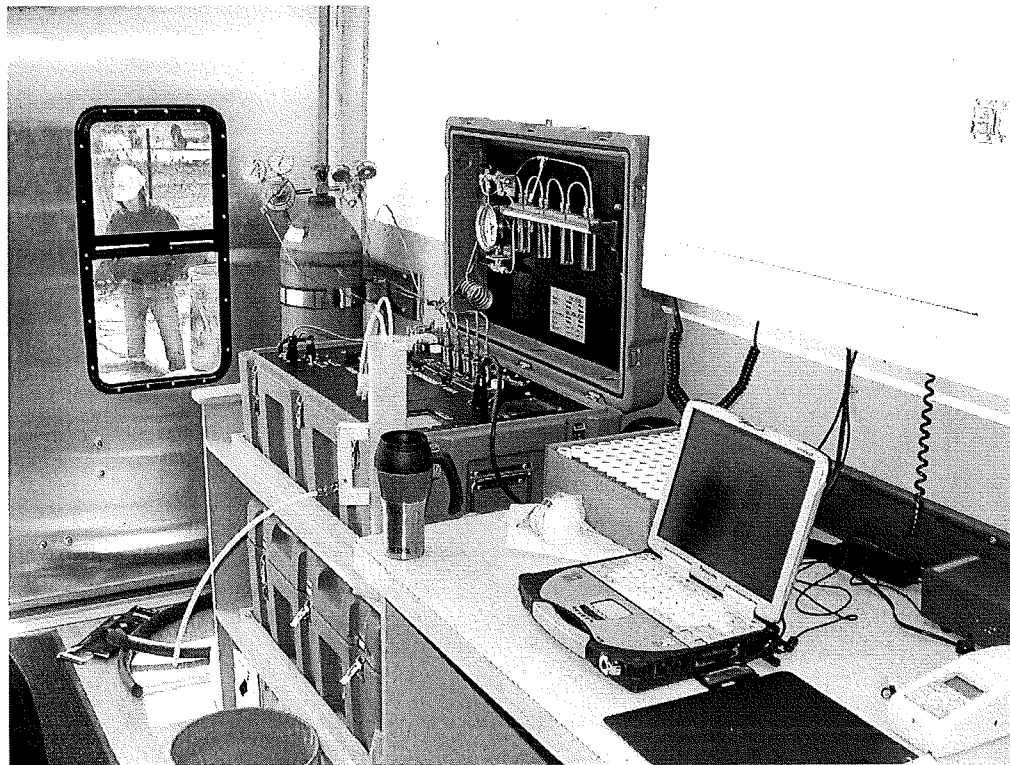


KPRO Box in Peristaltic Mode

The KPRO Measurement and data acquisition system consists of the following components:

- McMillan Model 102-4 (20-200mL/min) Flow Sensor
- Sensotec Model TGE/388-02TJA (0-50PSI) Pressure Transducer
- Celesco Model PT5DC-100-V62-UP-Z5-M6M String Potentiometer
- Analog Devices Acquisition System, includes signal conditioners and acquisition board. The removable container that houses the data acquisition system, flow sensor and pressure transducer is referred to as the “enclosure”.
- GeoTech Model Geopump peristaltic pump
- Labview KPRO Software Program
- Notebook computer (Toughbook or other)
- USB-Serial Cable or Serial Socket Card
- USB mass storage unit for data back up
- AC/DC power inverter or 12V deep-cycle battery

The following photo illustrates how the entire system looks when it is set up in the truck:



4.1.5 Sonde Water Quality Monitoring Systems

Specific instruction regarding the use, calibration and maintenance of these systems can be found in SEI SOPs 5.25.0 (Hydro Lab MS-5), 5.27.0 (Troll 9000 and 9500) and 10.7.1 (YSI 600XL). The YSI 600XL, Troll 9000, Troll 9500, Hydro Lab MS-5, and Hach HQ30 Water Quality Monitoring Systems consists of the following components:

- pH/ORP Probe
- Conductivity/Temperature Probe
- Dissolved Oxygen Probe
- Custom Made Flow-Through Cell.
- 3/8th Polyethylene tubing

4.1.6 Record Keeping Materials

- KPRO Calibration Log (dedicated to each profiling box).
- Groundwater Profiling Log (electronic and paper).
- Pens
- USB mass storage unit

4.2 General Procedure

The profiling procedure for the peristaltic pump mode and the gas drive mode consists of 6 main steps:

1. Set up of the KPRO box and associated equipment
2. Tip / Pump assembly
3. Adding rod and tubing
4. Drive the tool and acquire index of hydraulic conductivity data
5. Purge water from the system and obtain physico-chemical data from the Sonde water quality monitoring system
6. Collect samples and record data.

4.3 KPRO Box Set Up

4.3.1 Set up common to both Peristaltic and Gas Drive Modes

1. Open the KPRO box and support the top by using the built in wooden tab in the truck or the metal arm and screws that are located inside the KPRO box.

Plug the AC/DC inverter into the receptacle in the truck. Plug the power cable into the inverter and into the three pronged receptacle on the enclosure of the box.

2. Plug one end of the string potentiometer communication cable into the data port on the panel of the KPRO box and screw the other end into the string pot.
3. Connect the data cable to the Communication Port (COM port) on the KPRO box panel. Plug the other end of the cable into one of the serial ports on the computer or the USB – Serial Cable and secure it using the thumb screws on the cable.
4. Unpack the water quality sonde from its case. Unscrew the cal cup and screw on the flow through cell and connect the power and com cables to the sonde. Connect the com cable to one of the socket ports on the computer. Secure the sonde by putting it into the holder mounted on the counter. Connect a piece of poly tubing to the KPRO box out (peri or gas, depending on which method you are using) and the other to the bottom connection on the flow through cell. Connect a different piece of tubing to the other fitting on the flow cell. The other end of this tubing will go into a graduated cylinder. If you are using a stand-alone dissolved oxygen sensor, connect the “Out” tubing to the flow through cell of the DO meter, then use another length of tubing to connect to the sonde flow through cell.
5. Connect a male swage quick connect to a five foot length of stainless steel tubing and plug it into the female quick connect labeled KPRO In on the KPRO box. Connect the other end to the “out” port on the stainless steel KPRO reservoir using a reservoir quick connect fitting (black band).
6. Fill the stainless steel KPRO reservoir with analyte free water (distilled or spring water). Seal the top and close the pressure release valve.

4.3.2 Set up specific to Peristaltic Mode

1. Attach a low pressure regulator (0-500 psi) to the nitrogen cylinder.
2. Attach a five foot length of tubing to the “in” (white) port on the stainless steel KPRO reservoir using a quick connect fitting. Attach the other end to the outlet port on the nitrogen tank regulator. Open the valve on the nitrogen cylinder and set the regulator to 30 psi.
3. Attach a 20 foot length of stainless steel tubing to the inlet side of the SwageLok® fitting at the bottom of the pressure/vacuum gauge on the top panel. Tighten firmly. This line is the KPRO / sample line and is referred to as the harness.
4. On the KPRO box plug the male quick connect that is attached to the sample jig to the “KPRO Out” female quick connect on the KPRO box (Second from the right).

4.3.3 Set up specific to Gas Drive Mode

1. The gas drive system utilizes two regulators attached to the cylinder by a "T" adaptor. One of the regulators is low pressure (0-500) and the other is high pressure (0-4000).
2. Attach a five foot length of tubing to the "in" (white) port on the stainless steel KPRO reservoir using a quick connect fitting. Attach the other end to the outlet port on the low pressure nitrogen tank regulator. Open the valve on the nitrogen cylinder and set the regulator to 30 psi.
3. Connect a five foot length of tubing to the high pressure regulator. Attach a quick connect to the other end and insert into the "N2 In" female quick connect on the KPRO box. Set the regulator to 80 psi.
4. On the KPRO box plug the male quick connect that is attached to the sample jig to the "Sample In" female quick connect on the KPRO box (middle connection).
5. The harness for gas drive mode consists of three stainless steel tubes which are labeled with colored zip ties. Plug the KPRO line male quick connect (blue) into the "KPRO Out" quick connect on the KPRO box and plug the Nitrogen line (red) quick connect into the "N2 Out" quick connect. The Sample line (yellow) does not have a quick connect. This line connects to the 1/8" Swage fitting on the pressure gauge.
6. Attach a one end of a length of plastic tubing (FEP or other) to the "Peri Out" port located at the bottom right of the KPRO box and put the other end into a plastic 1L graduated cylinder. Attach a similar length of tubing to the "Gas Drive Out" port and connect this to the bottom port on the flow cell of the water quality sonde.
7. Inside each KPRO box is a vent tube, which is a length of poly tubing attached to a quick connect. Connect this tube to the port located on the outside front of the KPRO box.

4.4 Tip and Pump Assembly for Peristaltic and Gas Drive Modes

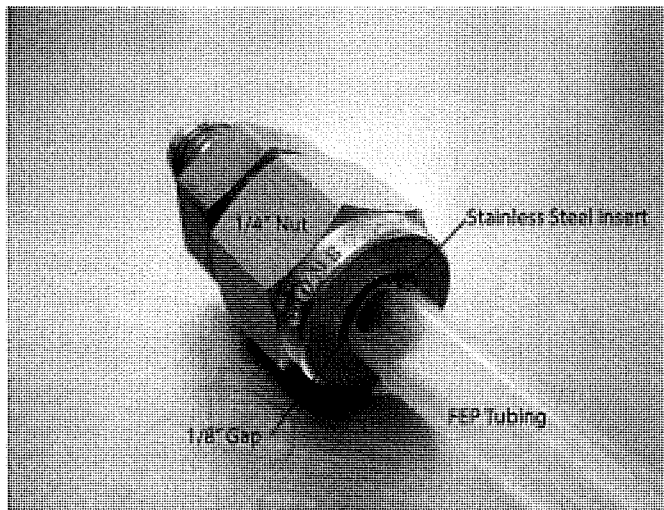
The 1.5 and 1.75-inch profiling tips have 4 plates and the 2.25-inch tip have 6. Behind the plate is a removable mesh screen. The size of the inner screen can be altered to prevent fines from entering the profiler or to maximize flow. Screen mesh sizes range from 40 (coarse) to 120 (fine). 80 size screen is usually the default screen size and can be changed depending on site geology. For peristaltic mode either the 1.5, 1.75 or 2.25-inch diameter tips can be used. With gas drive mode only the 1.75 or 2.25-inch tips can be used.

4.4.1 Peristaltic Mode

A small diameter tube (typically 1/4-inch outside diameter fluorinated ethylene propylene, or FEP) is fitted into the threaded hole in the center of the profiler tip by means of a 1/4- inch

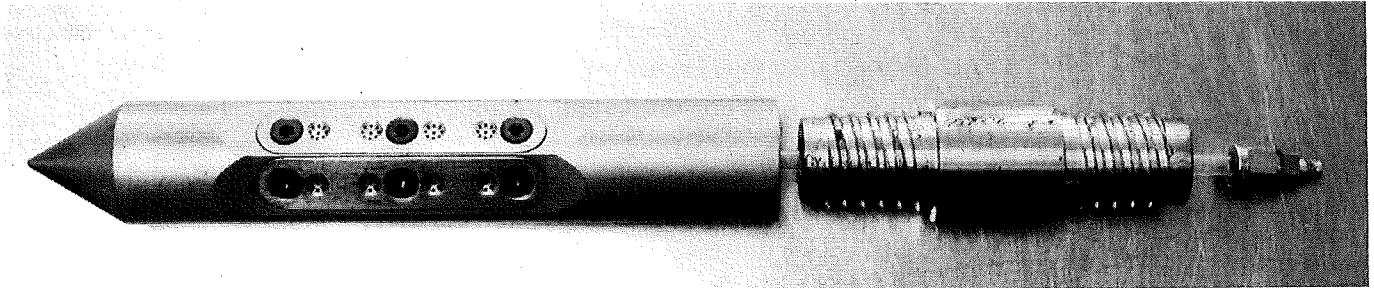
NPT thread to 1/4- inch SwageLok® fitting. The following procedure will outline the procedure for assembling the tip and adding rod and drive hardware.

1. Wrap the NPT threads of the 1/4- inch NPT to 1/4- inch SwageLok® fitting with Teflon tape and thread into the tip. With the tip locked into a vise, tighten the fitting as tight as you can with a 9/16" socket by hand. Most profiling tips already have this fitting installed and if so, there is no need to remove it.
2. Each tip has plates that are attached to the tip via T-25 torx plus screws. Each plate has sampling ports. Under each plate is a mesh screen (40-120 slot). The smaller the slot size the larger the opening is in the screen. The most common screen size used is 80 slot. If there are no plates on the tip first place the mesh screen into the space for the plate making sure to line up the screw holes. Put on the plate and tighten the screws as tight as possible using only a T handle screwdriver or similar tool. Do not use an impact driver as it will over tighten the screws. If you are using a tip that already has the plates installed, double check that the screws are tight.
3. Cut a 6-8" length of FEP tubing and insert a steel barb into each end.
4. For this step it is best to lock the tip into a vise. On the end of the FEP that will attach to the tip, slide a 1/4- inch SwageLok® nut onto the FEP and then slide on a 1/4" nylon ferrule. Insert the end of the FEP tubing into the 1/4" fitting on the tip making sure that it is inserted as far as it can go. Using a specialized 9/16" open ended socket, tighten the 1/4" nut until there is approximately 1/8" vertical gap between the top of the steel insert and the nut as shown in the following photo:



5. For the other end of the FEP, slide on another 1/4" SwageLok nut and 1/4" nylon ferrule. Insert the end of the FEP into a 1/4 "to 1/8" SwageLok® reducer. Using a 1/2" and 9/16" wrench, tighten the nut as before. Be careful to keep the FEP seated tightly into the fitting while tightening.

When using the 1.5" tip, a male/male adaptor must be screwed into the tip after the FEP tubing is attached to the 1/4- inch fitting on the tip. This allows the rod pin to be up so that the GeoProbe drive / slip cap can be utilized. After the adaptor is attached, then the 1/4 inch to 1/8 inch SwageLok® reducer can be attached. The inside diameter of the adaptor is not large enough to accommodate the reducer so it has to be fitted after the adaptor is attached.



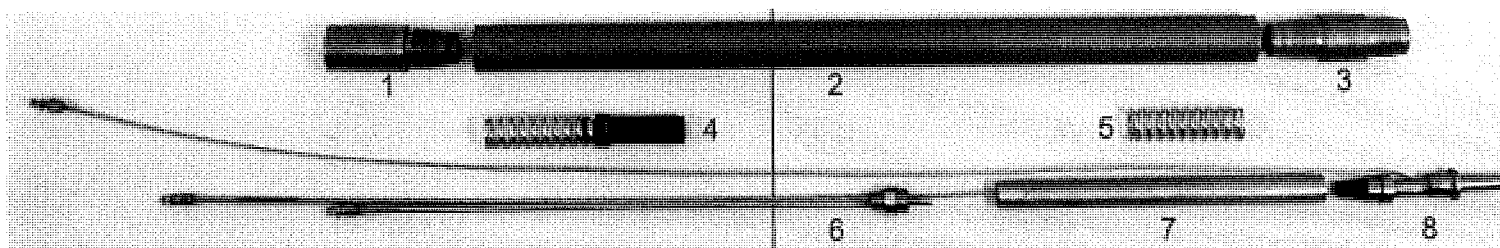
6. Gently pull on the reducer after the fittings have been attached to make sure that it is attached properly. If the fittings are over tight then the FEP can snap; if they are too loose than the FEP can pull out of the fitting.
7. A five-foot length of 1.75-inch diameter rod is slipped over the stainless steel tubing with the pin end down and is threaded into the profiler tip. When using the 1.5 or 2.25-inch tip the rod is threaded pin up. This union should also be "stepped on" using pipe wrenches to ensure that it does not vibrate loose. A sacrificial knock out tip should be fitted with two o-rings and the shank of the tip wrapped with Teflon® tape to minimize the movement of silt into the bottom of the tip. Electrical tape should only be used to affix the knock out tip to the profiler if toluene is not an analyte of concern at the site.
8. The top drive cap is then threaded into the top of the 5-foot 1.75-inch rod with the stainless steel tubing protruding through the center of the drive cap. The slotted slip cap adapter is then placed over the drive cap and fitted into the bottom of the hammer on the drive platform. When using the 1.5 or 2.25-inch tip there is no threaded drive cap. Because the rods are threaded pin up, a one piece GeoProbe style slotted drive cap is used instead.

4.4.2 Gas Drive Mode

1. Wrap the NPT threads of the 1/4- inch NPT thread to 1/4- inch SwageLok® fitting with Teflon tape and thread into the tip. With the tip locked into a vise, tighten the

fitting as tight as you can with a $\frac{9}{16}$ " socket by hand. Most profiling tips already have this fitting installed and if so, there is no need to remove it.

2. Each tip has plates that are attached to the tip via T-25 torx plus screws. Each plate has four sampling ports. Under each plate is a mesh screen (40-120 slot). The smaller the slot size the larger the opening is in the screen. The most common screen size used is 80 slot. If there are no plates on the tip first place the mesh screen into the space for the plate making sure to line up the screw holes. Put on the plate and tighten the screws as tight as possible using only a T handle screwdriver or similar tool. Do not use an impact driver as it will over tighten the screws. If you are using a tip that already has the plates installed, double check that the screws are tight.
3. Instead of FEP tubing, the gas drive system utilizes a $\frac{1}{4}$ " stainless steel tube ("piston"). To attach the piston, slip a $\frac{1}{4}$ " swage nut and $\frac{1}{4}$ " steel ferrule onto one end of the piston. Insert this end into the $\frac{1}{4}$ " fitting on the tip. It is best to have the tip locked in a vise for this step. Slip the open ended $\frac{9}{16}$ " socket over the piston and tighten the nut as tight as you can.



The above photo illustrates the components of the gas drive pump.

1. Pump Housing – Top
 2. Pump Housing – Middle
 3. Pump Housing – Bottom
 4. Top Spring with plastic bushing
 5. Bottom Spring
 6. Pump Body - top. Sample line is the middle tube and nitrogen is the short
 7. Pump Body – middle
 8. Pump Body – bottom with reed valve. The KPRO line is attached.
4. The gas drive pump body has three parts, the bottom (which has the KPRO line), the middle and top (which has the sample and nitrogen lines). Look into the narrow part of the pump bottom from the bottom. The piston on the tip will

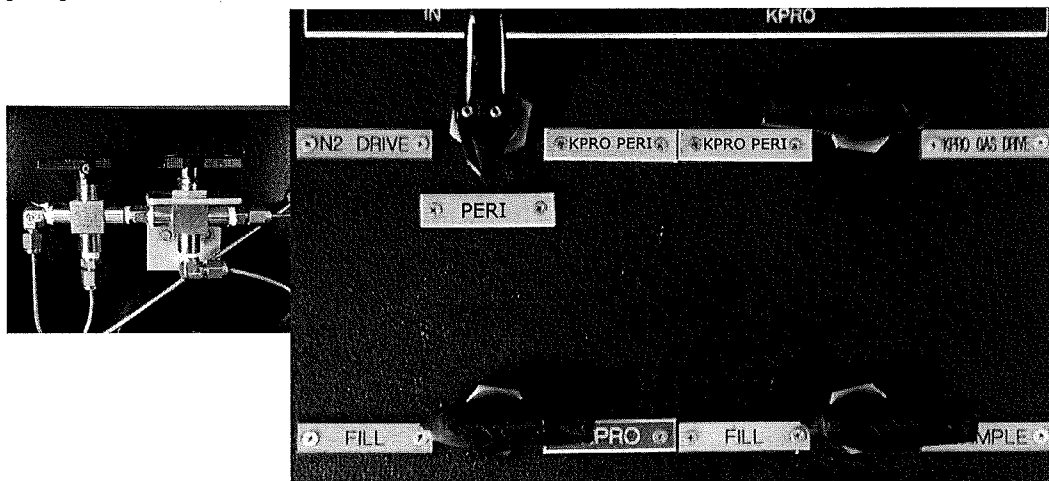
eventually be inserted into this end of the pump. There should be two very small rubber o-rings seated into two slots. If they are present, it is a good idea to replace them. If the o-rings get worn or dry out you will not get a proper seal between the piston and pump.

5. Pry the o-rings out with an angled pick and discard. Rinse out the slots with water. Replace the o-rings using the same pick.
6. Place an o-ring at the base of the threads of the top and bottom pump pieces and wrap the threads with Teflon[®] tape.
7. Trim a reed valve and place it onto the stub on the top of the pump bottom. In order for the reed valve to fit inside the middle pump piece, the flange of the valve must be trimmed. NOTE: There are two types of reed valves, one for depths shallower than 150' and one for profiles deeper than 150'. The storage container for the valves should be labeled as to which valve is which. Using a reed valves designed for shallow depths in a deeper profile could result in a catastrophic failure of the valve. If the container is not labeled assume the valve us for lesser pressures.
8. Thread the middle pump body onto the top and bottom pump pieces. Lock the middle of the pump into a vise and tighten the top and bottom pump pieces with a $\frac{9}{16}$ " open ended wrench until tight. The o-rings should squeeze out of the joint slightly.
9. Slide the plastic bushing and spring over the three stainless steel tubes so it rests snug on the top of the pump. Make sure that the KPRO line is located into the slot on the bushing.
10. The pump housing is comprised of three pieces: the middle 2.4-foot section of rod (with female threads on both ends), the bottom which has two male threads, and the top which has one male and one female thread. The 2.25-inch pump housing has the same parts but the female – male goes at the bottom and the male –male fitting is at the top. Insert the bottom spring into one end of the middle pump housing. Apply Teflon paste or tape to the male threads on all of the pump housing pieces as well as the profiling tip and first drill rod. This will prevent silt from migrating into the pump housing. Screw in the bottom housing piece so that the extended end is inside the pump. Make sure that the spring is at this end of the pump. Insert the pump into the housing. Screw on the top housing piece.
11. Take the profiler tip and slide the $\frac{1}{4}$ -inch stainless steel tube up into the receptacle in the pump bottom. Screw the tip onto the pump housing.
12. With the pump in a vertical position and the tip on the ground, grasp the three stainless steel lines and push them down. You should feel the springs move up and down smoothly. If they don't, the pump must be taken out of the housing and

checked. It is very important that the springs are free to move. If they cannot, the vibration of the hammer will damage the pump.

13. **Pressure testing the Gas Drive Pump:** The pump must be pressure tested before it is used to make sure that the o-rings and the reed valve have been installed properly. It is usually a good idea to pressure test the pump after collecting the equipment blank or decontaminating the KPRO box since the pump is attached and full of water. The following steps will lead you through this:

- a. Connect the pump to the tubing harness (all three tubes). You will notice that the three lines coming out of the pump are at three different lengths. The difference in length is the only way to be able to differentiate between them. The KPRO line is the longest, the nitrogen line is the shortest and the sample line is in the middle.
- b. Arrange the valves according to the following photo to start filling the pump:



- c. When a steady stream of water is flowing out of the Peri Out tubing on the KPRO box then the pump is full. Turn the two valves on the sample jig so that they are closed (facing the back of the box). Turn the bottom left valve 90 degrees to shut off the flow. Turn the top left valve to N2 Drive. The pressure on the gauge will rise to where it is set on the regulator. Make sure the pressure is set to around 100 psi or the expected working pressure.
- d. Disconnect the N2 Out quick connect on the KPRO box and watch the pressure gauge. If the needle on the gauge is steady then the pump is holding pressure. If the pressure drops then there is a leak. Check that all of the fittings are tight and refill and pressurize the pump. If that does not work, there is a

leak in the pump itself (either an o-ring or reed valve) or possibly there is a leaky valve in the KPRO box.

e. **Testing the Bottom O-rings.** If there is not a tight seal between the small o-rings at the bottom of the pump and the piston, KPRO water will not be able to flow into the tip, which will result in inaccurate IK data, sampling of the water inside of the drilling rods and a clogged tip. With the pump pressurized, turn on the flow by turning the bottom left valve on the KPRO box to KPRO. You should see water flowing out the tip. Grasp the pump just above the tip and invert the pump at a 45 degree angle so that your hand blocks the flow of KPRO water. If you see water flowing out of the pump housing then it is possible that the o-rings are leaking and they need to be checked.

NOTE: A more reliable way to determine if there is a leak is to check for air bubbles flowing through the vials while collecting the equipment blank. Double check that all of the fittings on the harness, KPRO box and pump are tight. If there are still bubbles then the o-rings need to be checked. Refer to section 4.9.3 on equipment blank procedures.

14. Add a 20-foot length of stainless steel tubing to each tube fitting leading from the pump.
15. Slide a 5' drill rod over the stainless steel tubing and screw it into the pump.
16. Tighten all joints by firmly by standing on the pipe wrench. To do this put one pipe wrench so that it is resting on the ground. Place the middle of the pump into the wrench. Put the other wrench on the tip and stand on it, making sure that the other end of the rod is weighted down (have a helper stand on it). This will tighten the tip and the bottom pump housing piece. Repeat for the top of the pump and rod.
17. The top drive cap is then threaded into the top of the 5-foot rod with the three pieces of stainless steel tubing protruding through the center of the drive cap. The slotted slip cap adapter is then placed over the drive cap and fitted into the bottom of the hammer on the drive platform.

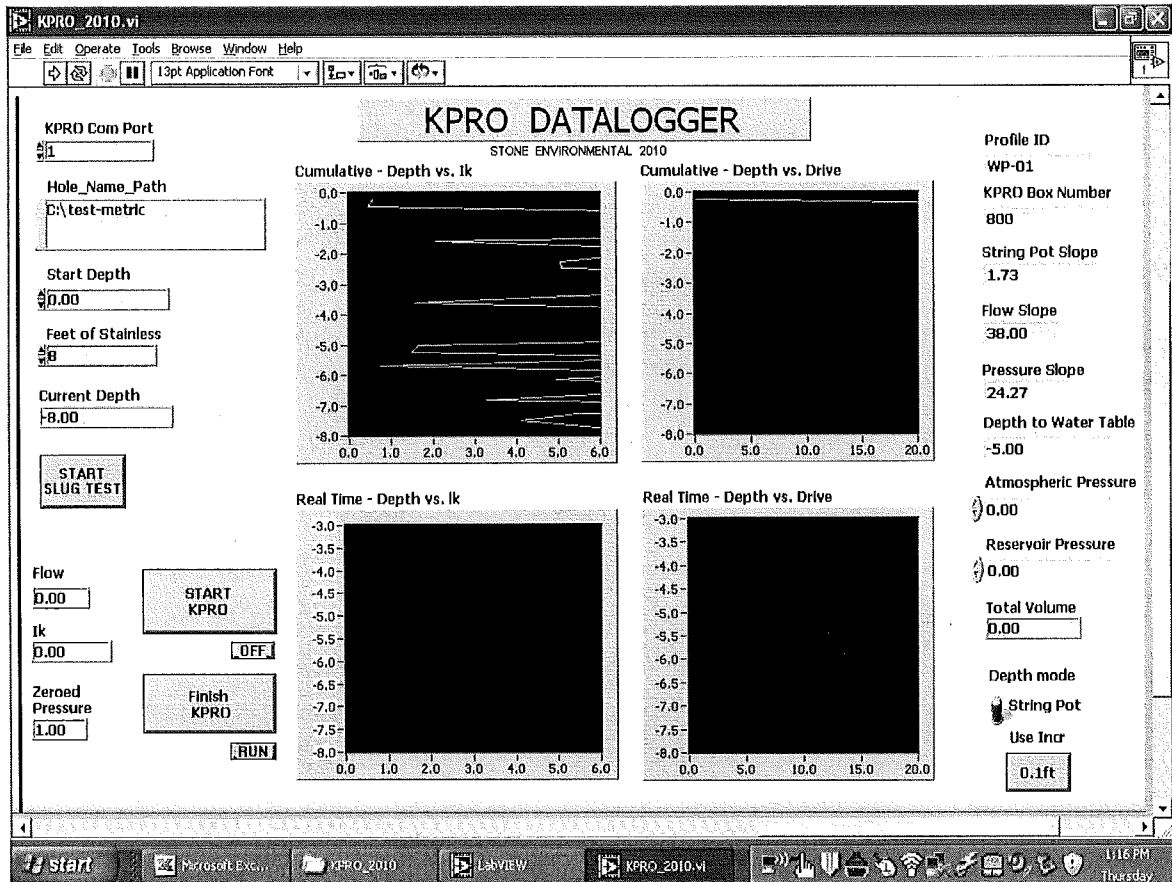
4.5 KPRO Software Calibration and Startup

4.5.1 Calibration

The KPRO box should be calibrated at the beginning of a new project and once weekly (or every 5 days if there is a longer shift). If an individual sensor or entire electronics enclosure

is replaced then there should be a recalibration. The calibration is saved on the field computer, so if the KPRO box was calibrated with a different computer then it needs to be recalibrated.

1. At this point the computer should be plugged in and booted up. If not, do so now.
2. Find the KPRO program icon on the desktop or located in the C:\KPRO_2010 folder. The program is named "KPRO_2010.vi". Double click on the icon. The Labview software will load and the KPRO software will look like this:



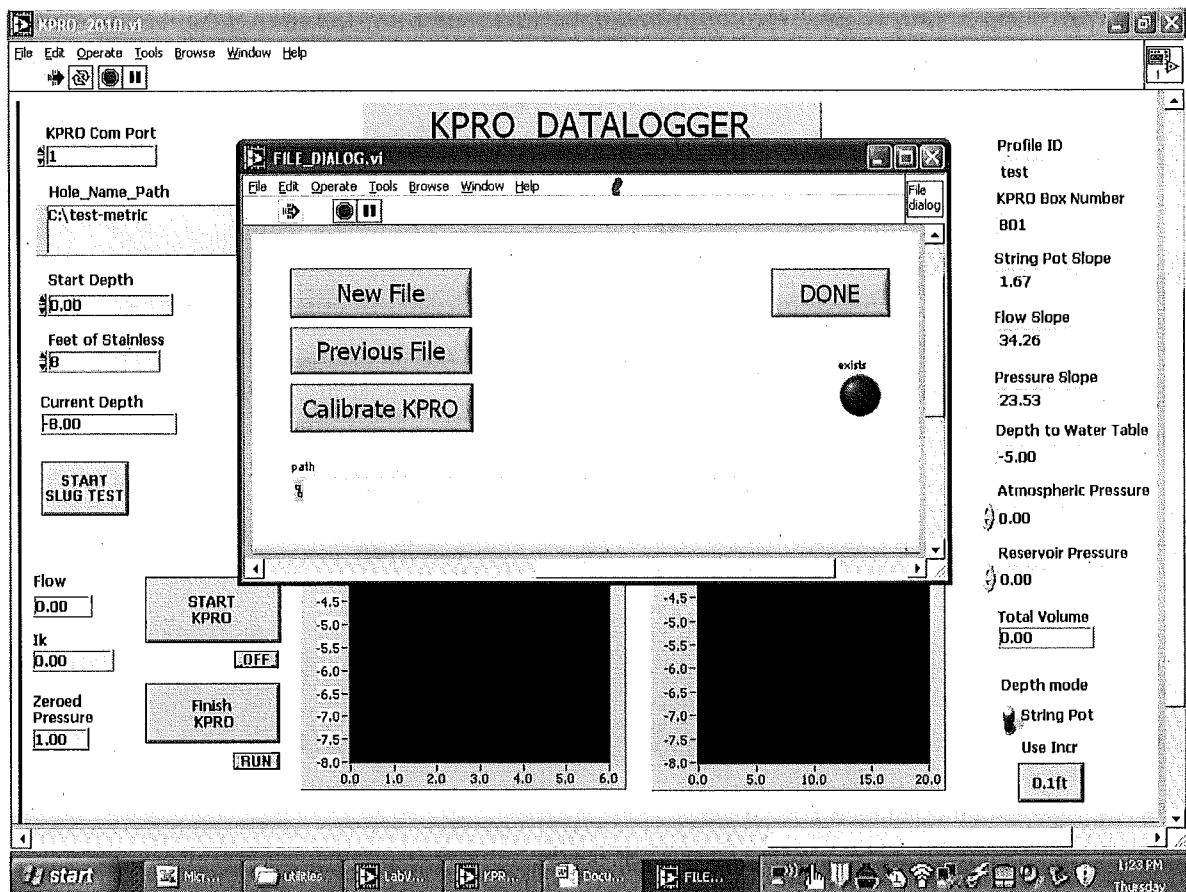
KPRO Software

3. Make sure that the correct COM port is provided for the KPRO box before starting the program and correct it if necessary. The text box for the COM port is located at the top left of the above figure. The COM port located at the back of the computer is COM1.

When using the USB-Serial cables navigate to Control Panel /System/Device Manager and scroll down to Ports. The cable will be listed as "Prolific USB-Serial" and the com port assignment will be listed. For the socket cards, click on the icon for the socket driver located in the taskbar to see which COM port numbers have been assigned to the

socket card (On the figure above it is the symbol fourth from the left at the bottom right of the screen).

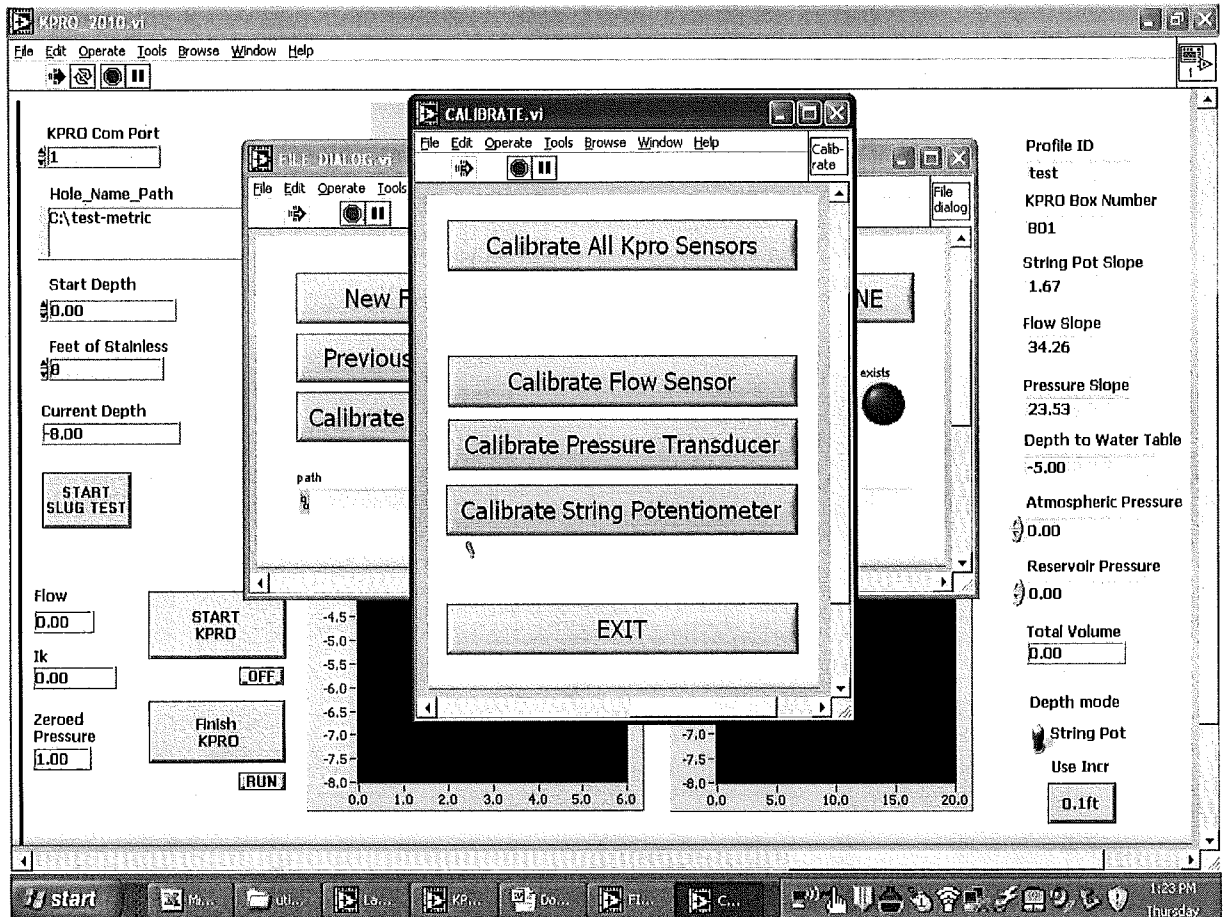
4. Start the KPRO program by clicking on the right arrow icon on the top left menu bar (above the COM port text box). There is no need to enter any data before starting the program (other than the COM port for the KPRO box), as the program will populate the fields or prompt you to enter a value.
5. A window opens and prompts you to enter the number of the KPRO sample box that you are using (800 through 809). Enter the number and select the enter button.
6. A window opens and prompts you to enter the profile ID. Enter the ID and select the enter button. The following screen will load.



Startup Screen

7. Select CALIBRATE KPRO. Make sure that there is at least a 20' foot length of stainless steel tubing attached to the profiling box when calibrating. This will ensure accurate calibration of the flow and pressure. Using a smaller piece of tubing can adversely affect the validity of the calibration.

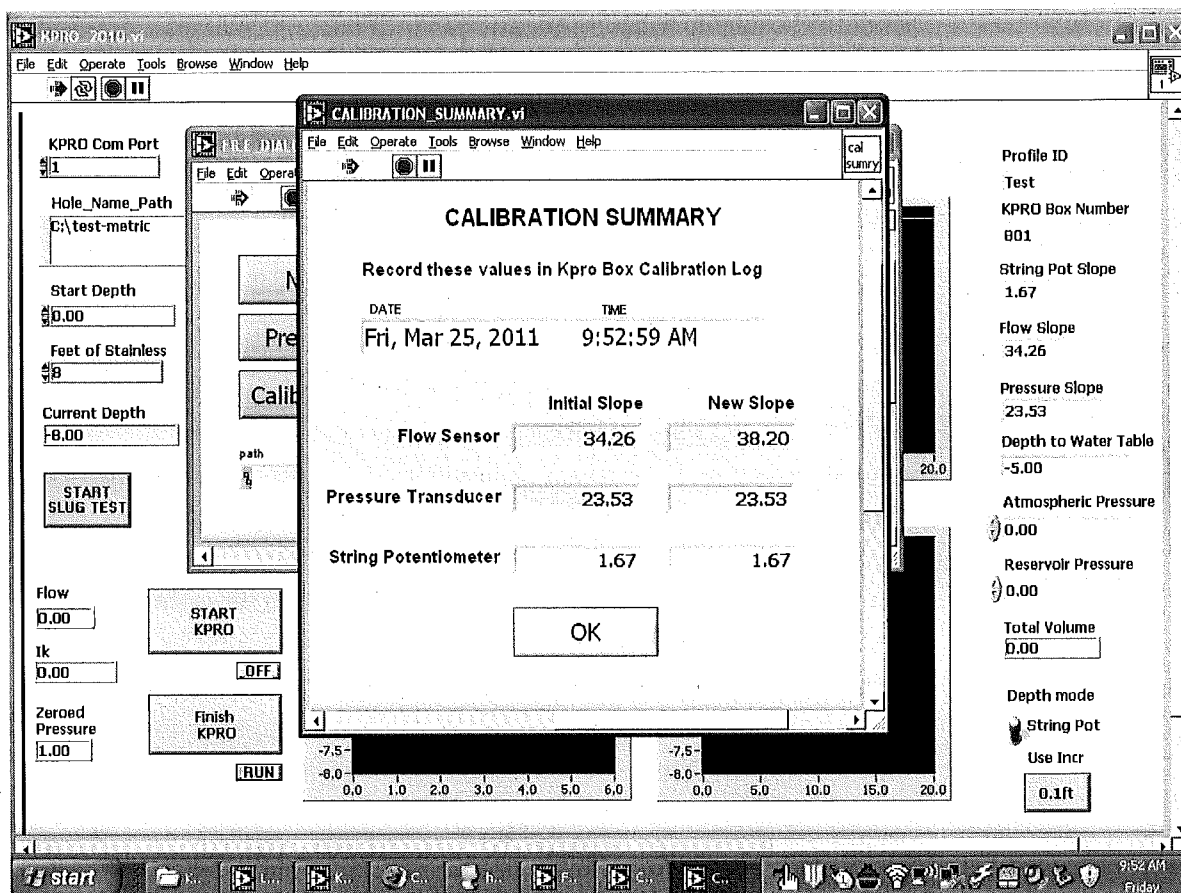
8. The next screen allows you to calibrate all of the sensors or each individual sensor (string pot, flow and pressure).



Calibration

Select the "Calibrate All KPRO Sensors" or the button corresponding to each individual sensor (if you do not need to calibrate all of the sensors). The program will then lead you through the calibration. Follow the directions on the screen to calibrate the flow, pressure and string pot. After calibration is complete, if you feel that one or more of the sensors was not calibrated correctly, you can repeat the entire calibration or just repeat the calibration for an individual sensor. If you decide to recalibrate one or all of the sensors, be aware that the program will use the original slopes and not the newly calibrated slopes for the recalibration.

9. After calibration, a summary screen will open.



Calibration Summary

Record the initial and new slopes in the calibration log (yellow book in the KPRO box) for the KPRO box you are using. Slope values should be within the following parameters: string pot 1.6-1.8, flow 32-38, and pressure 22-28. (There are a few string pots that have longer cables than normal and as a result will have a slope value double the normal value, usually around 3.2-3.6). If the slopes are off from these values, recalibrate. If that does not work, you may need to change out the pressure transducer, flow meter or string pot. Select the OK button to exit this screen.

Note: The program records the slope values in two files located in the C:\KPRO_2010\Output_Files folder. The file named "slopes.txt" is used by the KPRO program to import the slopes the next time it is started and after calibration. The other file, "cal-slopes-record.txt" is used only as a record of the calibration (it records date, time and KPRO box number as well as the slopes). Do not delete the files or any of the data in them or move them to a different folder. **Additional Note:** If the calibration slopes are off due to a calibration error, simply go through the calibration process again. If you are having problems calibrating, see the KPRO Problem Solving Guide for more

information. It may be necessary to delete bad slope values from the slopes.txt file in order to calibrate the box. The software uses the old slopes to calculate the new slopes, so if the slope that the software is using is way off, it may not be possible to get a good new slope using this value. If this seems to be the case, open the slopes.txt file and delete the entire line of bad data. Save and close the file.

4.5.2 Startup

1. After calibration or after clicking on the start button, the startup screen will load (Figure 4.5-2). If you are starting a new profile, select NEW, and if you are continuing a profile select PREVIOUS. There may be a path to the file you want to use already displayed in the box at the bottom of the screen. You still need to select the PREVIOUS button and navigate to the file. When starting a new profile, after selecting NEW, navigate to the C:\Projects\Project Name\kpro_raw folder and name and save the file. Name the file the same name as the profile ID. There is no need to add a file extension (.txt, .doc) as the program will add its own. The program will then create a file by adding “_KPRO.txt” to the end of the filename. For example “WP-01” becomes “WP-01_KPRO.txt”. If you selected PREVIOUS, after navigating to and selecting the file, the green indicator light next to the word “exists” will be illuminated. Make sure to select the filename with no extension when selecting an existing file (for example, select “WP-01” and not “WP-01_KPRO.txt”). Select DONE. You will now begin the software startup procedure.
2. The first window that appears is for setting the atmospheric pressure. Follow the instructions on screen to set the pressure. If there are only zeroes in the atmospheric readout, there is a problem with the connection between the KPRO box and the computer (incorrect COM port, bad cable) or the slopes file has been corrupted. Refer to the KPRO Problem Solvers Guide for more information. Record the atmospheric pressure on the Groundwater Profile Log. The atmospheric pressure reading should be close to 34 feet of water. If the reading is higher or lower by a few feet, the pressure transducer needs to be calibrated. This value can also change depending on where you are profiling (high or low elevations, Europe, etc). It is a good idea to check the local atmospheric pressure.
3. The next window is for setting the KPRO vessel pressure. Follow the instructions on screen to set the pressure. If the pressure is too high, turn the handle on the regulator counter-clockwise and release some pressure from the KPRO vessel by using the valve on the top of the vessel. If the pressure is too low, turn the handle on the regulator clockwise and allow pressure to stabilize. After adjusting the pressure make sure that the pressure has stabilized and is not falling or climbing before clicking the OK button. Record the pressure on the Groundwater Profile Log.

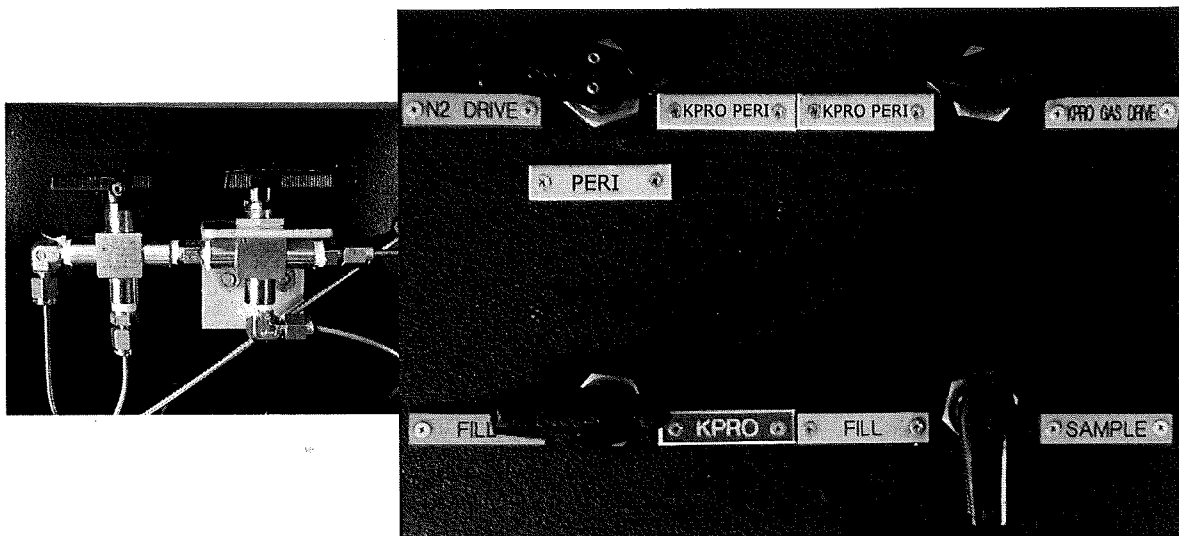
4. The next window will prompt you to enter the start depth. If you are continuing a profile, the last recorded depth will be provided. You can use this depth or enter a different depth. When entering a depth you can enter a positive or negative value; the program will make it negative regardless of the sign that was entered.
5. The next window will prompt you to enter the height of the sample box above the profile location. Measure the height from the ground to the pressure transducer and enter it. When profiling out of T5, T6, T7 or T8 the height is 7 feet. When profiling out of T9, the height is 5 feet. The value will be different if you are profiling out of a different vehicle or other situation. If the ground between the truck and profile location has a significant slope, this also must be accounted for.
6. The next window will prompt you to enter the depth to water. If you are continuing a profile, the last recorded depth to water will be provided. You can use this depth or enter a different depth. If you do not know the depth to water, you must make an educated guess. You can enter a more accurate depth later. When entering a depth you can enter a positive or negative number. Make sure you enter the depth to water from ground surface, not from the height of the KPRO box.
7. The last window will prompt you to zero the pressure to the ground at the profile location. Make sure that the graduated cylinder is placed on the ground as close to the profile location as possible. Follow the instructions on screen and select OK. The setup is now complete and the profiling can begin.
8. **Recording Data** - Navigate to and open the Microsoft Excel "Groundwater Profiling Log with Plot" template. This file should be located in the C:\Forms folder or in the file template in the Projects folder. Rename the spreadsheet to reflect the profile name (e.g. Groundwater Profiling Log_WP-01.xls). Select the tab labeled "Groundwater Profiling Log". Fill in the top section of the log. The bottom section of the log will be empty at first but will be populated with data for each separate groundwater sample. The following photo shows the log after sample data has been entered:

Client: ERM Starts Completed				GROUNDWATER PROFILE LOG STONE ENVIRONMENTAL INC		Profile Location: APS-018		
Dates: <u>5/27/2010</u> <u>5/28/2010</u>		KPRO Box Serial # / Acquisition Laptop: <u>808/ Rasc7</u>		Gas Drive or Peril Pump: <u>Gas</u>				
Location: <u>Plainville, CT</u>		Troll Serial #: <u>o2k0934 YSI</u>		Atmospheric Pressure: <u>34.89</u>				
SEI #: <u>092193-R</u>		Drilling Contractor: <u>Platform</u>		KPRO N ₂ Pressure (set via P transducer): <u>70.14</u>				
Sampler(s): <u>VLD</u>		Average Depth to Water: <u>-17.28</u>		Gas Drive Pump N ₂ Pressure: <u>80-100</u>				
PHYSICOCHEMICAL PARAMETERS								
Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-18.00	5/27/10 14:40	900	-17.20	519	8.00	6.50	63	
-26.70	5/27/10 15:30	850	-17.10	305	6.40	5.70	96	
-34.00	5/27/10 16:11	1300	-17.15	184	7.20	6.00	96	
-41.00	5/27/10 16:38	1000	-17.20	202	7.50	6.30	83	
-48.00	5/28/10 8:05	900	-17.70	212	6.30	6.40	38	
-55.00	5/27/10 8:43	1000	-17.20	140	7.30	6.16	53	
-63.00	5/28/10 9:38	910	-17.20	483	0.50	5.75	57	
-70.00	5/28/10 10:15	850	-17.30	763	0.46	5.90	65	
-77.00	5/28/10 10:50	900	-17.40	664	3.14	5.94	77	
-84.00	5/28/10 12:02	1000	-17.35	646	4.65	7.70	34	
-91.00	5/28/10 12:39	1000	-17.30	779	4.30	7.90	22	

Groundwater Profile Tab

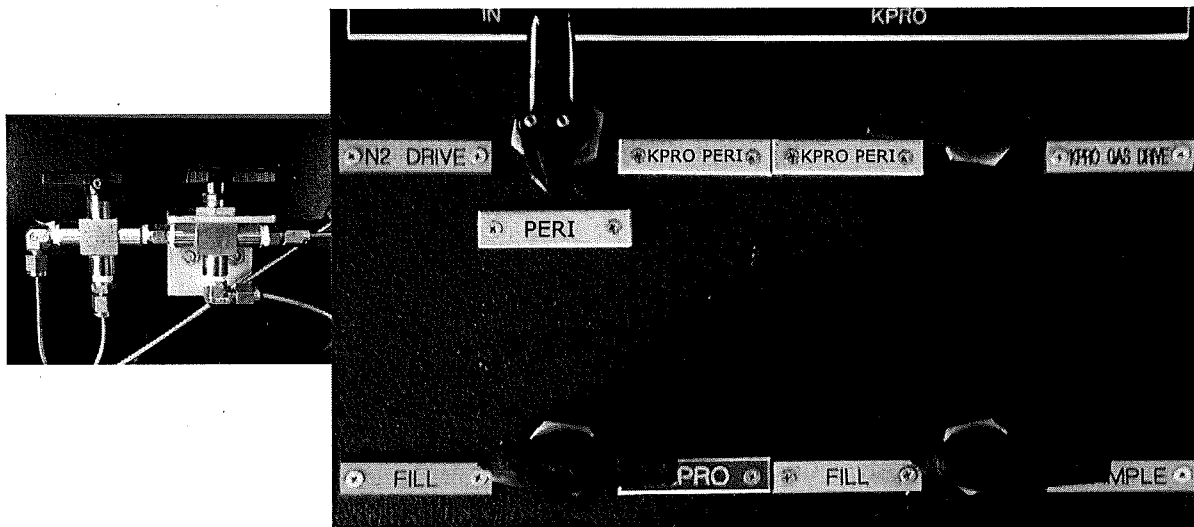
4.6 Drive the Profiler/Acquire I_k data for both Peristaltic and Gas Drive Modes

1. Attach the harness to the tube or tubes sticking up out of the top of the profiler rod at the drive platform. Place the string pot on the ground next to the drill rig and weight it down with a pipe wrench or the rod puller. Pull out the string and attach it to head of the drill dig.
2. **Peristaltic Mode:** turn on the KPRO flow by arranging the valves as shown below:



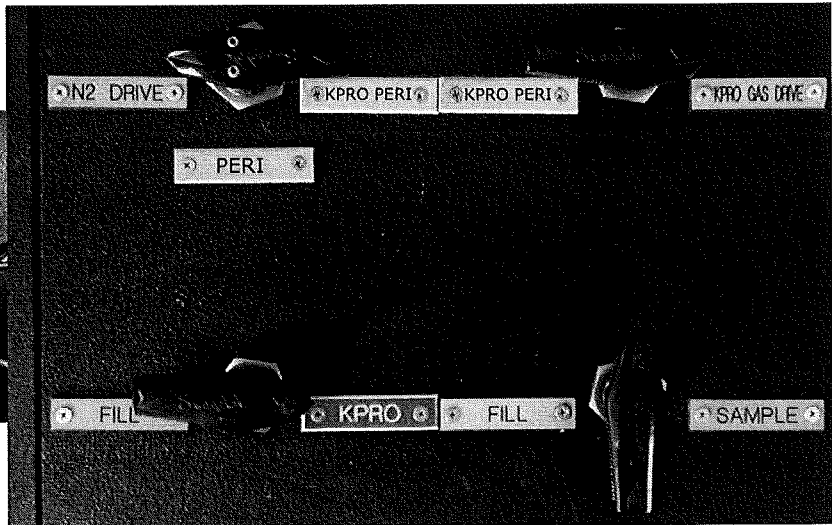
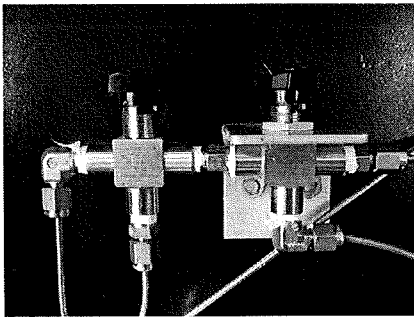
Peri Mode - Drive

Gas Drive: fill the pump by arranging the valves per the photo below:



Gas Drive Fill Pump

When the pump is full and a steady stream of water is flowing out of the Peri Out, lock off the pump (turn the valves on the sample jig so they face the back of the box), pressurize and turn on the flow per the following photo (make sure to lock off the pump first).

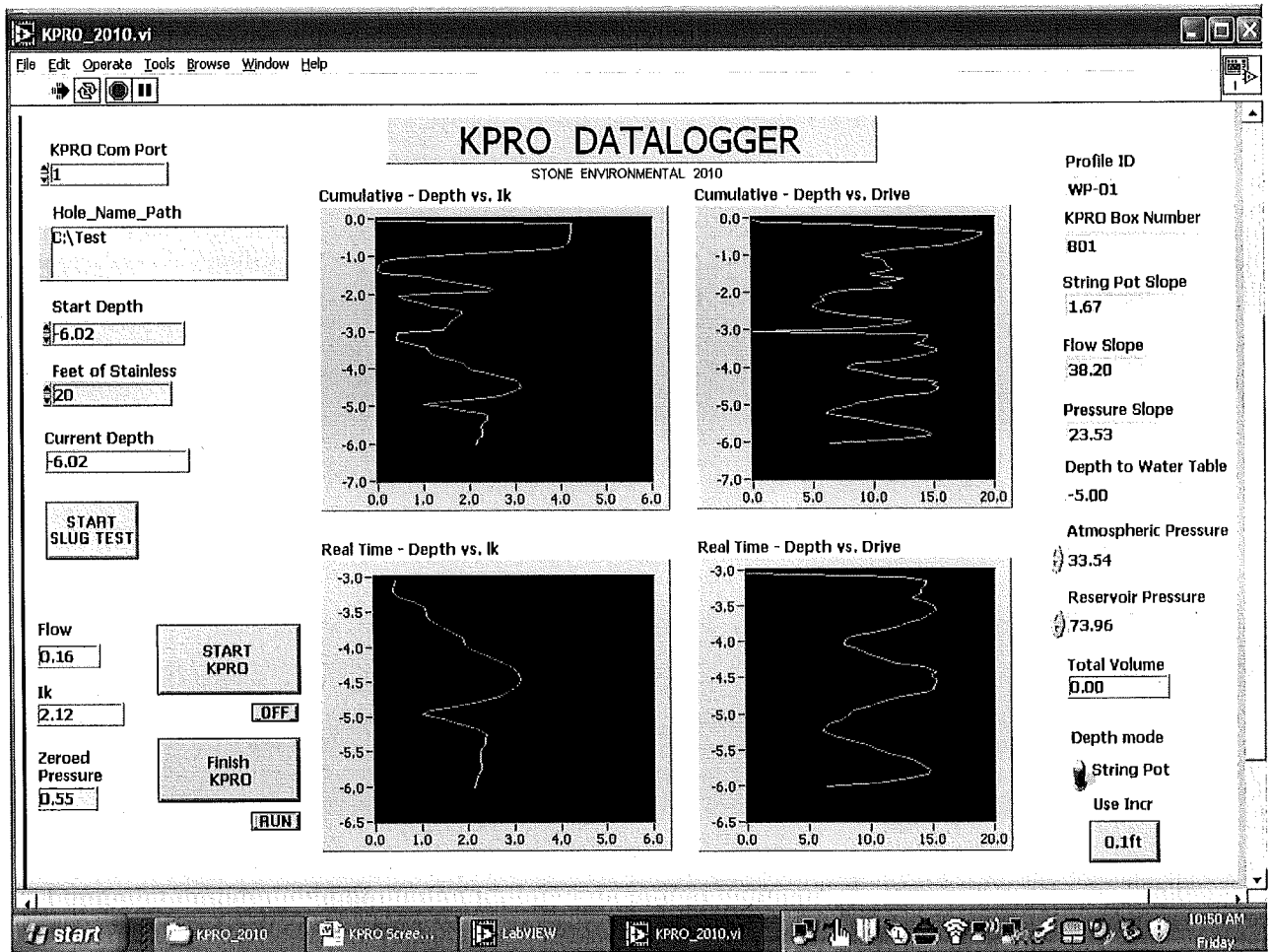


Gas Drive - Driving

3. With the flow on, put the profiling tip / rod assembly into the pre-cleared hole or so that the tip rests vertically on the ground surface. Have the driller lower the head of the probe so that the anvil of the probe rests on the slip cap. At this point the driller will adjust the probe so that the drill rod and probe are straight and level. **Note:** Make sure that the driller has broken through any surface concrete or asphalt. Driving through either of those will damage the tip.
4. When the flow value stabilizes click on the Start KPRO bottom at the bottom of the KPRO software. Make sure that the string put is extended and the head of the drill rig is resting fully on the slip cap before starting the software. The software will not read the depth correctly if it is started before the string pot is extended.
5. A window will open asking the depth to water. If this is the first drive, the depth provided is the depth entered during the startup procedure. If this is your second drive and the head measurement collected at the first sample location is different from the value originally entered, a new depth can be entered here. Enter a new depth or select OK. A pop up window will open showing the feet of stainless steel tubes. Set the feet of SS tubing to the correct feet of tubing used, including the 20' harness.
6. Signal to the rig operator that you are ready to commence driving the profiler. Just before the profiler begins to move, hit the Go button on the software.

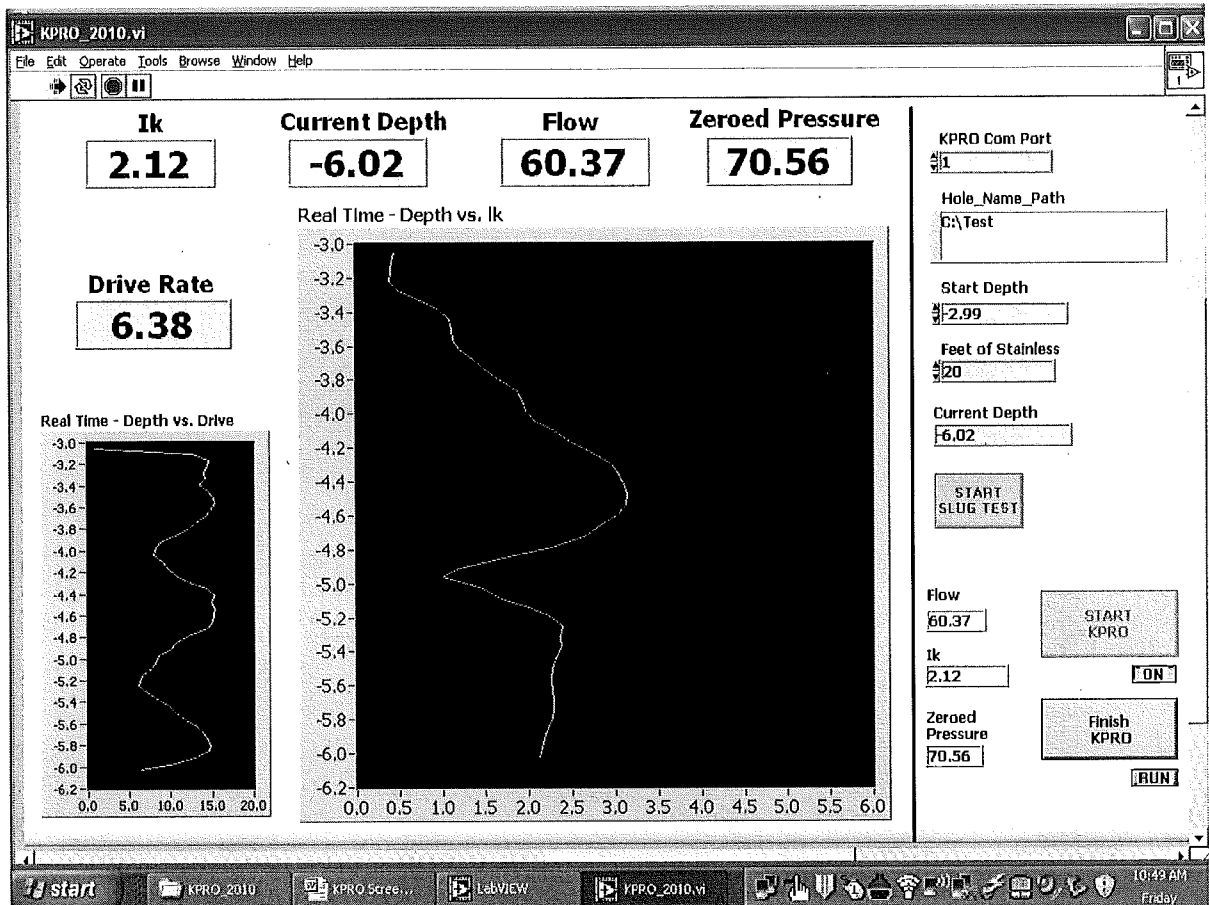
Notes on the string pot: 1. The KPRO software only records data while the string pot is moving. 2. If during a drive the driller needs to lift the probe, there is no need to stop the KPRO software. The software will only record data once the string pot has moved past the last recorded depth.

7. Observe the I_k plot on the screen as the tool is advanced as shown in the following figure:



KPRO Software Screen While Driving

The current I_k , flow and pressure are displayed at the bottom left of the screen. The I_k for the current drive is displayed in real time in the graph at the lower left. The cumulative I_k for the entire profile is displayed in the graph at the top left. The drive rate (feet/minute) for the current drive is displayed in the bottom right graph, and the cumulative drive rate is displayed in the top right graph. A larger I_k plot can be seen by scrolling the software screen to the left. The screen looks like this:



KPRO Software Screen While Driving

Notes on I_k : I_k can range from 0 to 6+. Fine grained (silts and clay) or compacted sediment will have an I_{kv} towards the lower end, and sands, gravels and looser material towards the middle to higher end. The software will correct the I_k for depth using a head loss equation, so I_k should remain relative for the profile regardless of how much stainless tubing is attached (even though the flow is lower and the pressure is higher). I_k is only calculated and recorded by the software if the string pot is moving. In some cases the flow will drop after hammering has stopped, which results in a lower I_k . Since the string pot is not moving this new I_k value is not displayed on the screen and is not recorded. In this case take note of the flow, because the flow reading on the software is constantly updating, whether or not the string pot is moving. I_k behavior when tooling advance has stopped should be recorded on the "Profile Info" tab of the Groundwater Profiling Log (see below).

8. When you reach a zone that you wish to sample, signal to the rig operator that he/she should stop. When he/she stops press and hold the Finish KPRO button down until the icon (located below the button) changes from Run to Done.

9. **Determining whether to sample or not:** Observe the flow. If the flow drops significantly it may be an indication that the sample interval will not yield a timely sample. If the flow stays the same or increases, then it is probably a good interval to sample. In the Groundwater Profiling Log there is a "Profile Info" tab. The purpose of this worksheet is to record additional data regarding the driving and sampling of the profiler.

I_k and Sample Attempt Log STONE ENVIRONMENTAL INC						
Client: ERM		Profile Location: APS-018				
Date: <u>5/27/2010</u>		KPRO Box Serial #: <u>808/ Rasc7</u>			Gas Drive or Peri Pump: <u>Gas</u>	
Location: <u>Plainville, CT</u>		Troll Serial #: <u>o2k0934 YSI</u>			Atmospheric Pressure: <u>34.89</u>	
SEI #: <u>092193-R</u>		Drilling Contractor: <u>Platform</u>			N ₂ Pressure (set via P transducer): <u>70.14</u>	
Sampler(s): <u>VLD</u>		Depth to Water: <u>-17.28</u>			Gas Drive Pump N ₂ Pressure: <u>80-100</u>	
Depth (ft)	I _k Behavior Type	Unsuccessful Sample Attempt	Hole Termination Type	COMMENTS		
-8.00	No change when hammer stops	3	#N/A	#N/A		
-13.00	No change when hammer stops	3	#N/A	#N/A		
-18.00	No change when hammer stops	3	#N/A	#N/A		
-23.00	No change when hammer stops	3	Could not produce water	4	#N/A	
-26.70	IK increase when hammer stops	2	#N/A	#N/A		
-28.00	No change when hammer stops	3	#N/A	#N/A		
-33.00	IK decrease when hammer stops	1	Yield deemed too slow	6	#N/A	
-38.00	No change when hammer stops	3	#N/A	#N/A		
-41.00	No change when hammer stops	3	#N/A	#N/A		
-48.00	No change when hammer stops	3	#N/A	ROP dropped below threshold	9	

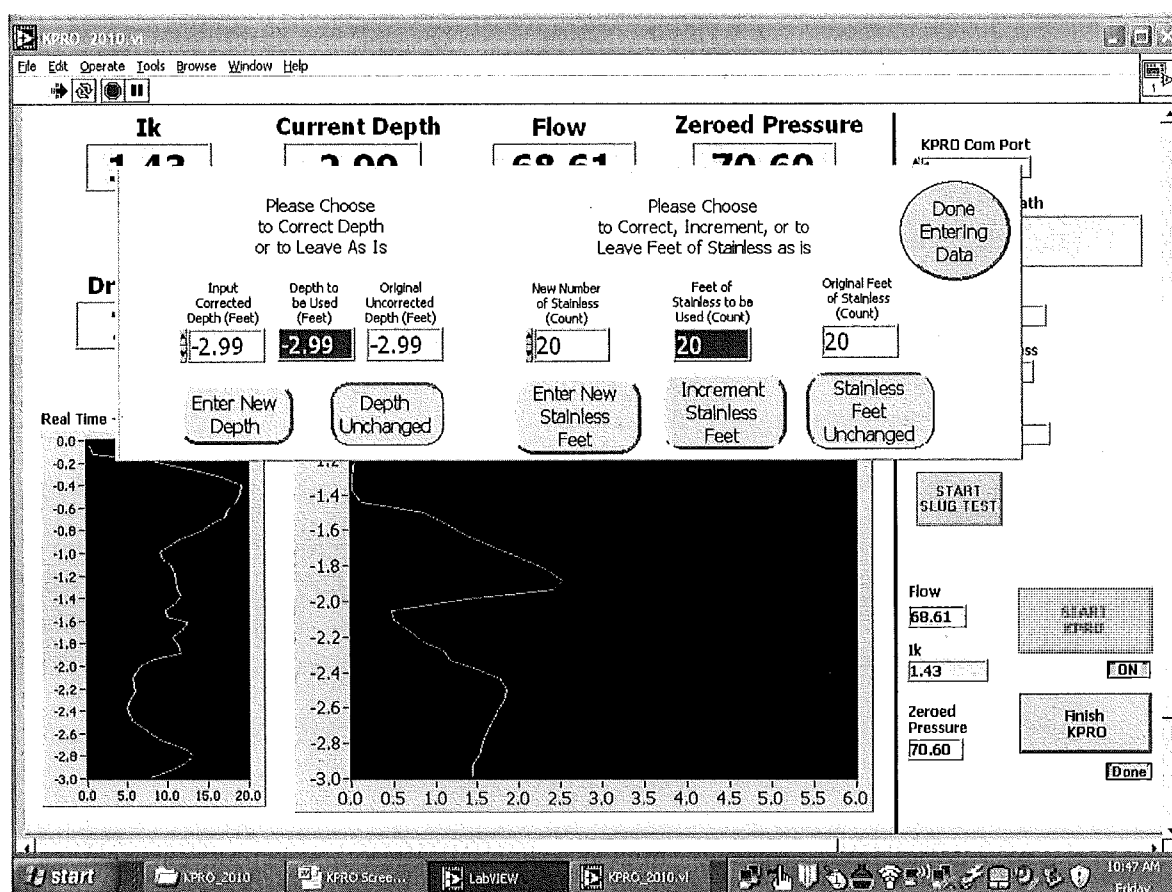
Profiling Info Tab

Each time the hammer is stopped (to add rod, sample, determining whether or not to sample), the I_k Behavior column must be filled in. Record the depth and behavior type from the drop down menu.

It will take experience to get a feel for which intervals will yield fast samples and which will not. The I_k and flow are a good indication as to which samples will be fast or slow but remember that the flow decreases with the amount of stainless tubing that is

attached. So at shallower depths a flow of 60 ml/min may be slow but at a depth of 60 feet it may be fast.

10. Turn off the KPRO flow by turning the lower left valve from the red KPRO label 90 degrees to an off position.
11. Measure the stick up from the ground surface to where the drive cap abuts the top of the 1.75-inch rod, or to the shoulder if using the 1.5 of 2.25-inch rod. Subtract the stick up from the total length of rod in the ground including tip and/or pump. For peristaltic, the tip length used is 0.4 feet. For gas drive, the length of the tip and pump is 3.2', so add this to the length of rod in the ground.
12. Compare the measured value to the depth reading on the screen:



Correct Depth

If the measured depth is different than the depth given in the "Original Uncorrected Depth" box, enter the correct depth into the "Input Corrected Depth" box and click on the "Enter New Depth" button. You can also change the feet of stainless if required. If no other data needs to be corrected, click on the "Done Entering Data" button on the software.

13. **Measuring Hydraulic Head:** Observe the Zeroed Pressure text box. When this value equilibrates, record the value on the field form along with the depth (Attachment 2). The water in the stainless steel tubing will equilibrate to the head of the groundwater when the flow is turned off. Turn on the flow and leave it on for 30 seconds. Turn off the flow and again observe the Zeroed Pressure and wait for equilibration. If this value matches the first value, the head measurement is valid. If it is different, repeat turning the flow on / off until two successive head readings are obtained.

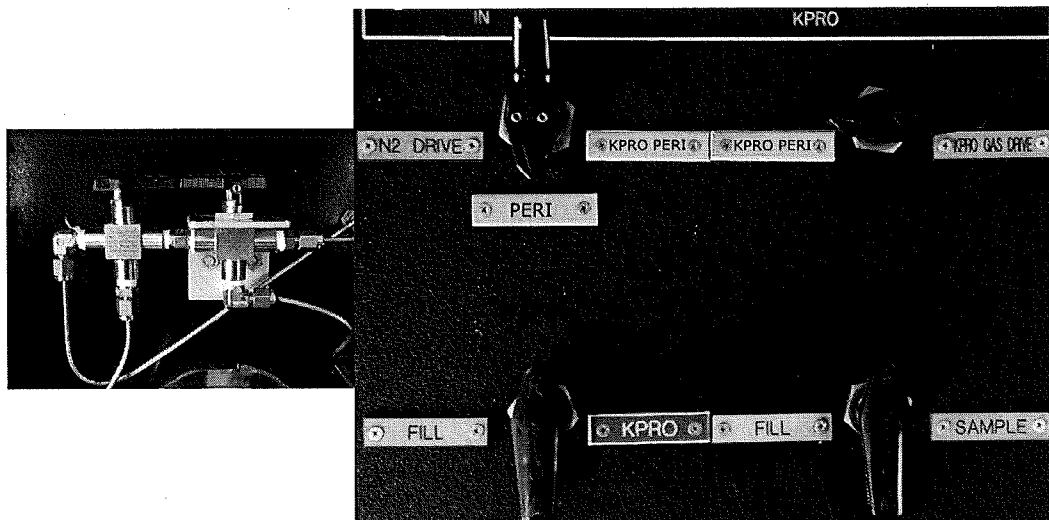
NOTE: When the water table is at a depth of more than 25' the head value is not valid. When using gas drive mode this is often the case. If so do not record the head value.

14. Double click on the appropriate Sonde water quality monitoring system icon on the notebook computer desktop (Ecowatch for the YSI, Win-Situ for the Troll, and HydraS3 LT for the Hydrolab). Instructions on how to operate the specific software for each Sonde can be found in SEI SOP 5.25.0 (Hydro Lab MS-5), 5.27.0 (Troll 9000 and 9500) and 10.7.1 (YSI 600XL).
15. **Missing a sampling interval.** It may be required to pull the profiler up to sample an interval that was passed on the way down. To do this first make sure that the "Finish KPRO" button has been clicked. For Peri mode make sure that the flow is on, and in gas drive mode make sure that the pump is pressurized and the flow is on. Determine at what interval you would like to sample. Hold a measuring stick next to the drill rod as the driller pulls back on the rod and have the operator stop when the depth is achieved. Check the flow on the software to be sure that the interval will yield a timely sample. It is also possible to watch the flow on the KPRO software as the driller pulls the rod up. When the flow increases, tell the driller to stop. Measure the stickup and record in the paper log that the profiler was pulled up and record the new depth. Before your next drive you will have to correct the depth in the KPRO software. To do this do a "fake" drive by starting and stopping the software as you would during a drive but correct the depth to the new depth. You can also mark the rod before pulling it back and then drive the rod back to that depth (with the flow on) before starting the program.

4.7 Purging the Profiler and Sample Collection

4.7.1 Purging in Peristaltic Mode

1. Turn on the peristaltic pump and set the +/- selector to –
2. Set the valves shown below.



Peri Mode Purging

3. Observe the vacuum gauge. A vacuum should build toward -30 inches of mercury
4. Observe water flowing through the bottles. The water will be clear at first but should become silty. This is because there is some KPRO water still in the tubing.
5. If vacuum does not build and water does not flow it is possible that there is a leak in the system. Refer to the Problem Solver's Guide on how to proceed.
6. Observe the volume of water in the graduated cylinder into which the purge water discharges. On the Groundwater Profiling Log, select the tab "Sample 1". The top section of the sheet except the date should be populated with data that was entered on the first tab. Record the time, cumulative purge volume and physio-chemical parameters in the Excel spreadsheet after every 50-100 mL of sample discharges to graduated cylinder. This data is used as a benchmark for future readings and is not recorded in the field form (paper log).
7. If the sample purge rate is slow (less than 10 ml/min) then it may be necessary to surge the pump. Sometimes silt can get smeared on the outside of the profiling tip or can be drawn into the tip. Surging the pump can loosen up the silt to increase the flow. Reverse the flow of the pump by turning it off, then switching the directional switch. Turn the pump back on and observe the pressure gauge. Once the gauge maxes out, turn off the pump and reverse again. Repeat this two to three times. Continue to purge the sample. If the purge rate is still slow, it may be necessary to drive the profiler to a better sampling interval. If no sample was collected, record this in the Profile Info tab of the log.

8. When all of the physico-chemical parameters stabilize on two successive readings (separated by 50-100 mL, indicated by yellow in the Microsoft Excel worksheet) record the depth, time, head value, total volume purged and the values of the physico-chemical parameters on the paper field form (only record the final line of stabilization parameters). The paper log serves as a backup in case there is a problem with the electronic Groundwater Profiling Log. Put any character in the column labeled "Final ?" (located to the left of the depth column) next to the last row of data. This tells the spreadsheet to display that row of data on the "Groundwater Profiling Log" tab. The following photo illustrates what the data looks like for a sample that has equilibrated.

Client: ERM				PARAMETER EQUILIBRATION LOG				Profile Location: APS-018				
Date: 5/27/2010				KPRO Box Serial #: 808/Rasc7				Gas Drive or Peri Pump: Gas				
Location: Plainville, CT				Troll Serial #: 02K0934 YSI				Atmospheric Pressure: 34.89				
SEI #: 092193-R				Drilling Contractor: Platform				KPRO N ₂ Pressure (set via P transducer): 70.14				
Sampler(s): VLD				Depth to Water: -17.2816182				Gas Drive Pump N ₂ Pressure: 80-100				
PHYSICO-CHEMICAL PARAMETERS												
Depth (ft)	Head (ft)	Time	Volume Purged (mL)	SC (uS/cm)	SC %Change	DO (ppm)	DO %Change	pH	pH %Change	ORP (mV)	ORP %Change	COMMENTS
-41.00	-17.20	16:27	300	136		5.50		6.30		81		
		16:29	480	159	16.9	8.60	20.0	6.30	0.0	77	4.9	
		16:32	650	183	15.1	8.00	21.2	6.36	1.0	78	1.3	
		16:34	800	197	7.7	8.20	2.5	6.35	0.2	80	2.6	
		16:36	900	201	2.0	7.60	7.3	6.33	0.3	83	3.8	
		16:38	1000	202	0.5	7.50	1.3	6.30	0.5	83	0.0	

Sample Log Showing Equilibrated Sample

Notes on Purging the Sample: Make sure to purge at least 500ml before collecting a sample. The first few physico-chemical readings may indicate that the sample has equilibrated but that is because the tubing contains the analyte free water and there is still water from the previous sample interval in the flow through cell of the water quality sonde. The volume of the flow cell is usually 100-200 ml, so it will take some time for the groundwater from the current interval to replace the water in the flow cell from the previous sample.

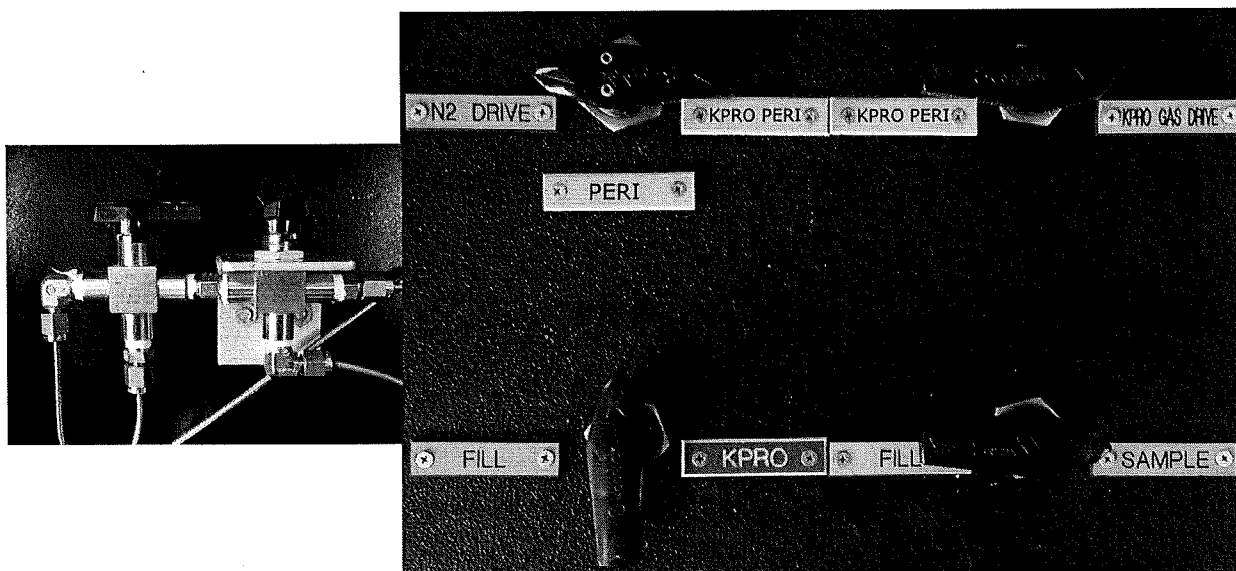
4.7.2 Collect Sample in Peristaltic Mode

1. Turn the top right valve on the sample jig so that it is locked off (pointing towards the back of the box).

2. Reverse the direction of the pump by changing the toggle switch on the box panel from minus (-) to plus (+).
3. Run the pump backward for 2 to 3 seconds
4. Shut off the pump
5. Remove the sample bottle on the left.
6. Remove the bottle on the right.
7. If there is headspace in the tops of the vials (this is normal), hold a vial cap under the right bottle holder and run the pump in reverse slowly. Water will flow into the vial cap. Transfer this water from the vial cap to the vials until the headspace is gone and cap the vial. Turn the vial upside down and tap the vial lightly on the palm of your hand. If there are any air bubbles present, you must uncap the bottle and repeat the headspace procedure.
8. Label the vials appropriately. Note the time of sampling on the field form.
9. Replace the vials with new vials. Prepare to drive as before after adding tubing and rod as necessary.

4.7.3 Purging in Gas Drive Mode

1. At this point the pump is already pressurized from driving. Arrange the valves per the following photo:



Pressurized Gas Drive Pump Ready to Purge

Turn the top right valve on the sample jig slowly to the right. This allows the nitrogen to push the water up from the pump and through the sample jig. The pressure on the gauge will drop and stabilize as the water flows.

2. Observe the pressure gauge. Just before the pump body is completely emptied, the pressure will start to rise. When you observe the rise, turn the top left valve on the KPRO box 90 degrees clockwise, which will stop the flow of nitrogen and vent the gas out of the pump (you will hear a hissing sound).
3. Watch the pressure gauge and when the pressure drops below zero, lock off the right valve on the sample jig and spin the top left valve on the KPRO box clockwise to Peri. Make sure that the peristaltic pump is on. At this point the pump is depressurized and is filling with groundwater. These three steps complete one pump purge, or “whack”.
4. Observe the volume of water in the graduated cylinder into which the purge water discharges. Record the time, cumulative purge volume and physico-chemical parameters in the Excel spreadsheet after every purge of sample discharges to graduated cylinder. This data is used as a benchmark for future readings and is not recorded in the field form (paper log). The first whack will be larger than most because the pump and lines are already filled with water. If after the second whack the amount of sample discharged is less than 80 ml then you need to wait longer between evacuations (3-4 minutes). If after waiting 5-6 minutes the pump evacuation yields less than 50 ml, it may not be prudent to collect a sample at that location. Check with the client oversight to see if they want you to continue sampling or drive to a better sampling interval. If the volume is significantly larger (150-200ml) you can evacuate the pump more often (1-2 minutes). If no sample was collected, record this in the Profile Info tab of the log.

Note on purge volume: The volume of the gas drive pump is 100 ml. The volume of the stainless steel tubing is 0.8 ml/ foot, and there are two lines (the sample and gas lines) that are full of water (water from the previous sample and water used to fill the pump). For example, if you have 60 feet of tubing attached, the volume would be $100\text{ml} + (2 * 60 * 0.8)$, for a total of 196 ml. When purging a sample this water will be purged first so the physico-chemical parameters may appear to be stable. It is common to see the parameters rise (previous sample water left in pump), then fall (analyte free water used to fill the pump) before starting to equilibrate (fresh groundwater).

5. After the previous whack, allow some time (as explained in step 4) for the pump body to fill such that you receive at least 50 mL of sample on subsequent evacuation (Step 4).
6. To purge the pump turn the top left valve on the KPRO box to N2 and watch the pressure gauge. When the pressure crosses zero, turn the top right valve on the sample

jig to the right. You are now back at Step 1. Follow the rest of the steps to complete the whack and record the parameters.

7. When all of the physico-chemical parameters stabilize on two successive readings (indicated by yellow in the Microsoft Excel worksheet) record the depth, time, head value, total volume purged and the values of the physico-chemical parameters on the paper field form. The paper log serves as a backup in case there is a problem with the electronic Groundwater Profiling Log. Put any character in the column labeled "Final ?" next to the last row of data. This tells the spreadsheet to display that row of data on the "Groundwater Profiling Log" tab.

4.7.4 Collect Sample in Gas Drive Mode

1. Arrange the valves as you would for purging the pump but when the pressure builds do not open the valve on the sampling jig.
2. Remove the sample bottle on the left.
3. Hold the sample vial under the straw for the first vial holder on the sample jig. Slowly open the right valve on the sample jig. Water will flow out of the straw and into the vial. When you have a mounding of water on the top of the vial, shut the valve and cap the vial. Repeat this process for subsequent vials. Check for bubble by inverting the vial and lightly tapping it on the palm of your hand. If there are bubbles, uncapped the vial and fill again.
4. Label the vials appropriately. Note the time of sampling on the field form.
5. Replace the vials with new vials.
6. Prepare to drive as before after adding tubing and rod as necessary by filling and pressurizing the pump. Refer to section 4.6 above for the procedure.

4.8 How to Determine the End of the Profile

There are several ways to determine the end of a profile. Some profiles have a predetermined depth set by the client. The end of the profile is most often determined by the Drive Rate. As the profiler is advanced into the ground the drive rate will decrease as the skin friction of the rod in the ground increases. There are also stratigraphic layers that are more compact than others (clays, tills) that can slow the drive rate. It is important not to drive the profiler once the drive rate gets below 1.5-2 ft per minute for the 1.5 and 1.75-inch rods and 0.5-1.0 ft per min for the 2.25-inch rods. If the rods, tips and drive hardware are hammered on too much they can fatigue and break, crack or bend. The skin friction can also become too great so that the profiling rods cannot be pulled back out of the ground. Consult with the driller / probe operator during profiling to determine when to stop drilling.

It is also possible to drill into bedrock or other subsurface objects (boulders, cobbles, concrete chunks or slabs, etc.). In this case the drive rate can drop very quickly. Stop hammering immediately and discuss with the driller and client how to proceed.

Be sure to note on the paper field log as well as the Profile Info tab in the Groundwater Profiling Log how the profile was completed.

4.9 Decontamination

The only decontamination step required between samples in the same hole is to flush the line with analyte free water (distilled or spring water) while driving to the next depth. There are required decontamination procedures for the tip and pump, drill rod, stainless steel tubing and KPRO box that need to be completed at the end of a profile. Some sites and clients may require that all the down-hole tooling be decontaminated using a steam cleaner. If this is the case remove the plates and screens from the tip and take the pump out of the housing so that all of the parts can be cleaned. Usually the drillers will provide the steam cleaner and will clean everything.

4.9.1 Tip and Pump Decontamination

The tip and pump need to be disassembled and cleaned prior to reuse. For the tip, remove the plates and screens. The screws can be reused if they are not rusted or stripped. It may be required to use an impact driver to remove the screws if they are stuck. Rinse out the inside of the tip as well as the screens and plates with Alconox and water to remove all sediment. Scrub the tip and plates with a firm brush or use a pipe cleaner to lean the inside of the tip. Carefully check the plates to make sure that the sampling ports are clear. Use a pick to remove any sediment from the sampling port holes. Remove and replace the FEP tubing. The piston for the gas drive system can be reused.

For the pump: unthread the tip from the pump housing and unthread the top and bottom housing pieces. Take the pump body out of the housing. Use a brush and bucket of Alconox and water to clean the inside and outside of the housing pieces and pump as well as the springs and plastic bushing. Disassemble the pump body and discard the o-rings, reed valve and Teflon tape. Rinse out the inside of the pump with Alconox and water and then clean water. Check the small o-rings at the narrow end of the pump bottom and replace if necessary.

4.9.2 Drill Rod and Stainless Steel Tubing Decontamination

Upon completion of the sampling and grouting of the hole, the drill rods should be cleaned by steam cleaning, pressure washing or by washing with Alconox and water. It is important to clean the inside, outside and threads of the rod. The stainless steel tubes should have any grout, drilling mud or soil removed from the outside using a steam cleaner, pressure washer or Alconox and water. The inside should be rinsed with analyte free water (distilled or spring water). It is very important that before the stainless steel tubing is reused that it is checked for clogs by using a garden sprayer with an adaptor.

4.9.3 KPRO Box Decontamination and Equipment Blank Procedure

The KPRO box should be decontaminated at the end of each profiling location to make sure that there is no possibility of cross contamination between profiles.

1. The four o-rings located at the top of each bottle holder on the sample jig should be replaced at the completion of the profile. Remove any vials from the sample jig and discard them. Remove the o-rings located at the top of each bottle holder with a straight or slightly angled pick, being careful not to score the threads on the plastic bottle holder. Alconox and water should be squirted up into the top of each bottle holder before the new o-rings are installed.
2. After changing out the o-rings on the sample jig, the box and jig should be flushed out with at least 1L of Alconox and water and 1L of clean water. This can be done in conjunction with the collection of an equipment blank (as required).
3. For peristaltic mode, connect a clean profiling tip to the KPRO box via the harness. Place the tip into a clean vessel containing Alconox and water (the vessel needs only to be as deep as to make sure all of the ports on the tip are submerged). Screw four new vials into the sample jig and arrange the valves on the box to the same orientation for sample collection. Turn on the peristaltic pump. Top off the water in the vessel as the water is pumped through the box. Once you have pumped 1L of Alconox and water, place the profile tip into a second clean vessel containing only clean, analyte free water and pump 1L of clean water through the box.
4. For gas drive mode, connect all three stainless steel tubes from the pump to the corresponding tubes on the harness and place the tip of the pump in a clean vessel containing Alconox and water. Screw four new vials into the sample jig and arrange the valves on the box to the same orientation for sample collection in peristaltic mode. Disconnect the N2 Out quick connect from the KPRO box. Disconnect the Sample In quick connect and connect it to the N2 Out quick connect and turn on the peristaltic pump. Top off the water in the vessel as the water is pumped through the box. Once you have pumped 1L of Alconox and water, place the profile tip / pump into a second clean vessel containing only clean, analyte free water and pump 1L through the box.
5. If an equipment blank is required, simply collect the required number of vials from the sample jig as you would if you were collecting a groundwater sample using the peristaltic mode. If no equipment blank is required, the decontamination process is complete.
6. Record on the paper Groundwater Profile Log that the box has been decontaminated with 1L of Alconox and water and 1L of clean water. Record the date, time and name of the equipment blank (if required).

4.10 Profile Field Data Deliverables

One of the biggest advantages to using the Waterloo^{APS} is that field data can be quickly processed in the field and given to the client in a matter of minutes. At the end of the profile the raw data needs to be processed so that it can be imported into either Origin to provide a field log to the client or into gINT.

The data should be processed as soon as possible after finishing a profile; either during the decontamination of the KPRO box or during the collection of the first few samples of the following profile. All efforts should be made to get the data to the client by the end of the working day unless otherwise directed. These are the steps:

1. Open the kpro_raw.txt file associated with the profile. Select All (shortcut - Control A) and Copy All (Control C).
2. In the Groundwater Profiling Log Excel workbook, select the Processed Ik tab. Select the top left cell and Paste (Control V) the raw data.
3. This is where alterations or corrections can be made to the data. You can change the depth to water, feet of stainless or other parameters that the software uses to calculate the I_k . If you pulled the profiler up you can delete duplicate data as well.
4. After any corrections are made, scroll to the two far right columns of data; "Corrected Depth to Water" and "New Ik". Both of these columns have data in the first row only. Highlight the data cell and double click on the small black square at the bottom right corner of the cell. This will populate the entire column with data. Do this for both columns.
5. Copy the entire New Ik column. Right click on the top row of the Ik column and select Paste Special – Values. This will overwrite the I_k that was generated by the software in real time with a corrected Ik based on any changes that were made to the data. Even if no changes were made to the data this step should be done anyway.
6. Select the Ik Plot tab. Follow the instructions on the screen to plot the Ik data. Carefully check the plot for any errors or bad data. Bad data can be generated a variety of ways and should be deleted from the plot. Examples of bad data are: driving the profiler with the flow off (flow is zero), driving the profiler without starting the software (no data is recorded), not stopping the software after a drive, entering the wrong depth after a drive, etc. If any of these things happen, delete or change the bad data from the Processed Ik tab. Leave a blank row where the data was deleted so that the Ik Plot does not connect the data with a straight line.

There are other cases where after adding a length of stainless tubing the flow drops so there is a horizontal line on the plot. This data must be shifted up or down to match the previous data. Consult the Data Manager or Project Manager on how to proceed.

7. Open the Origin file named "Physchem_hole_id.opj". This file should be located in the Origin folder in the project directory or in the Forms folder. Save the file to reflect the profile name (Pyschem_WP-01.opj). If you are using gas drive mode and did not collect head measurements, select the file "Physchem_No_Head_hole_id.opj".
8. Select and copy all the data on the Processed Ik tab on the Groundwater Profiling Log. On the Origin file select the Ik record sheet from the bottom of the screen. Select the top left cell and paste the data. It may take a few seconds to paste all of the data.
9. Back on the Groundwater Profiling Log click on the Groundwater Profiling Log tab. Select all the data and paste it into the Physchem sheet in the Origin file.
10. Click on the Layout sheet on the bottom of the Origin file. Check the plots to make sure that the scale is correct and all the data is displayed properly. If the scale needs to be changed select the PhysPlot sheet on the Origin plot and select the axis of the graph you want to change. Select the Scale tab to change the range of values. It is important that all of the plots from a particular site are consistent. Finally, save the file as a PDF.
11. Provide the client with a copy of the Origin plot by copying the PDF file to a data stick or printing out a hard copy. Double check the Groundwater Profiling Log and make sure that all of the fields on the Groundwater Profiling tab, Profile Info tab and processed Ik tab are completed. At the end of the day email the data (only the Groundwater Profiling Logs and a scan or photo of the field form) to the Project Manager and/or Data Manager and back up the entire project folder to a data stick.
12. Metric Data – There are versions of all of the electronic field logs in metric (either as depth in meters or elevation). There is also a version of the KPRO software that displays the depth in meters but does not record the depth in meters to the kpro_raw file. Before importing the data to the Origin plot it needs to be converted from feet to meters in the Processed Ik tab. To do this insert a blank column to the right of the Corrected Depth column after all of the changes or corrections have been made to the data. In the first cell of the new column create a formula that divides the Corrected Depth by 3.281. ($=C2/3.281$ where C2 is the cell of the depth you want to convert). Copy this formula to the entire column. Select and copy the entire column and right click on the Corrected Depth column and select Paste Special – Values. Delete the column where the data was copied from.

4.11 Cold Weather Operation

During the winter months when temperatures fall below freezing special precautions need to be taken to protect and successfully operate the Waterloo^{APS} equipment, KPRO box, and associated equipment.

4.11.1 Exposed Stainless Steel Tubing and Rods

While attempting to collect a groundwater samples with below freezing temperatures a cold weather harness may be required. The cold weather harness is a combination of heat tape and pipe insulation wrapped around the stainless steel tubing exiting the KPRO Box. In extreme cold the rod stickup and stainless steel tubing exposed between the cold weather harness and the ground may need to be heated using either a brush-burner or torpedo heater. Flexible duct work can be used to cover the stainless steel and exposed rod to direct the heat from the torpedo heater and to help insulate.

4.11.2 Leaving the site overnight

If freezing conditions will occur overnight the KPRO Box needs to be winterized. The enclosure should be removed and stored where temperatures will not fall below freezing. The KPRO box and cold weather harness should be drained of water:

1. Disconnect the stainless steel tubing harness from the down-hole tubing.
2. Remove the enclosure and replace with a short piece of stainless steel tubing with a female quick connect at each end or leave the enclosure in place.
3. Disconnect the nitrogen "in" (white) KPRO vessel quick connect.
4. Remove the water "out" (black) KPRO vessel quick connect.
5. Turn the regulator dial counter clockwise so that regulator is off. Attach the stainless steel piece that was connected to the "out" (black) quick connect to the low pressure regulator on the nitrogen tank.
6. In the peristaltic pump mode set up the valves on the box as if you were in drive mode and slowly turn the knob on the regulator clockwise slowly until the smallest amount of nitrogen is flowing. If the pressure is too high the flow meter in the enclosure can be damaged. After a few seconds you should see water being pushed out of the harness. After all of the water has been pushed out turn off the nitrogen regulator.
7. In gas drive mode you need to blow out the KPRO box as well as all three of the harness lines. To blow out the nitrogen line, simply turn the 5 way valve to the N2 Out and wait for all of the water to be pushed out of the nitrogen line on the harness. To blow out the sample line (middle tube on the harness), arrange the valves as you would if you were filling the pump. Disconnect the N2 In and KPRO in quick connects on the KPRO box. Connect the N2 In to the KPRO In. Slowly turn the knob on the regulator clockwise slowly until the smallest amount of nitrogen is flowing and wait for all of the water to be pushed out of the sample line. To blow out the KPRO line, set up the valves on the box as if you were in drive mode and slowly turn the knob on the regulator clockwise slowly until the smallest amount of nitrogen is flowing. If the pressure is too high the flow meter in the enclosure can be damaged. After a few seconds you should

see water being pushed out of the harness. After all of the water has been pushed out turn off the nitrogen regulator.

The KPRO enclosure, KPRO vessel, “out” (black) quick connect, Sonde water quality monitoring system, and calibration solutions should be stored where temperatures will not fall below freezing.

4.12 Other Profiling Configurations

It is possible to set up the KPRO box on a table, cart, tailgate or other surface in order to profile in locations that cannot be accessed with the truck. In instances such as this it may be necessary to power the equipment using a battery. Do not use a standard car battery as repeated draining and charging will diminish its capacity over time. It is better to use a deep cycle RV or similar battery that is designed to power devices and not for starting engines. It is possible to power the KPRO box (including peristaltic pump), field computer and water quality sonde off of a battery for an entire 10 hour day as long as the battery is charged at night. The KPRO box can be connected directly to the battery because it already is 12V. The computer and sonde need to be connected to a DC to AC power inverter that is connected to the battery.

5.0 RESPONSIBILITIES

1. It is the responsibility of the individual employee to read SOPs and document training associated with the area of work they are performing.
2. It is the responsibility of the individual employee to follow SOPs covering activities in his/her work area or to identify a deviation from the written SOP.
3. All personnel will legibly record data and observation to enable others to reconstruct project events and provide sufficient evidence of activities conducted.
4. All personnel will label each page with the date, the signature of the person taking notes (initials may also be appropriate), and the page number. All notes, signatures, and other observations should be entered in the field at the time the notes are taken.
5. SEI field staff should take care to ensure proper data management and integrity of samples.

6.0 DEFINITIONS

KPRO: Hydraulic Conductivity (K) Profiling

7.0 REFERENCES

None

8.0 TABLES, DIAGRAMS, FLOWCHARTS, AND VALIDATION DATA

Diagrams and Attachments:

1. Schematic of Waterloo Profiler Tips and Gas Drive Pump
2. Attachment 1: Groundwater Profiling and KPRO Testing Equipment List
3. Attachment 2: Groundwater Profiling Field Form

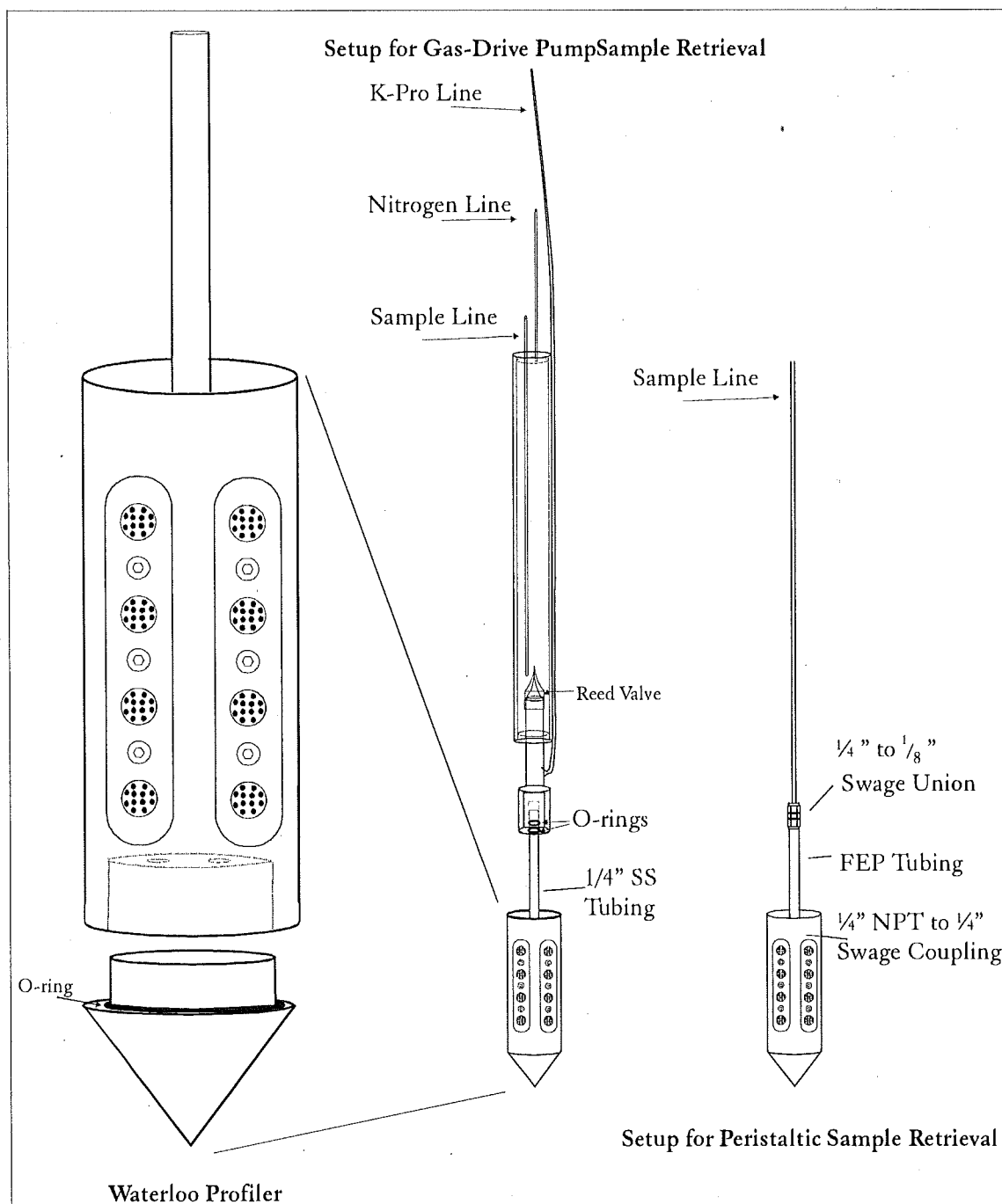


FIGURE 4.1: Schematic of Waterloo profiler with Gas-Drive and Peristaltic Retrieval Systems
SOP #10-5-0: GROUNDWATER PROFILING AND KPRO TESTING

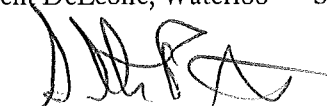
Source: I:\GLP\SOP\SEI_SOPs\CH10_EnvDrill\current\10-5-0 Figure 4.1
7-10-02 dtv



9.0 AUTHORIZATION

Revised by:  Date: 8/24/12

Vincent DeLeone, Waterloo^{APS} Service Leader

Approved by:  Date: 24 Aug 2012

Seth Pitkin, Vice President

10.0 REVISION HISTORY

Revision 1:

1. Modified Attachment 1: Groundwater Profiling and K-Pro Testing Equipment Checklist.
2. Modified Attachment 2: Groundwater Profiling Log

Revision 2:

1. ADD trade name APS Advance Profiling System to Waterloo.
2. Under Section 4, changed startup and calibration procedures for the KPRO software to reflect the new KPRO-2006 revision.

Revision 3:

1. Renumbered to take out of laboratory SOP location.
2. Changed and added text
3. Changed the order of steps
4. Replaced photos of valve orientation
5. Deleted old KPRO box photos
6. Added photos of KPRO software
7. Added text for Data Processing
8. Replace KPRO checklist
9. Update Problem Solver
10. Update quick reference Guide
11. Added text and figures about the 2.25" tip and rod

ATTACHMENT 1

GROUNDWATER PROFILING AND KPRO TESTING
EQUIPMENT CHECKLIST

PROFILING EQUIPMENT

- Profiler Tips (Sac-tip or Integral)
 - Sacrificial Tip
 - O-rings for Sac Tip
 - SS Profiler Screens (4 per tip)
 - SS Allen Screws for Screen Plates
- 5' x 1.75" Drill Rod (2 X max. anticipated depth)
- 2' x 1.75" Drill Rod (1)
- Swivel pull
- Geoprobe Pull Clamp for 1.75" Rod
- Drive Cap (3-4)
- Slip Cap (3)
- 1/8" SS Tubing
- SS Caps for SS Tubing
- Extra 1/8" SS Compression Fittings
- Stainless steel mesh for tips
 - o 80 X 80
 - o 60 X 60
 - o 100X 100
- 1 1/2" Geoprobe X 1 3/4" Rope crossover (for hooking to grout pump swivel)

KPRO TESTING BOX AND RELATED EQUIPMENT

- String Pot
- Com Cable (2)
- Quick Clamp
- Compressed N₂ Tank (Large(T) for Gas drive, Small(Q) for peri-sampling)
- Dual phase regulator (0-60 psi) for K-pro
- Double Pressure Regulator Set (1, 0-60 psi; 1, 0-600 psi), if gas drive
- Pressure Vessel (2)
- Pressure Vessel quick connects
 - o White-N₂ side (2)
 - o Black-Water side (2)
- 1/8" SS Tubing Harness
- 1/8" swage to quick connect (peri/gas) (2+spare)
- 1/8" swage to quick connect (gas drive) (5+spare)
- KPRO Box
 - Com Cable (2)
 - Power Cable (2)
- Regulated Power Supply
- 1 Liter Graduated Cylinder (plastic)
- Field Computer (2)
 - Serial Port Card, PCMCIA
- Power Adapter
- CD-Drive
- Floppy Drive
- Extra Battery and Charger
- USB Data Stick
- External Keyboard and Mouse, USB
- USB Hub (optional)
- Field Software CD
- Current Templates
- Blank CD's
- Color Printer
- Com Cable (parallel or USB)
- Power Cable
- Printer Paper
- 5 Gallon Pails for Purge Water/Decon (2)
- Water Quality Sonde
 - Com Cable
 - Flow Cell
 - extra D-cell Batteries (Troll)
 - power cable (YSI)
 - Calibration Standards
 - DO membrane maint. kit (Troll)
- Field Book/Field Forms

GAS DRIVE PUMP ASSEMBLY

- 2.4' x 1.75" female – female drill rod (3-4)	- Pump Top
- male – male pin (bottom) (3-4)	- Reed Valves (bag of 50)
- male – female pin (top) (3-4)	- O-rings for Pump Body
- Springs (2 per pump)	- O-rings for Pump Bottom
- Nylon Bushing (1 per pump)	- 1/4" SS Tubing (10)
- Pump Bottom	- 1/4" NPT male to 1/4" compression fitting
- Pump Body	- 1/4" Ferrules, SS
-

PERI MODE TIP ASSEMBLY

- FEP Tubing (1/4" OD X 3/16 ID)	- Barbed inserts for FEP Tubing, SS (3/16 OD)
- 1/4" NPT male to 1/4" compression fitting	- 1/4" compression to 1/8" compression fitting
- Ferrules, Nylon	
-

SAMPLE COLLECTION

- Quatro-rings for Sample Jig	- Silicon tubing for Peri Pump (10 feet)
- 40mL VOA Vials (Eagle Pitcher) (2-3 cases)	- Coolers and Ice
- Vial Labels	
-

DECONTAMINATION EQUIPMENT

- Alconox	- Plastic Sheeting
- Squirt Bottles	- Contractor Garbage Bags
- Garden Spray Bottle (3 gallon)	
-

AUXILIARY EQUIPMENT

- Lumber Crayons	- Coffee Maker
- 100' Engineers Tape	- Green Mountain Coffee French Roast Beans
- Electrical Tape	- Grinder (if whole beans used)
- Ratchet Straps and Bungee Cords	- Filters
- Teflon Tape	- Coffee Cups
- Colored Zip Ties	- Paper Towels
- Halogen Work Lights	- Broom
- Extra Bulb	- Ground Fault Circuit Interrupt
- Chair	- Extension Cords
- Fan (optional)	- Land line for Circuit panel
- Padlock with Long Hasp	- Surge Protector
-

PERSONAL PROTECTIVE EQUIPMENT/SAFETY EQUIPMENT

- Nitrile Gloves (2 cases)	- Safety Glasses
- Cotton liner Gloves (4-6 pairs)	- Hardhats (1 per person + spare)
- Leather Work Gloves	- Hearing Protection
-

- Tyvek Suits
- Emergency Eyewash
- First Aid Kit
- Compressed Air Horn
- Respirator and Cartridges

- Spill Kit
- Spare absorbent Pads
- Fire Extinguisher
- Flashlight

HAND TOOLS AND POWER EQUIPMENT

- 7/16" Wrenches (4)
- Pipe Wrenches, 2, 24"
- Open Ended Wrenches, Standard, Full Set
- Screw Drivers, Regular and Phillips
- Impact Wrench
- Oil Filter Wrench (suitable to
- Allen Wrenches, Standard and Metric
- Crescent Wrench
- Socket Set, Standard, Full Set
- 9/16" Socket, Open Ended for removing fittings from Profile Tip
- Taps for Profiler Tip Screws
- Tap Handle
- Torx Bits, T-25
- Picks, Full Set
- Pliers, Standard, Needle Nose, and Channel Lock

- Vise Grips
- Wire Strippers
- Electrical Multi-meter
- Soldering Iron
- Tin Snips
- SS Screen Hole Punch
- Files
- Utility Knife
- Extra Blades
- Tubing Cutter
- Sledge Hammer, 3lb
- Butane Lighter
- Electric Drill
- Drill Bits, Full Set
- Carbide Bit for Reaming SS Tubing
- Angle Grinder

ADDITIONAL WINTER GEAR

- Pipe Insulation
- Heat Tape

- Propane Heaters
- Kerosene Heaters

SWAGE BOX

- Ferrules
- 1/4" Nylon
- 1/8" Stainless Steel
- 1/4" Stainless Steel
- Extra Profiler Tip Plates (4)
- O-Rings for K-pro Reservoir (large and small)
- Hose Clamps
- 1/8" Elbows
- Barb/NPT fittings
- Compression/NPT fittings
- Spare Pressure Transducer
- Spare Flow Meter
- 1/4" to 1/4" Barb Plastic-NPT
- 1/4" to 1/4" Barb Plastic T's
- 1/4" in-line Filters

- Spare 5-way valve
- Spare 3-way valve
- 1/4" NPT
- 1/8" NPT
- 1/8" SS tube Caps
- Extra Regulators
- 100 psi
- 300psi
- Extra pressure gauge
- Screws for tip (3/8" #10/32, flathead T-25)
- Quick disconnect for stainless (4)

DOT REQUIRED EQUIPMENT

- Driver's Log Notebook	- Windshield Wiper Fluid
- Spare Bus Fuses	- Flashlight
- Flares/Reflective Triangles	
- Fire Extinguisher in Cab	

VEHICLE MAINTENANCE EQUIPMENT

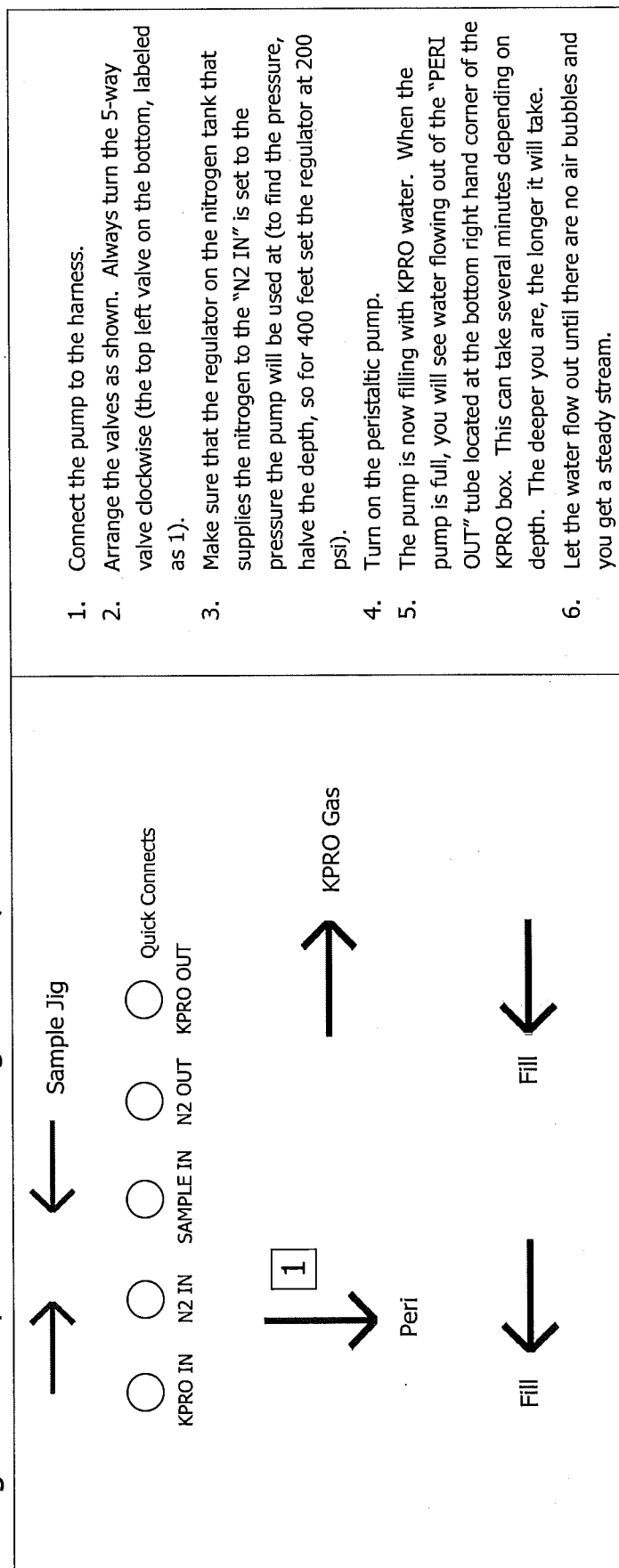
- Generator Maintenance Log	- Spare Oil Filters (Generator and Truck)
- Truck Maintenance Log	- Antifreeze
- Owners/Shop Manual (Generator and Truck)	- Oil Filter Wrench (Generator and Truck)
- Oil Pan	- Battery terminal brush
- Spare Oil (Generator and Truck)	- Oil Funnel

RENTAL TRUCK GEAR

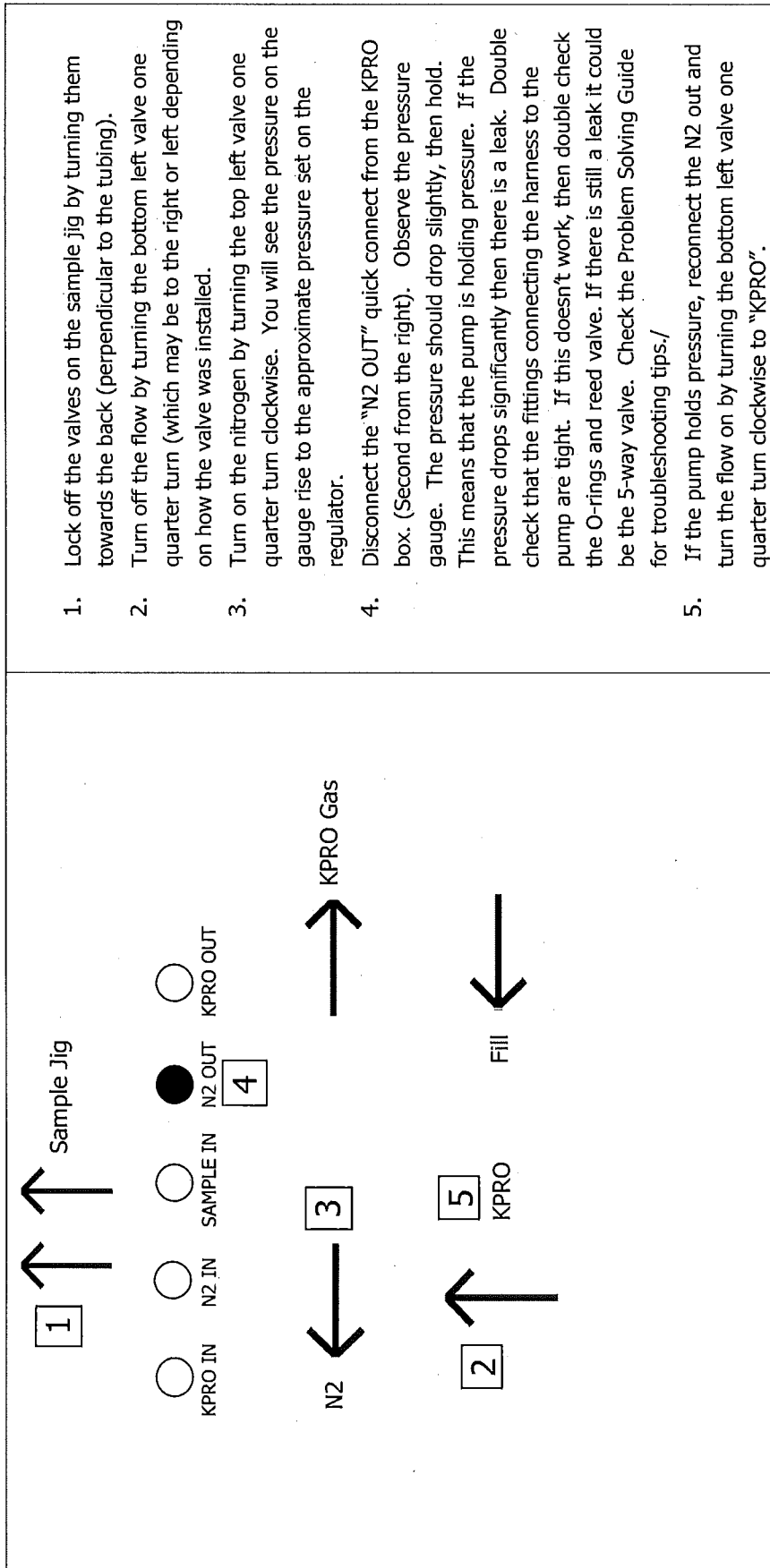
(In addition to the equipment listed above)

Gas Drive Quick Reference Guide

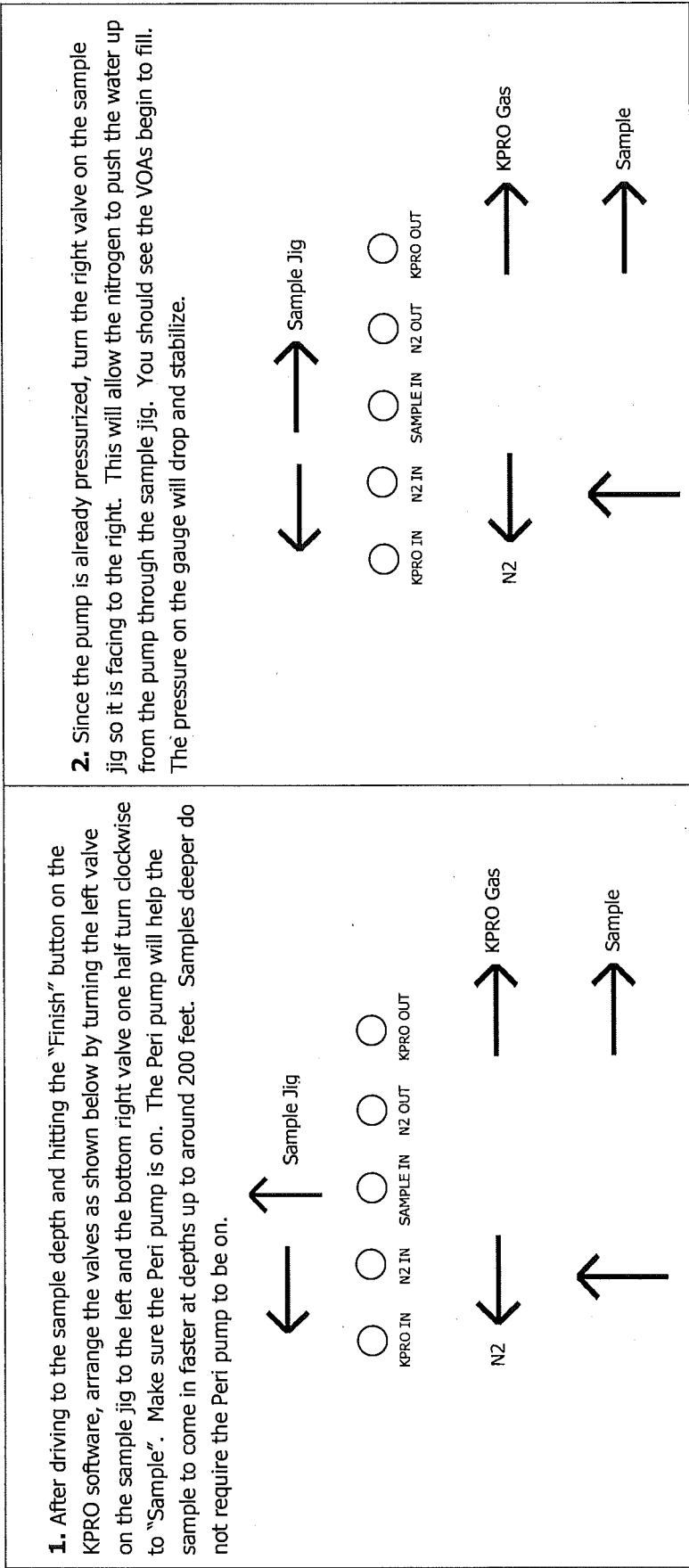
Filling For Drive / Pressure Testing the Pump



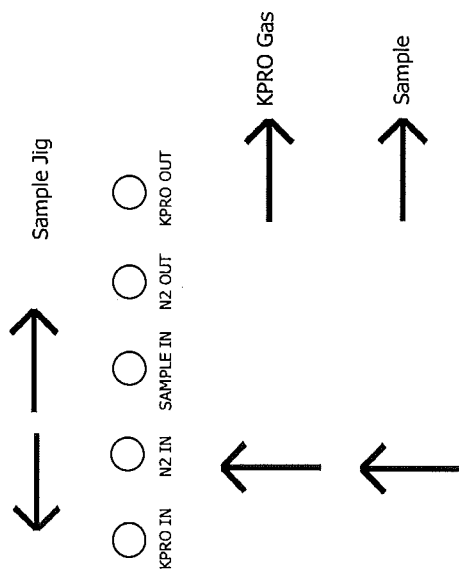
1. Connect the pump to the harness.
2. Arrange the valves as shown. Always turn the 5-way valve clockwise (the top left valve on the bottom, labeled as 1).
3. Make sure that the regulator on the nitrogen tank that supplies the nitrogen to the "N2 IN" is set to the pressure the pump will be used at (to find the pressure, halve the depth, so for 400 feet set the regulator at 200 psi).
4. Turn on the peristaltic pump.
5. The pump is now filling with KPRO water. When the pump is full, you will see water flowing out of the "PERI OUT" tube located at the bottom right hand corner of the KPRO box. This can take several minutes depending on depth. The deeper you are, the longer it will take.
6. Let the water flow out until there are no air bubbles and you get a steady stream.



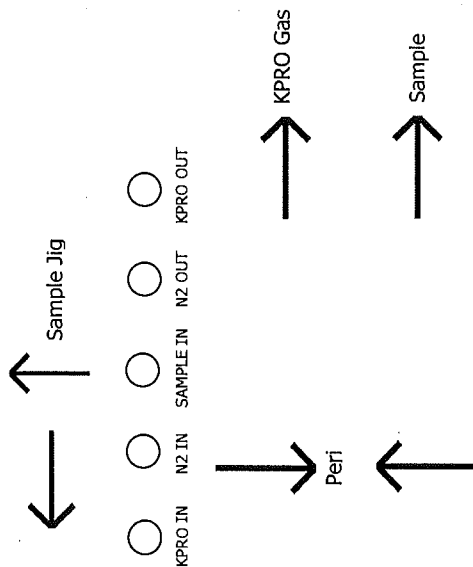
Sampling / Purging The Pump



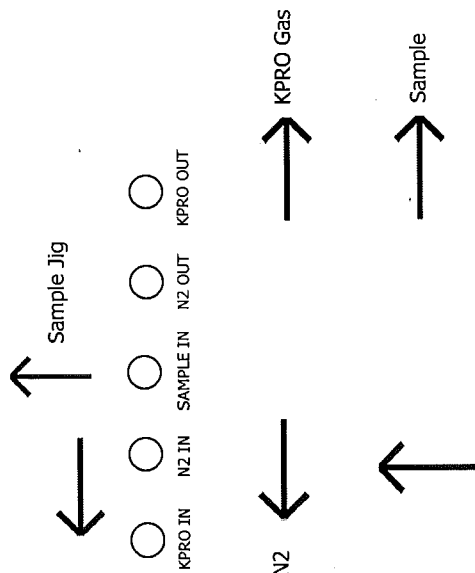
3. Keep a close eye on the pressure gauge. When the pressure gauge starts to move up, turn the top left valve a quarter turn clockwise. This will vent the nitrogen, which will make a hissing sound.



4. After venting the nitrogen, the pressure gauge will drop. When it crosses zero, turn the right valve on the sample jig towards the back (locked off). Wait for all of the gas to vent (the hissing sounds will dissipate) and turn the top left valve one half turn clockwise so it is on "Peri". Record the physchem values.



5. After waiting three minutes (or more or less, depending on how much water was purged during the previous whack) turn the top left valve one quarter turn clockwise to "N2". This will send nitrogen down to pressurize the pump. This is called a "whack". Watch the pressure gauge. When it moves up past zero, turn the right valve on the sample jig to the right. Go back up to step 3 above and follow the sequence.



6. Once the physchem parameters have stabilized and the sample vials have been collected, the pump needs to be filled and pressurized again for driving. Go back up to that section for instructions.

Some notes:

After driving, the stainless steel lines and pump are filled with KPRO water. This water needs to be purged before formation water will appear. To calculate how much KPRO water is in the tubing and pump, multiply the amount of stainless by two, then by 0.8, then add 100. (This accounts for the volume of the tubing going down, coming back up and the pump. There is 0.8 ml per foot of tubing). The first whack should produce almost all of this volume of water.

A good whack should yield 50-60 ml minimum. If you do not get this volume after waiting 3 minutes, wait longer (4 minutes, then 5, etc). If you get more volume than 50-60, do the whacks more often (2 minutes). If you do not get 50-60 ml after waiting 5 or 6 minutes, you may want to drive to a better sampling interval.

If after the first whack you have purged the volume of KPRO that is in the pump and tubing, and after waiting longer between whacks you get nitrogen coming back up instead of water, chances are the sampling interval will not yield a sample. To double check, refill the pump with KPRO water and start the purging/sampling process again.

If you have just added stainless and notice that the flow is a lot lower than it was at the end of the previous drive, you may have a blocked or kinked piece of stainless. Before driving, disconnect the stainless and blow it out with water to make sure all the lines are clear.

Please see the Problem Solving Guide if you have problems that aren't listed here, or if you can't figure it out call the office or somebody to help.



ATTACHMENT 3

Profiling Problem Solvers Guide



KPRO Trouble Shooting Guide

Version 1.0

Updated 2-26-08 by VLD

Software / Electrical Issues

Symptom	Possible Problem	Solution
Kpro Software Will Not Recognize Box	COM port set incorrectly in Software	There is a text box labeled "Kpro Com Port" on the Kpro software. Make sure that the number matches that of the com port where the Kpro box is plugged in. If it is plugged into the Com port on the back of the computer it is Com 1. If it is plugged into the socket card, click on the socket icon on the toolbar at the bottom right corner of the computer screen to determine which Com ports the computer has assigned to the socket card. A fast way to determine if the box is reading is to start the Kpro software and select "Calibrate" when the dialogue box pops up. Select one of the three choices (Flow, Pressure, String Pot). If the red light in the enclosure comes on and blinks and there are numbers other than zero for the readings, you have a good connection. Double check that the wiring harness inside the Kpro box is securely connected to the enclosure. On the newer tough book laptop computers (Rasc 6,7 and 8), sometimes the socket cards are given Com ports of 9 and or 15 and 16. The Kpro software does not like these higher numbers. Click on the socket card icon at the bottom right corner of the computer screen. Change the com ports of the socket card to Com 2 and 3. If the Kpro box is connected to the socket card, make sure you change the number in the software. If for some reason the socket card will not change the com ports, connect the Kpro box to Com 1 and the water quality sonde to Com 9. After checking all of the above, the data cable may be broken. Double check the connections and maybe try another cable.
	Wiring harness inside Kpro box not connected/ or is loose	
	Computer assigns higher com port for serial card	
	Bad data cable	

Bad data cable connector

Check the connection plugs on the left-side of the Kpro box. All of the pins should be sticking out about the same distance. If not try using pliers to gently pull out any sunken in pins to the same level as the others. If this is not the case or does not work, if the truck has a spare wiring harness connect that to the enclosure and plug the data and string pot cables directly to it. If there is no spare harness and the truck has another Kpro box, swap out the boxes. Insert the serial com card and click on the socket card icon on the lower right corner of the computer screen. If the text box says "no socket card detected" then the driver needs to be installed. On the software disk with each computer there is a socket driver folder with a read me text file in it. Open the text file and follow the instructions.

Computer is not reading the serial card
(dual or single)

No power to enclosure

Blown Fuse

The fuses are located inside the top compartment of the enclosure to the right of the LED voltage readout. Remove and inspect the fuses.

Bad Power cable

Check that the ends of the power cable are securely fastened to the power inverter. If they are and the inverter is on, try replacing the power cable.

Bad Power inverter
Broken Enclosure

The on/ off switch on the inverter will light up when it is on. If after trying all of the above and the enclosure still will not power up, then the enclosure may be broken. You can either swap out the enclosure or the entire Kpro box.

String Pot Malfunction

String pot reads intermittently

Make sure that the connection form the cable to the string pot is tight and that the cable is properly connected to the Kpro box. If they are, try swapping out the cable. If that doesn't work try swapping out the string pot. Also make sure that the wire that extends out of the string pot is not getting hung up on the drill rig or something else (wrench or pulling plug used to weight it down). Make sure that the cable is properly connected to the string pot and the box. If there is still no reading, try swapping out the cable and/or the string pot.

String pot not reading at all

String pot not reading during drive

Make sure that the string pot is extended before pressing the "Start Kpro" button on the software. If the button is pressed when the string pot is retracted, it will not read.

	String pot reading long/ short	Recalibrate the string pot. If that does not work and the string pot it not off by that much (+/- .5') then correct the depth at the end of the drive or when you stop to collect a sample. If it is off by more than that, try swapping out the string pot, then recalibrate. The string pot slope should be around 1.65 (+/- 0/2). If it is more or less than that, swap out the cable or string pot.
Flow Meter Issues	Flow seems too high/ or low	Make sure that all of the connections inside the enclosure are tight. Flow out with one piece of stainless attached should be between 170-270. The flow slope should be close to 38 (+/- 2). Recalibrate the flow. If after recalibrating the slope is above or below this, try replacing the flow meter and recalibrating. You can also do a manual check of the flow by timing how long it takes to fill 100ml. If the flow rate matches what the software is reading and it is too high or low, change out the flow meter.
	No flow	Double check that the quick connects that go to the enclosure are connected. Make sure that the bottom left valve is on "Kpro". Check Kpro reservoir for water. In Peri mode, make sure that the top left and right valves are in the "Kpro Peri" position. For gas drive make sure that the top right valve is in "Kpro Gas Drive" position.
	Flow out but flow meter does not read any flow	Make sure that the flow meter is properly connected (electronics cable and plumbing). Make sure that the Kpro software is on and is connected properly. If it is, then replace the flow meter.
Pressure Transducer	Pressure seems too high/ or low	First, make sure that there are no leaks in the enclosure. When checking atmospheric pressure, the pressure should be between 32 and 36. If it is higher or lower, recalibrate the pressure transducer. The pressure slope should be around 22-28. If it is higher or lower than this and the transducer is still reading way off, replace the pressure transducer.
Calibration Problems	KPRO software folder in wrong directory	Make sure that the KPRO_2006 folder is located in the root directory of the C drive (*C:\Kpro_2006). There is an output file that gets written to and if the folder is in the wrong place, the software does not know where to find it.

Slopes do not change, unrealistic numbers

If the slopes were calibrated with a bad cable, flow meter or pressure transducer, the program can come up with some crazy slopes (~16777 for string pot). The program uses the old slope to calculate the new slope, so it cant create a proper slope based on some crazy unreal number. After replacing the bad component, go to C:\Kpro_2006\Output Files\slopes.txt. Open the file and delete the bad slopes from the file. Make sure that the cursor is at the end of the line with the slopes when you save the file, otherwise the Kpro software will read in from the next line, which is blank, and will give a "NAN" (Not A Number) in place of the slope. Save and close the file, then try calibrating.

Note on calibration: If you calibrate and want to recalibrate right away due to a bad calibration, the program will NOT use the freshly calibrated slopes, but will use the slope that was read in when the program first started. So if you think the newly re-caled slopes are bad, simply recalibrate. If you think that the slopes the program are using are bad, go in and delete the bad slopes from the text file according to the directions above.

KPRO Box Issues

General Peristaltic Pump Problems

Symptom	Possible Problem	Solution
Peri pump not working - no power	Loose connection / bad switch	Make sure that the wiring harness is connected, the power cord is connected, all other connections are good. Some peristaltic pumps are connected to the power supply via a cigarette lighter plug located inside the Kpro box. Make sure that this connection is tight and that there is no corrosion/ and or dirt on the plug. Double check that the connections from the wiring harness to the pump are tight and there is no corrosion on the connectors and switches. If all the connections and switches appear to be fine, then the problem is probably in the wiring harness. In this case you will need to replace the harness or bypass the harness with a spare, or use a different Kpro box.
Pump head will not spin but pump motor is on	Broken spindle	There is a plastic piece inside the pump that has a slot in it that the shaft from the pump head fits into. Over time the slot can get worn and break off. If this happens you need to open up the pump and replace the spindle, or replace the entire pump.

Peristaltic Pump Repair / Replacement

If there is time, remove all the tubing and electrical connections and detach the old pump from the black plastic piece that holds it in the box. Connect the new pump to the black plastic piece and rewire the switches to connect to the switches on the kpro box and reconnect the tubing. A quicker solution is to disconnect the tubing and electrical connection and remove the old peri (black plastic piece and all) and put in the new pump by laying it in the open space in the box and connecting the tubing and electrical. When changing the tubing in the pumps do not tighten the pump head down with a screwdriver, these are meant to be finger tight, using a screwdriver causes the plastic framework within the pump to fatigue and break.

None of the fittings for the pump between the black plastic and the switches/pump body are water tight which has lead to corrosion and switch failure. In an effort to extend the life of this equipment using a little silicon sealant at these points is a good idea, if you are working on a box that does not have this please apply a small amount between the 2 parts, any questions please feel free to call me.

Peristaltic Mode

Cannot pull vacuum

Upper left valve on box not on peri

Worn out silicon tubing

Peri pump on reverse

Check if problem is in sample jig or other stainless

If leak is in sample jig:

Loose fittings

Double check that all of the swage fittings on the sample jig are tight.

Loose Vials / Bad vials

Make sure that the sample vials are tight. They should not be excessively tight. If there is still a leak, replace the vials. Sometimes the threads on the vials can be slightly off and won't fit correctly in the bottle holder.

No o-rings or bad o-rings

There are special quad o-rings that are located in the bottle holder. Double check that there are o-rings in there and that they are in good condition (not dried out, cracked or cut).

Sample straw too close to vial bottom

On some of the sample jigs, the straw that extends down into the sample vial is too long and will come in contact with the bottom of the vial. Sometimes this will result in the vial bottom breaking.

Other times it will block the straw and water will not be able to pass through. If it looks as if the straw is too long, try inserting an additional o-ring in the bottle holder. If this does not work, file down the straw or cut a small amount off the bottom with a tubing cutter or grinder.

Plastic bottle holder is worn out / scarified

The threads of the bottle holder can become scarified from people not being careful when removing the o-rings with a pick. If after trying all of the above, the bottle holder may need to be replaced. There are screws located on the under side of the plastic piece (hex screws). Once the holder has been removed, inspect the inside of the threads and if they are scratched and gauged then replace the plastic piece.

If leak is not in sample jig:
Leaky fittings

If it is determined that the leak is not in the sample jig, then you may have a leaky fitting on the harness or down hole. Double check that all the fittings on the Kpro box, harness and stainless are tight.

Gas Drive Mode

Symptom

No inflow of sample water

Possible Problem

No Flow during whack. Pressurize pump then open sample jig, but no water flows.

Solution

Make sure the bottom right valve is on "sample". Make sure that there are no kinks in the tubing coming out of the box and going to the water quality sonde's flow cell. Also sample straw in jig could be too close to the bottom of the sample vial and is preventing flow. Try loosening the vials to see if you get flow.

Gas bubbles when filling pump for drive

Leaky 5-way valve

If the 5-way valve (the top left valve on the Kpro box) is leaking, nitrogen can leak through. Tighten the valve by first removing the know with a hex wrench. Remove the metal plate. If you see metal shavings, it is possible that the pump has been tightened before and needs to be replace. Insert needle nosed pliers into the two holes on the valve and turn. If the valve still leaks, it needs to be replaced.

Silicon tubing pops off peri pump

Leaky 5-way valve

See above. Another test to determine if the valve is leaking is to pop off the silicon tubing and put your finger over the peri intakes and remove it after a second or two. If you hear a pop, then gas is leaking through the valve. Another way is that with the valve pointed to "Peri", place the vent tubing into some water. If there are bubbles coming out of the tubing, the valve is leaking.

Replacing 5-way valve

Disconnect the "N2 in" quick connect from the Kpro box. Before removing the valve, take note of which way the fittings are pointing on the under-side of the valve. Is is helpful to make a drawing showing how they are oriented. Remove the knob of the valve with a hex wrench. There is a large nut/ ring on the top-side of the valve that can be removed using a crescent wrench. Disconnect the valve (there are 5 connections). Remove the fittings from the valve, and re-use them if you can. Some of the plastic fittings can become worn out and break, so do not reuse these (there should be new ones in the Swage box). Before installing the fittings on the new valve, wrap the threads with teflon tape. It is much easier to install the fittings onto the valve before putting the valve into the box. Orient the fittings the same way that they were on the old valve, making sure that they are tight. This will make re-installation much easier. It is also easier to re-attach all of the connections before putting the valve through the hole in the plastic and securing the nut/ ring on the top side of the valve.

Profiling Problems

Peristaltic Mode

Symptom	Possible Problem	Solution

Head values seem odd	FEP is broken or disconnected	If you know you are in the water table, and based on previous head readings the head value seems wrong (i.e. a previous head reading was -10, and now it is -1) the FEP tubing could be broken. Slightly pull on the stainless steel tubing coming out of the rods. If you feel resistance, then the tubing is still intact. If the FEP is still intact, there could be a loose fitting that is leaking. To test this, pour water down the rods and watch the pressure reading on the Kpro software. If the pressure rises, there is a leak and the tooling needs to be tripped out and replaced. If the profiling tip is in lower-lk zone, it can take a while for the head value to settle, and it still may settle at a value different than the previous head value (usually a few feet above). Wait a few minutes and record the head value once it stabilizes. Orient the valves and turn on the peri pump to start pulling a sample. If you do not get a sample, the profiler needs to be advanced to a higher lk zone.
	Loose fitting	
	Silty layer	
No flow out	Valves in wrong position	Make sure that the valves on the sample jig are pointing towards each other, then that the top left and right valves on the box is pointing towards "Kpro Peri", and that the bottom left valve is turned towards "Kpro". After attempting to pull a sample, orient the valves for flow and turn on the Kpro. If the flow was good before pumping and is now zero, then the tip became clogged during pumping. Try to advance the profiler, as sometimes the vibration will loosen the soil in the tip and can free it up. If after a few feet there is still no flow, trip out the tooling and replace the tip. Make sure there is water in the Kpro reservoir. Disconnect the line going from the nitrogen regulator to the reservoir before opening the top.
	Tip is clogged	
	Kpro reservoir is empty	
Good flow out, no water back	Tip is slightly encased with soil	Develop the formation by alternately flowing Kpro water out the tip and pumping, or by alternating the direction of the peri pump for a few seconds. Make sure to turn the pump off before switching between forward and reverse because it can damage the pump. The profile tip should be at least 6" into the water table. Check previous section listed above Check previous section listed above If the drill rod has broken off it will shear the stainless steel. Pull on the stainless to see if it is still connected.
	Not deep enough in water table	
	Not pulling vacuum	
	FEP is broken or disconnected	
	Stainless is broken or has sheared off	

Pull in very dirty sample	Water from drilling rods is being pulled in	If the sample water is excessively silty and a lot of silt has filled up the sample vials, then there is a chance that the FEP tubing is broken. Check FEP - see above.
Start to get good sample return, then nothing	Tip is clogged	Develop the formation by alternately flowing Kpro water out the tip and pumping, or by alternating the direction of the peri pump for a few seconds. Make sure to turn the pump off before switching between forward and reverse because it can damage the pump.
Gas Drive Mode		
Symptom	Possible Problem	Solution
No flow out tip	Tip is clogged / smeared	The profile tip can become clogged after pulling in a sample that contains fine particles such as silty or fine sand. If after pulling a sample the flow out the tip is lower than before pulling the sample, try advancing the tip a few feet. If during the drive the flow is good but drops off when the hammer is stopped, there is a good chance that the tip is clogged and must be changed. When profiling through a clay layer, it is possible that clay will smear on the tip and cover the sampling ports. See the clogged lines section below
No flow out tip - deep profiling	Kpro line is clogged Rubber inner tube still on tip	When profiling using a drill rig where the drill rods are lowered down into casing filled with drilling mud, it is necessary to put a rubber inner tube over the profile tip to prevent it from clogging. The tip must be advanced at least 1-1.5 feet for the inner tube to be pushed back to expose the sampling ports on the tip.
Cannot fill pump for drive	Nitrogen pressure set to high - reed valve failure	Make sure that the pressure regulator is set at the appropriate pressure for the depth. the conversion is 1 psi = 2.3 feet of water (So for a depth of 200 feet, the regulator should be set around 90 psi, at 500 feet at 220 psi). If the pressure is set to high the reed valve will fail.

Leaky fitting / reed valve, reed valve silted up	Make sure that the fittings on the harness are tight. The pump will not fill if the reed valve located in the pump is not closing correctly due to silt or a defective valve. Sometimes it is possible to "shock" the reed valve by first making sure that the valves on the sample jig are facing each other, then connecting the "sample out" line to the "N2 out" line and turning the valve on the top right of the box to "N2". This will send nitrogen down the sample line (the sample line inside the pump ends above the reed valve) hopefully mobilizing any silt, or by forcing the valve to close. If this does not work, then the pump needs to be removed from the hole and the reed valve must be replaced.	
Cannot pressurize pump	Leaky fitting / reed valve, reed valve silted up / pressure set to high	See above.
Pump loses pressure during drive	Leaky fitting / reed valve, reed valve silted up / pressure set to high	See above. See above.
Good flow out, no sample back	Tip is clogged	Sometimes while driving the vibration from the hammer will allow flow out, but when the hammer stops flow will drop. If the flow goes to zero or very low after the hammer is stopped, the tip could be clogged or the formation is tight. You need to either pull out the tooling or drive further.
	Kpro line is loose or came unscrewed	If the flow out is high enough where you think a sample can be pulled but you get no water back when whacking, the Kpro line could be broken or unscrewed. While driving, the tip will become clogged if no water is flowing out. The Kpro water will flow out the open stainless giving the illusion of high lk. Another clue to this is if you cannot pull a sample and the lk is high and didn't vary at all over a large depth.
Small sample return (small volume whacks)	Lines are switched	If you are well into the water table and the lk is high and the whacks are small (less than 50 ml) then the stainless steel lines could be reversed. If there are two lines that are very close in length (usually the sample and nitrogen lines) a short piece of stainless can be added to sample line to separate them.
Sparge sample	Tip is clogged	The pump volume is approximately 120 ml and there is approximately 0.8 ml per foot of stainless. If after purging the appropriate amount of water to fill the pump and stainless the sample sparges, refill the pump, pressurize the pump and turn on

the Kpro to see if the tip is clogged.

It is too low to sample

Wait longer between whacks. If you purge the volume of the lines and pump and do not see formation water (usually silty) advance the profiler.

Not venting nitrogen when needle moves

If excess nitrogen gets into the pump the sample will sparge. Be sure to vent the nitrogen as soon as the needle on the gauge tips up. If it sparges, try doing smaller whacks by venting the nitrogen before the needle tips up. If the sparge is too much try refilling the pump and starting over.

Clogged Lines

1. Before attempting to unclog any lines, turn the valves on the sample jig so that they are facing each other, thereby bypassing the sample jig.
2. If you think a line is clogged, the first and fastest thing to check is the harness. The harness can become plugged if it touches the ground while adding stainless. Try disconnecting the harness from the stainless lines and turn on the nitrogen and kpro and see if the lines are clear. You can check the sample line by putting the valves on fill, or plugging the sample line into the kpro out and turning the kpro on.

Determining if a line is clogged

Line
Kpro line

Problem

No flow - pump is full and pressurized, flow bottoms out to zero before driving.

Solution

Depressurize the pump by venting the nitrogen and turn the valves on the sample jig in. Turn on the Kpro and look at the flow on the Kpro software. Since the pump is de-pressurized and pressure in the pump is less than the pressure outside the tip, Kpro water should flow up into the pump at about 10-20 ml/min. If the flow is still zero, the Kpro line is clogged. See the "Unclogging lines" section below.

Sample Line	Pump does not fill	Turn the left valve on the sample jig so that it faces the wall (closed) if the needle on the pressure gauge does not drop, the line is probably clogged. To double check, plug the sample line into the Kpro out and turn on the Kpro. Watch the flow on the computer. If the flow is zero, then the line is clogged. See the "Unclogging lines" section below. Plug the nitrogen out line into the Kpro out and turn on the Kpro. Watch the flow on the computer. If the flow is zero, then the line is clogged. See the "Unclogging lines" section below.
Nitrogen Line	Pump does not fill	
Unclogging Lines	Kpro Line	1) Isolate zero-headspace sampling apparatus by pointing the two valves handles, located above pressure gauge, inward towards each other. 2) Place "KPRO out" quick connect into "Nitrogen Out" quick connect slot. 3) Turn nitrogen/peri valve to "Gas Drive" position, which will allow nitrogen flow down the KPRO line and out into the formation. 4) Listen to gas drive regulator to determine if regulator stops delivering flow, as indicated by the regulator becoming silent. If regulator continues to make "hissing noise", then the KPRO line is free of any obstructions. 5) If the obstruction cannot be removed via the nitrogen pressure, the tool must be removed from the ground and inspected to determine where the clog is present.
	Nitrogen Line and Sample Line	1) Isolate zero-headspace sampling apparatus by pointing the two valves handles, located above pressure gauge, inward towards each other. 2) Turn nitrogen/peri valve to "Gas Drive" position and disconnect the sample line from where it enters the pressure gauge. This will allow nitrogen flow down the nitrogen line and up the sample line. 3) Listen to gas drive regulator to determine if regulator stops delivering flow, as indicated by the regulator becoming silent. If regulator continues to make a "hissing noise" and nitrogen flow is observed at the effluent of the sample line, then the nitrogen line, the gas drive pump and the sample line are free of any clogs. If regulator stops delivering flow, as indicated by the regulator becoming silent, then either the sample line, the nitrogen line, or the

gas drive pump may be clogged.

- 4) If the obstruction cannot be removed via the nitrogen pressure, the tool must be removed from the ground and inspected to determine where the clog is present.

Water Quality Sondes

Symptom

Sonde is not recognized by the computer

Possible Problem

Wrong Com Port in Software

Power not connected/ batteries are dead

Cable is broken

Water quality parameter values are way off

Computer/ Sonde needs to be restarted or recalibrated.

Individual probes need to be changed.

Solution

Make sure that the com port assigned in the software is the same one that the sonde is connected to. Most of the software will only go up to Com 9.

The YSI and Hach sondes have a power supply. The Trolls have batteries. To change the batteries first unscrew/ disconnect the data cable and then unscrew the top of the sonde.

If after trying the first two steps listed above there is still no

connection between the sonde and the computer, the data cable connecting the sonde to the computer could be faulty. Try a different cable.

Sometimes the sondes can read strange numbers (i.e. pH of 100, DO of 300). The first thing to try is to restart the computer. If this does not work try recalibrating the sonde. It is better to calibrate/ check each probe individually rather than using an all in one cal solution (such as Quick Cal). If the sonde is still off, look below.

From time to time the individual probes on the sondes can be faulty. Each troll/ YSI case should have extra probes. Swap out the probe and check/ and or recalibrate. Make sure when checking/ calibrating that the probes are fully immersed in the cal solution.

Also, it is very important to store the probes in the correct manner. Never store the probes dry, even overnight. At the end of the day, take the sonde out of the flow cell and store it in the screw on cap filled with pH 4 solution. For long term storage (longer than a week) remove the individual probes and store them in the appropriate solution (check the manual for the particular sondes for the correct way to do this).

Bad Cal Solutions

Calibration solutions can go bad if they have been opened for a while (especially conductivity). Always write the date opened on any bottle of solution when it is opened for the first time. If you think they solution may be old, recheck or calibrate with fresh solution.

Water Temperature - DO calibration

When calibrating or checking the DO using the water saturated air method, make sure that the water you are using is relatively warm. If you are checking the sonde first thing on a cold morning with water that was in the truck, it will take longer for the water to vaporize in the flow cell and therefore the calibration will take longer or won't happen at all. Try heating the water in a cup using a space heater prior to calibration. Make sure to record the DO value and temperature in the log book for the sonde after calibration or check. Make sure that the sonde is kept vertical, otherwise sediment can build up in the flow cell and coat the probes.

Values do not change Clogged flow cell - silted up probes

Calibration Notes for Hach Hydrolab

1. There is a reference solution for the PH/ORP probe that needs to be changed monthly (not sure if that is only in use or always) it is very easy to do following the instructions in the manual.
2. When you calibrate the PH on these units it is IMPORTANT to calibrate the PH 7 standard first followed by either the 4 or 10 or both as the calibration method uses the 7 as zero and calculates the slope with the 4/10.

Torpedo/ Salamander Heaters

***** UNPLUG THE HEATER WHEN YOU ARE TROUBLESHOOTING IT EXCEPT IN AN ATTEMPT TO START IT*****

Symptom	Possible Problem	Solution
Unit will not start / shuts off	Not plugged in / no power	1. Make sure the unit has Power.
Fuel		2. Check your fuel source for diesel treatment; they do not fire quite the same as a diesel engine and the treatment in the fuel may not be working for the heater. Possible solutions include more additive, a different additive and using kerosene.

Starter element is bad

3. Look inside the unit (FROM THE REAR) as it tries to start, if there is not a red glow inside then the element must be replaced, parts available at Home Depot.

Air filter is plugged / clogged.

4. Check the air filter on the back of the unit: This can become iced up or plugged with dust/dirt. Clean it!

Fuel filter

5. If the temperature isn't far below freezing and the fuel is not in question you may try replacing the fuel filter. This can be found by removing the control panel (2 Philips screws above the controls) it is a white inverted cone with a black tube attached to it sticking out of the fuel tank. To remove the filter you must pull out the rubber bushing it sits in; failure to do this will remove the fuel pickup tube from the bottom of the filter and cause the unit to only be able to utilize 10% of the fuel tank capacity (the first 10) replacement filters can be purchased at Home Depot.

Fuel line

6. Check the fuel pickup line mentioned above.

Other issues:

1. If the unit runs for a while then shuts off repeatedly it is likely 2 or 6 above.
2. Sometimes the unit will start with the top cover off and not with it on, I have come across this while troubleshooting and it is the result of improper fuel supply pressure, this can be corrected with the pressure gauge from the manufacturer but they are too costly to have in every truck. For a temporary solution you can restrict the airflow from the back with a piece of cardboard to get it to fire then remove the cardboard for operation, doing so will cause the fuel supply to spread further and interact properly with the igniter.
3. They get very hot, allow them to cool after use before placing them in a truck.
4. While in operation they are a serious hazard and must be used in such a manner as to not melt nearby objects (people, drill rigs etc.) keep in mind that the heat from these is dangerous for more than 10 feet.
5. Do not fuel them while in use.
6. Do not fuel them to the very top, the caps have a vent that will leak if not perfectly level.

DO NOT USE GASOLINE IN THEM !!!



STANDARD OPERATING PROCEDURE

SEI-10.12.2

USE, CALIBRATION, AND MAINTENANCE OF THE MEMBRANE INTERFACE PROBE

SOP Number: 10.12.2

Date Issued: 08/4/04

Revision Number: 2

Date of Revision: 05/18/12

1.0 OBJECTIVE

The objective of this standard operating procedure (SOP) is to describe and document the procedures necessary for the use, maintenance and calibration of the Membrane Interface Probe (MIP), which includes an integral electrical conductivity (EC) system, manufactured by Geoprobe Systems. The MIP is a direct push tool used to determine the distribution of volatile organic compounds (VOCs) in saturated and unsaturated soils and to infer unconsolidated subsurface geology.

2.0 POLICIES

All Stone Environmental staff shall read and document that they have read, understand and agree to follow this SOP prior to using the MIP system. All data will be collected and handled in accordance to SOP SEI-4.5.n.

3.0 SAFETY ISSUES

The corporate Health and Safety Plan and the Site Health and Safety Plan specify the procedures to be followed and equipment to be used during site activities. The following is a brief and general overview of safety issues.

- Potential Safety Issues include:
 - Heavy equipment (drill rigs or direct push rigs) hazards
 - Overhead utility hazards
 - Underground utility hazards
 - Traffic/ motor vehicle hazards
 - Working with hazardous chemicals, both as standards and as residual contaminants on the probe as it is withdrawn.
 - Slip, trip and fall hazards
 - Pinch point hazards



- Compressed gas hazards
- Fire hazards from hot work (e.g., grinding)
- Gasoline/Diesel fuel hazards (filling generator)
- In addition, the MIP system presents a potential electrical hazard due to the high voltage (120 V) heater lines that extend from the SEI truck to the tip of the MIP. Operators should unplug the MIP Controller when performing maintenance to either the controller or the connections adjacent the probe.
- During use, the heater block assembly within the probe tip is heated to over 100 °C. Care should be taken to prevent burns when handling the tip.
- During use, heated trunklines are heated to 100 °C. Care should be taken to prevent burns when handling heated trunklines.
- MIP operators should take extra care when working with standards. When working with neat standards, make certain that there is adequate ventilation and that Nitrile or Latex gloves are worn and if necessary safety glasses.
- SEI staff and others under contract with SEI that may be present on-site will wear a hardhat whenever overhead hazards are present.
- Appropriate eye protection should be worn
- Hearing protection shall be worn whenever the direct push rig is actively advancing profiling equipment.
- Steel toed boots will be worn
- SEI staff will read and sign the site health and safety plan (HASP) where required prior to beginning on-site work.
- Additional personal protective equipment shall be worn in accordance to the health and safety plan.

4.0 PROCEDURES

4.1 Introduction

The MIP provides continuous measurements of VOCs in soil and groundwater. The probe contains a permeable, Teflon membrane, which is maintained within a steel block at approximately 120 °C. As the probe is driven into the subsurface volatile compounds in the soil and/or groundwater are volatilized by the heat, diffuse through the membrane under a concentration gradient, enter the nitrogen carrier gas stream, and are delivered to the surface. The VOC content of the carrier gas stream is then measured using a HP5890 gas chromatograph (GC) equipped with a series of detectors. In addition to the detection of subsurface VOCs, the tool is equipped with an electrical conductivity (EC) dipole array at the leading edge of the tool for measuring the electrical conductivity of the surrounding soil and the soil pore water. The electrical conductivity is used to



infer the lithology of the soil in contact with the probe. As a general rule, the electrical conductivity of the soil is inversely proportional to grain size. For example, sandy matrices will generally have lower EC values than soil rich in clays.

4.2 Equipment

4.2.1 Geoprobe Equipment

For all Geoprobe equipment see section 3.0 of Geoprobe Membrane Interface Probe Standard Operating Procedure (GMIPSOP) included as Attachment 1. A checklist of equipment used for MIP fieldwork is included in Attachment 2.

4.2.2 Detection Equipment

The MIP detection equipment has the following components:

- Gas Chromatograph: Hewlett Packard 5890 Series II system complete with all required accessories including column supplies, ultra high purity gases, syringes and data system.
- Detectors:
 - photoionization detector (PID)
 - electron capture detector (ECD) and/or halogen specific detector (XSD)
 - flame ionization detector (FID)

4.3 System Assembly

Schematics of the detector systems for the MIP are given in Figure 1. This schematic shows the basic setup for the MIP system, in which the carrier gas travels through the PID upon entry into the GC, then branches off to the ECD and FID, which are connected in parallel. This configuration may be adjusted to meet the specific needs of a given site. A detector wiring schematic for the PID is shown in Figure 2.)

4.4 Field Operation

Operation of the MIP will follow the procedure described in section 5.0 of GMIPSOP (Attachment 1). In addition, signal attenuation will be performed with the procedures described in the following subsections.

4.4.1 Response Testing

A response test (RT) is required before and after each sampling location. To conduct a RT, a standard solution must be created either at the beginning of each project, or at the beginning of every two-week period on-site. When possible, the RT will be performed with one or more of the compounds that are the subject of the field investigation. Generally, Stone

Environmental prepares 2 mL standard solutions that consist of 50 000 ppm tetrachloroethene (PCE) and 250 000 ppm benzene in methanol.

To conduct a RT the probe is submerged in clean water (Figure 2) to stabilize the detector's baselines. A RT solution is created by adding 20 μ L of the standard solution to 1 L of clean water to make a concentration of 1 ppm PCE and 5 ppm benzene. The RT solution is then decanted into the RT bucket (Figure #a). A new response test file is created. After the file has been set up, the probe is transferred from the clean water to the RT solution and the MIP-T log is started. The probe is transferred back to the clean water after an appropriate amount of time has elapsed, typically 45 seconds. When the detector response maximum is observed, the response of the EC dipole is checked using the supplied tool from geoprobe. The bronze coloured prongs should give a resistance value of 55 (+/- 5%) mS/m and the silver coloured prongs should give resistance values near 285 (+/- 5%) mS/m. Once the EC dipole has been checked the log can be ended and the data evaluated in Excel® or other graphing software. The generally accepted, change in detector response is 200 mV ECD and 20 mV PID for a 100 ft trunkline. Due to small chromatography effects, longer trunklines may have lower acceptable changes in detector response (ie for a 150 ft trunkline Stone's generally accepted Δ ECD response is 150 mV) .

4.4.2 Maintaining the MIP Log

A MIP log must be filled out for each location at which the MIP is used at a given site. The MIP log, given in Attachment 2, is divided into three sections: general information, response tests, and profile information. The general information section refers to site details such as hole name, site location, date, client name, MIP operator name and SEI job number as well as MIP diagnostics such as detector baseline(s), carrier gas flow and pressure, heater temperature, and dipole tester measurements for each profiling location. The response test section of the MIP log is divided into initial and final response tests, and requires documentation of completed response tests before and after each profile location. The final section, referring to profile information, is for documenting actions taken during the profile as well as the corresponding depths of those actions. Potential actions include signal attenuation, sample collection for speciation tests, and correction of problems that arise during operation.

4.4.3 Signal Attenuation

Signal attenuation is required when the detector signal is above the allowable range, as signified by a horizontal line in the response versus time graph on the field instrument. Signal attenuation should be performed in the following order:

1. Adjust range on the detector
2. Adjust the attenuation on the field instrument by the same multiple.

When the signal has decreased back towards the baseline, the range can be adjusted back to the original setting by completing the above steps in the reverse order. It is important that this sequence of steps be performed correctly so that false "peaks" are not created in the data.

ECD FID, and PID attenuation is performed using the "range" button, which is located on the keypad on the front of the GC. The signal range for these detectors is multiplied by values of 2 to a given exponent. Thus, entering 0 for the range gives a total attenuation of 2^0 or 1, entering 1 gives a total attenuation of 2^1 or 2, etc.

4.5 Maintenance

4.5.1 General

The MIP system must be assembled as shown in the EC, Heater and Thermocouple Wiring Schematic given as Figure 3a. Figure 3a can also be used as a trouble-shooting guide in the field. To further assist in the electrical troubleshooting of the MIP system, Figures 3b and 3c are included as part of this SOP. Non-routine maintenance that is performed on the MIP system should also be documented in the MIP Maintenance Log. Note the date on which the action is taken, and describe the action taken. Be sure to sign and date each entry. The MIP Maintenance Log should be kept with the MIP system at all times.

4.5.2 Membrane Leak Test and Replacement

Membrane leaks are considered to occur frequently and can result in an increase in tailing of detector response. Membrane leaks most often occur around the edges of the membrane and can be observed by spraying a soapy solution onto the membrane while the heater is at room temperature. Note that a small amount of gas flow (1-3 mL/min) can be observed through the center of the membrane during this procedure. Membrane leak testing should be performed at carrier gas pressures between 15 and 20 PSI. This pressure range can be achieved by disconnecting the outlet line of the MIP system and restricting flow with a finger or end cap.

Membrane replacement will be performed on an as-needed basis, either due to a reduction in response or excessive leaking. The membrane replacement procedure is described in Section 6.0 of GMIPSOP.

5.0 RESPONSIBILITIES

It is the responsibility of the individual employee to read SOPs and document training associated with the area of work they are performing.

It is the responsibility of the individual employee to follow SOPs covering activities in his/her work area and to identify and document a deviation from the written SOP.

6.0 DEFINITIONS

None

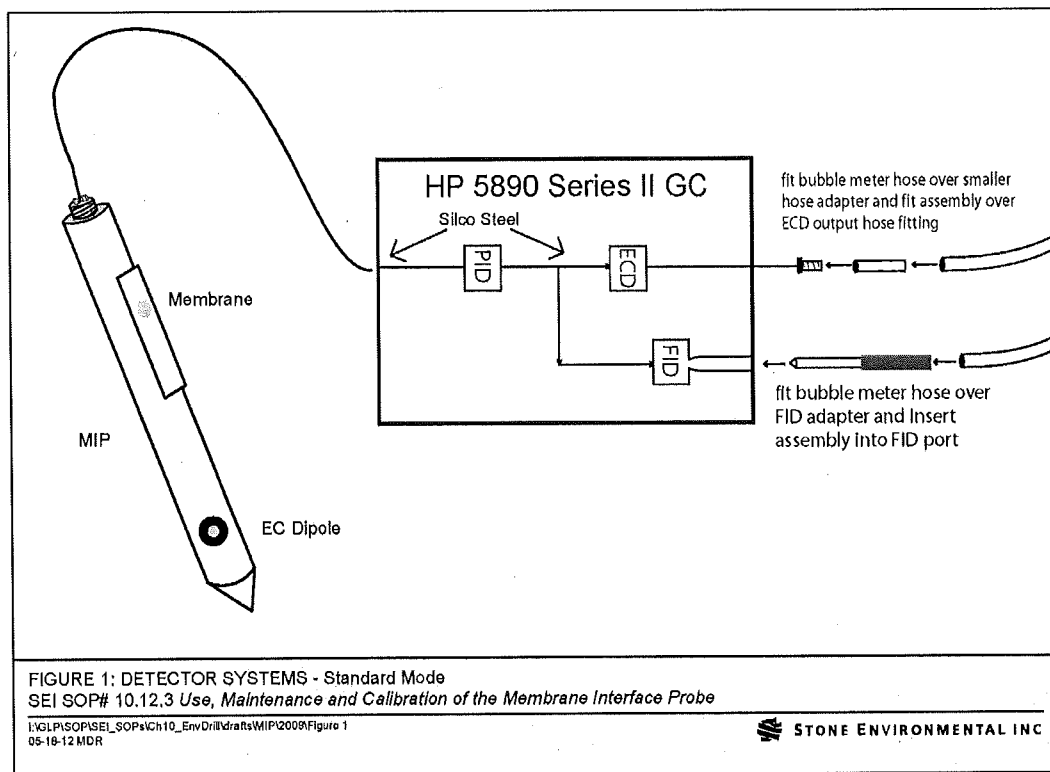
7.0 REFERENCES

Pawliszyn, Janusz, 1999, Applications of Solid Phase Microextraction, in RSC Chromatography Monographs; Smith, Roger S., Series Editor, Royal Society of Chemistry, Cambridge, UK, 655 p.

SW846. ASTM D6520.

Geoprobe Membrane Interface Probe (MIP), Standard Operating Procedure, Technical Bulletin No. MK3010, Prepared: May 2003

8.0 FIGURES



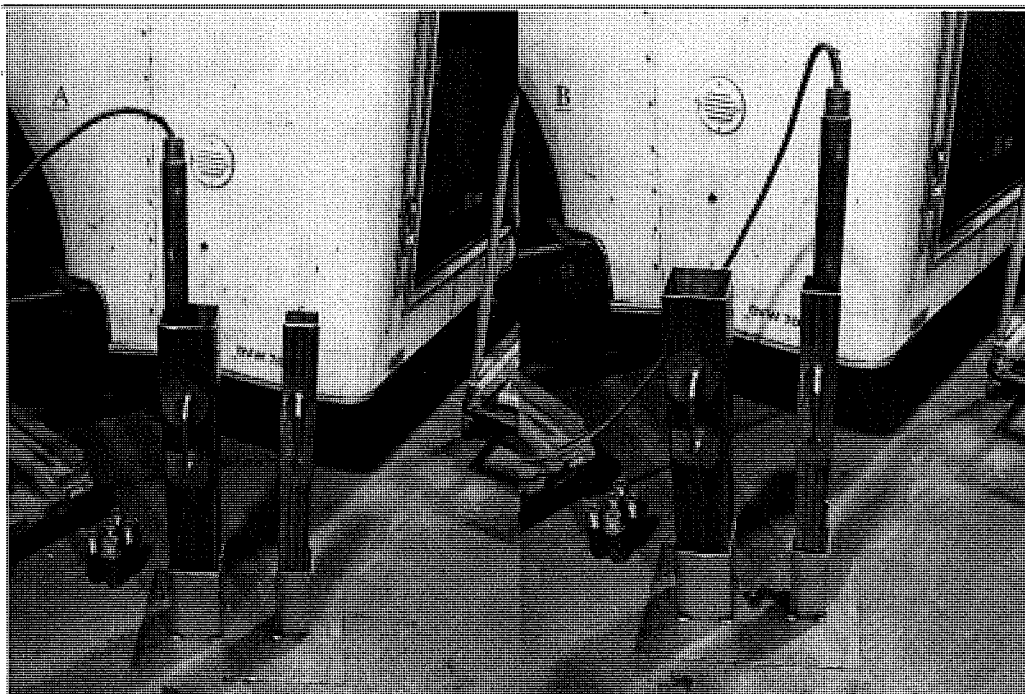


FIGURE 2 - PROBE IN CLEAN RESPONSE TEST BUCKET (A) AND A RESPONSE TEST SOLUTION (B)

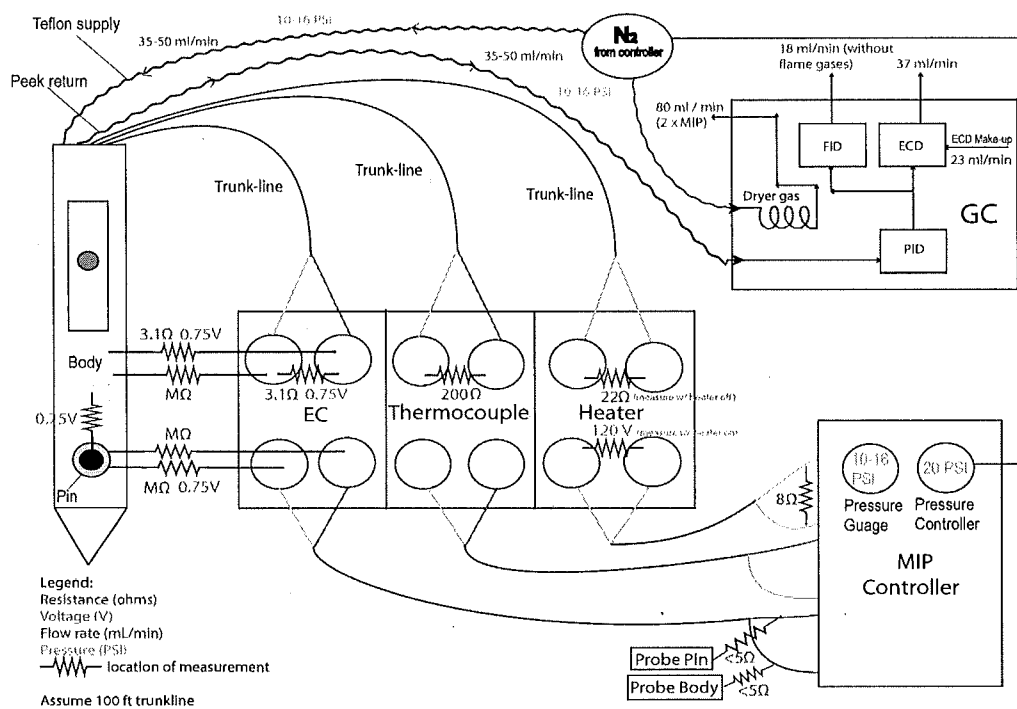


FIGURE 3a: Wiring and flow troubleshooting schematic
 SEI SOP# 10.12.3 Use, Maintenance and Calibration of the Membrane Interface Probe
 I:\GLP\SOP\SEI_SOPs\Ch10_EnvDrill\SEI_Current\SEI-10.12.2 MIP.doc
 05-18-12 MOR

Figure 3b: Isolated Trunkline

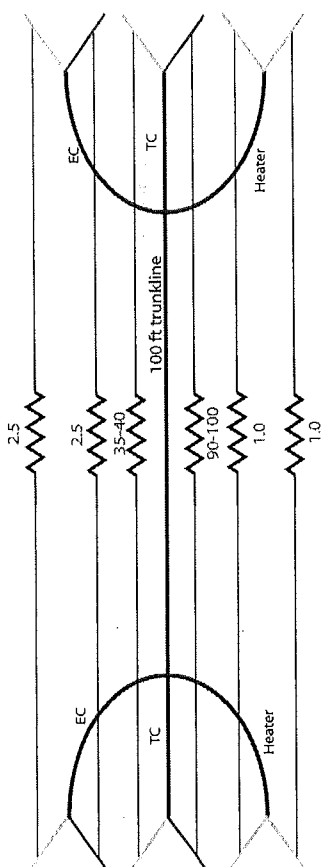


Figure 3c: Isolated Probe

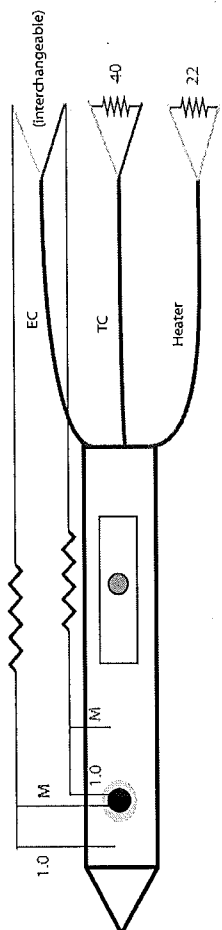


FIGURE 3b, 3c: Wiring and flow troubleshooting schematic
SEI SOP# 10.12.3 Use, Maintenance and Calibration of the Membrane Interface Probe
I:\GLP_NELAC\SOP\SEI_SOPs\Ch10_EnvDrill\SEI_Current\SEI-10.12.2 MIP.doc
05-18-12 MDR



AUTHORIZATION

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Date:

7/12/12

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Approved by:

Date:

7/13/12

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9.0 REVISION HISTORY

Revision 1:

1. Section 4.4.4 – FC4000 changed to FC5000. Extraction time changed from 10 to 8 minutes.

Revision 2:

1. Section 4.1 – Added FID to list of detectors in GC.
2. Section 4.3 – Changed description of GC layout to account for alterations done to GC by Dan Pipp of Geoprobe, May 20, 2009.
3. Section 4.4.2 – “dipole voltage” changed to “dipole tester measurements” to account for new method of testing dipole.
4. Section 4.4.2 – Added to reasons for documenting actions in MIP log.
5. Section 8.0 – Replaced former Figure 1 with new Figure 1a and Figure 1b.
6. Section 8.0 – Replaced former Figure 2 with new Figure 2.
7. Section 8.0 – Replaced former Figure 3 with Figure 3a, Figure 3b, and Figure 3c.
8. Attachment 2 – Replaced former MIP log with new MIP log.
9. Attachment 2 – Replaced former MIP diagnostics log with new MIP diagnostics log.
10. Attachment 2 – Replaced former MIP checklist with new MIP checklist.
11. Removed text and figures describing speciation procedure.
12. Added text to further define response test procedure.



Attachment 1

**Geoprobe Membrane Interface Probe
Standard Operating Procedure (GMIPSOP)**

D





Attachment 2

MIP Log

MIP Diagnostics Log

MIP Inventory





MIP Checklist

Product #	ITEM	Total	Needed	Notes	Product #	ITEM	Total	Needed	Notes
	Probe					Tools			
MP8501	1.75" Probe		3		16172	Membrane Wrench		2	
MP3512	Membranes		5			Pipe wrenches		2	
15328	Membrane Washers		5			Flat head screwdriver		1	
MP2550	Trunkline		5			Crimper		1	
16172	Membrane Wrench		2			Multimeter		1	
	Polyolefin heat shrink tubing		5 ft			5/16" wrenches		2	
SC160	Stringpots		3			7/16" wrenches		2	
SC161	Stringpot Cord		1			1/2" wrenches		1	
SC112	Stringpot Piston Assembly		1			1/4" wrenches		1	
28089	Dipole Tester		1			Crescent wrench		1	
23852	Rod Wiper Donut		1			Wire stripper		1	
36378	Trunkline Seal Spacer		3			T-n snips		1	
37032	Trunkline Water Seal		3			Lighter		1	
15488	Drive Cap adaptor (bell cap)		3			Wire brush		1	
	Replacement thermocouples		2			Needle-nose pliers		1	
	Teflon tape		10 ft			Vise grip pliers		1	
	Electrical tape		5 ft			Straight file		1	
20701	1.75" Connector tube		2			Round file		1	
20712	1.75" to 1.5" tube adaptor		2			Exacta-knife		1	
MP2515	MIP Service Kit		1			Drill with grinding bit		1	
	Plumbing/Electrical					General			
31740	1/16" Brass Ferrules		10			FC5000 data card		2	
8636	1/16" Hex Nut		10			1L Erlenmeyer		1	
3805	1/16" SS Union		5			Response Test Vessels		1	
39806	14/16 Crimp connectors		16			Purge Bucket		2	
39807	16/20 Electrical crimp connectors		16			Printer Paper			
9130K25	16 Terminal blocks		2			Data Stick			
	Geoprobe					Ruler/measuring tape		1	
15007	1.5" Threaded Drive Cap		2			Squirt bottles		2	
32722	1.5" Threadless Drive Cap		2			Alconox carton		1	
15184	1.5" Pull Cap		2		6978K777	15A 125 VAC 5mm x 20mm fuses		5	
23321	Drive Cushion Assembly		1			Fiberglass tubing for rod stringing		5 ft	
20400	1.5" Pull Dog		1			Z-p ties		15	
18465	8" Soil Anchor		1			3-hole punch		1	
15513	Soil Anchor Extension		1			Nitrile gloves		2 boxes	
10187	Anchor Plate		1			Aluminum foil		3ft	
10809	Hex adaptor for Anchor Assembly		1			Traffic cones		5	
10076	Chain Vise		1			Mouse		1	
	GC					Keyboard		1	
	MeOH		200 mL			Monitor		1	
	Benzene for neat std		2 mL			USB Hub		1	
	PCE for neat std		2 mL			Printer Ink		1 spare set	
	Syringes		4						
	N2		1 week supply						
	Air		1 week supply						
	H2		1 week supply						
	Bubble flow meter		2						
	FID bubble flow meter adapter		1						
	Needle valve for purging TL		1						
	Glass Sample Trap		2						
	Fiber Holder		2						
	Fibers		2						

L:\RASC\MIP\MIP Inventory Template.xls

QSM
Revision 10
Date: March 25, 2013

APPENDIX E

References

References

40 CFR Part 136, Appendix A and Appendix B

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TNI-National Environmental Field Activities Program (NEFAP) Field Sampling and Measurement Organization Sector Volume 1 General Requirements For Field Sampling and Measurement Organizations, 5/1/2007

General Requirements for Competence of Testing and Calibration Laboratories, ISO/IEC 17025, December 1999.

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PJLA PL-1 Perry Johnson Laboratory Accreditation, Inc. Proficiency Testing Requirements, 10/11

PJLA PL-2 Perry Johnson Laboratory Accreditation, Inc. Measurement Traceability Policy, 10/11

PJLA PL-3 Perry Johnson Laboratory Accreditation, Inc. Policy on Measurement Uncertainty, 10/11

PJLA PL-4 Perry Johnson Laboratory Accreditation, Inc. Calibration Scopes of Accreditation, 10/11

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Revision 10
Date: March 25, 2013

APPENDIX F

Terms and Definitions

Terms and Definitions

Accuracy: the degree of agreement between a measurement and true or expected value, or between the average of a number of measurements and the true or expected value.

Audit: a systemic evaluation to determine the conformance to specifications of an operational function or activity.

Batch: environmental samples, which are prepared and/or analyzed together with the same process, using the same lot(s) of reagents. A preparation batch is composed of one to 20 environmental samples of a similar matrix, meeting the above mentioned criteria. Where no preparation method exists (example, volatile organics, water) the batch is defined as environmental samples that are analyzed together with the same process and personnel, using the same lots of reagents, not to exceed 20 environmental samples. An analytical batch is composed of prepared environmental samples, extracts, digestates or concentrates that are analyzed together as a group. An analytical batch can include prepared samples originating from various environmental matrices and can exceed 20 samples.

Chain of Custody (COC): an unbroken trail of accountability that ensures the physical security of samples, data and records.

Clean Air Act: legislation in 42 U.S.C. 7401 et seq., Public Law 91-604, 84 Stat. 1676 Pub. L. 95-95, 91 Stat., 685 and Pub. L. 95-190, 91 Stat., 1399, as amended.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA/Superfund): legislation (42 U.S.C. 9601-9675 et seq., as amended by the Superfund Amendments and reauthorization Act of 1986 (SARA), 42 U.S.C. 9601 et seq.

Compromised Sample: a sample received in a condition that jeopardizes the integrity of the results. See Section 18.0 for a description of these conditions.

Confidential Business Information (CBI): information that an organization designates as having the potential of providing a competitor with inappropriate insight into its management, operation or products.

Confirmation: verification of the presence of a component using an additional analytical technique. These may include second column confirmation, alternate wavelength, derivatization, mass spectral interpretation, alternative detectors, or additional cleanup procedures.

Corrective Action: action taken to eliminate the causes of an existing non-conformance, defect or other undesirable situation in order to prevent recurrence.

Data Audit: a qualitative and quantitative evaluation of the documentation and procedures associated with environmental measurements to verify that the resulting data are of acceptable quality.

Demonstration of Capability (DOC): procedure to establish the ability to generate acceptable accuracy and precision.

Equipment Blank: a portion of the final rinse water used after decontamination of field equipment; also referred to as Rinsate Blank and Equipment Rinsate.

Document Control: the act of ensuring that documents (electronic or hardcopy and revisions thereto) are proposed, reviewed for accuracy, approved for release by authorized personnel, distributed properly and controlled to ensure use of the correct version at the location where the prescribed activity is performed.

Environmental Data: Any measurement or information that describes environmental processes, locations, or conditions; ecological or health effects and consequences; or the performance of environmental technology. DoDI 4715.15, December 11, 2006.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA): legislation under 7 U.S.C. 135 et seq., as amended.

Federal Water Pollution Control Act (Clean Water Act, CWA): legislation under 33 U.S.C. 1251 et seq., Public Law 92-50086 Stat. 816.

Field Blank: a blank matrix brought to the field and exposed to field environmental conditions.
Field of Testing (FOT): a field of testing is based on NELAC's categorization of accreditation based on program, matrix, analyte.

Good Laboratory Practices (GLP): formal regulations for performing basic laboratory operations outlined in 40 CFR Part 160 and 40 CFR Part 729 and required for activities performed under FIFRA and TSCA.

Holding Time: the maximum time that a sample may be held before preparation and/or analysis as promulgated by regulation or as specified in a test method.

Instrument Blank: a blank matrix that is the same as the processed sample matrix (i.e. extract, digestate, condensate) and introduced onto the instrument for analysis.

Instrument Detection Limit (IDL): the minimum amount of a substance that can be measured with a specified degree of confidence that the amount is greater than zero using a specific instrument. The IDL is associated with the instrumental portion of a specific method only sample preparation steps are not considered in its derivation. The IDL is a statistical estimation at a specified confidence interval of the concentration at which the relative uncertainty is +100%. The IDL represents a range where qualitative detection occurs on a specific instrument.

Quantitative results are not produced in this range.

Laboratory Control Sample (LCS): a blank matrix spiked with a known amount of analyte(s), processed simultaneously with, and under the same conditions as, samples through all steps of the analytical procedure.

Laboratory Quality Manual (QSM): a document stating the quality policy, quality system and quality practices of the laboratory. The QSM may include by reference other documentation relating to the laboratory's quality system.

Limit of Detection (LOD): the minimum amount of a substance that an analytical process can reliably detect.

Limit of Quantitation (LOQ): the minimum concentration of an analyte or category of analytes in a specific matrix that can be identified and quantified above the method detection limit and within the limits of precision and bias during routine analytical operating conditions.

Matrix: the substrate of a test sample. Common matrix descriptions are Air (air samples as analyzed or as adsorbed into a solution or absorption matrix and desorbed), Aqueous includes surface water, groundwater and effluents, Drinking Water Aqueous sample that has been designated a potable water source, Saline Aqueous sample from an ocean or estuary, or other salt-water source, Liquid: Liquid with <15% settleable solids, Solid: Soil, sediment, sludge or other matrices with >15% settleable solids, Waste (a product or by-product of an industrial process that results in a matrix not previously defined), Tissue Sample of a biological origin such as fish tissue, shellfish, or plant material.

Matrix Duplicate (MD): duplicate aliquot of a sample processed and analyzed independently; under the same laboratory conditions; also referred to as Sample Duplicate; Laboratory Duplicate.

Matrix Spike (MS): field sample to which a known amount of target analyte(s) is added.

Matrix Spike Duplicate (MSD): a replicate matrix spike.

Method Blank: a blank matrix processed simultaneously with, and under the same conditions as, samples through all steps of the analytical procedure.

Method Detection Limit (MDL): the minimum amount of a substance that can be measured with a specified degree of confidence that the amount is greater than zero using a specific measurement system. The MDL is a statistical estimation at a specified confidence interval of the concentration at which the relative uncertainty is $\pm 100\%$. The MDL represents a range where qualitative detection occurs using a specific method. Quantitative results are not produced in this range.

Non-conformance: an indication, judgment, or state of not having met the requirements of the relevant specifications, contract, or regulation.

Precision: an estimate of variability. It is an estimate of agreement among individual measurements of the same physical or chemical property, under prescribed similar conditions.

Preservation: refrigeration and/or reagents added at the time of sample collection to maintain the chemical, physical and/or biological integrity of the sample.

Proficiency Testing: determination of the laboratory calibration or testing performance by means of inter-laboratory comparisons.

Proficiency Test (PT) Sample: a sample, the composition of which is unknown to the analyst that is provided to test whether the analyst/laboratory can produce analytical results within specified performance limits. Also referred to as Performance Evaluation (PE) Sample.

Proprietary: belonging to a private person or company.

Quality Assurance (QA): an integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

Quality Assurance Project Plan (QAPP): a formal document describing the detailed quality control procedures by which the quality requirements defined for the data and decisions pertaining to a specific project are to be achieved.

Quality Control (QC): the overall system of technical activities, the purpose of which is to measure and control the quality of a product or service.

Quality Control Sample: a control sample, generated at the laboratory or in the field, or obtained from an independent source, used to monitor a specific element in the sampling and/or testing process.

Quality Management Plan (QMP): a formal document describing the management policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an agency, organization or laboratory to ensure the quality of its product and the utility of the product to its users.

Quality System: a structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementing, and assessing work performed by the organization and for carrying out required QA/QC.

Quantitation Limit (QL): the minimum amount of a substance that can be quantitatively measured with a specified degree of confidence and within the accuracy and precision guidelines of a specific measurement system. The QL can be based on the MDL, and is generally calculated

as 3-5 times the MDL, however, there are analytical techniques and methods where this relationship is not applicable. Also referred to as Practical Quantitation Level (PQL), Estimated Quantitation Level (EQL), Limit of Quantitation (LOQ).

Raw Data: any original information from a measurement activity or study recorded in laboratory notebooks, worksheets, records, memoranda, notes, or exact copies thereof and that are necessary for the reconstruction and evaluation of the report of the activity or study. Raw data may include photography, microfilm or microfiche copies, computer printouts, magnetic/optical media, including dictated observations, and recorded data from automated instruments. Reports specifying inclusion of “raw data” do not need all of the above included, but sufficient information to create the reported data.

Record Retention: the systematic collection, indexing and storing of documented information under secure conditions.

Reference Standard: a standard, generally of the highest metrological quality available at a given location, from which measurements made at that location are derived.

Reporting Limit (RL): The level to which data is reported for a specific test method and/or sample. The RL is generally related to the QL. The RL must be minimally at or above the MDL.

Resource Conservation and Recovery Act (RCRA): legislation under 42 USC 321 et seq. (1976).

Safe Drinking Water Act (SDWA): legislation under 42 USC 300f et seq. (1974), (Public Law 93-523).

Sampling and Analysis Plan (SAP): a formal document describing the detailed sampling and analysis procedures for a specific project.

Selectivity: the capability of a measurement system to respond to a target substance or constituent.

Sensitivity: the difference in the amount or concentration of a substance that corresponds to the smallest difference in a response in a measurement system using a certain probability level.

Spike: a known amount of an analyte added to a blank, sample or sub-sample.

Standard Operating Procedure (SOP): a written document which details the method of an operation, analysis or action whose techniques and procedures are thoroughly prescribed and which is accepted as the method for performing certain routine or repetitive tasks.

Storage Blank: a blank matrix stored with field samples of a similar matrix.

Systems Audit: a thorough, systematic, on-site, qualitative review of the facilities, equipment, personnel, training, procedures, record keeping, data validation, data management, and reporting aspects of a total measurement system.

Test Method: defined technical procedure for performing a test.

Toxic Substances Control Act (TSCA): legislation under 15 USC 2601 et seq., (1976).

Traceability: the property of a result of a measurement that can be related to appropriate international or national standards through an unbroken chain of comparisons.

Trip Blank: a blank matrix placed in a sealed container at the laboratory that is shipped, held unopened in the field, and returned to the laboratory in the shipping container with the field samples.

Verification: confirmation by examination and provision of evidence against specified requirements.

APPENDIX G

Organizational Chart

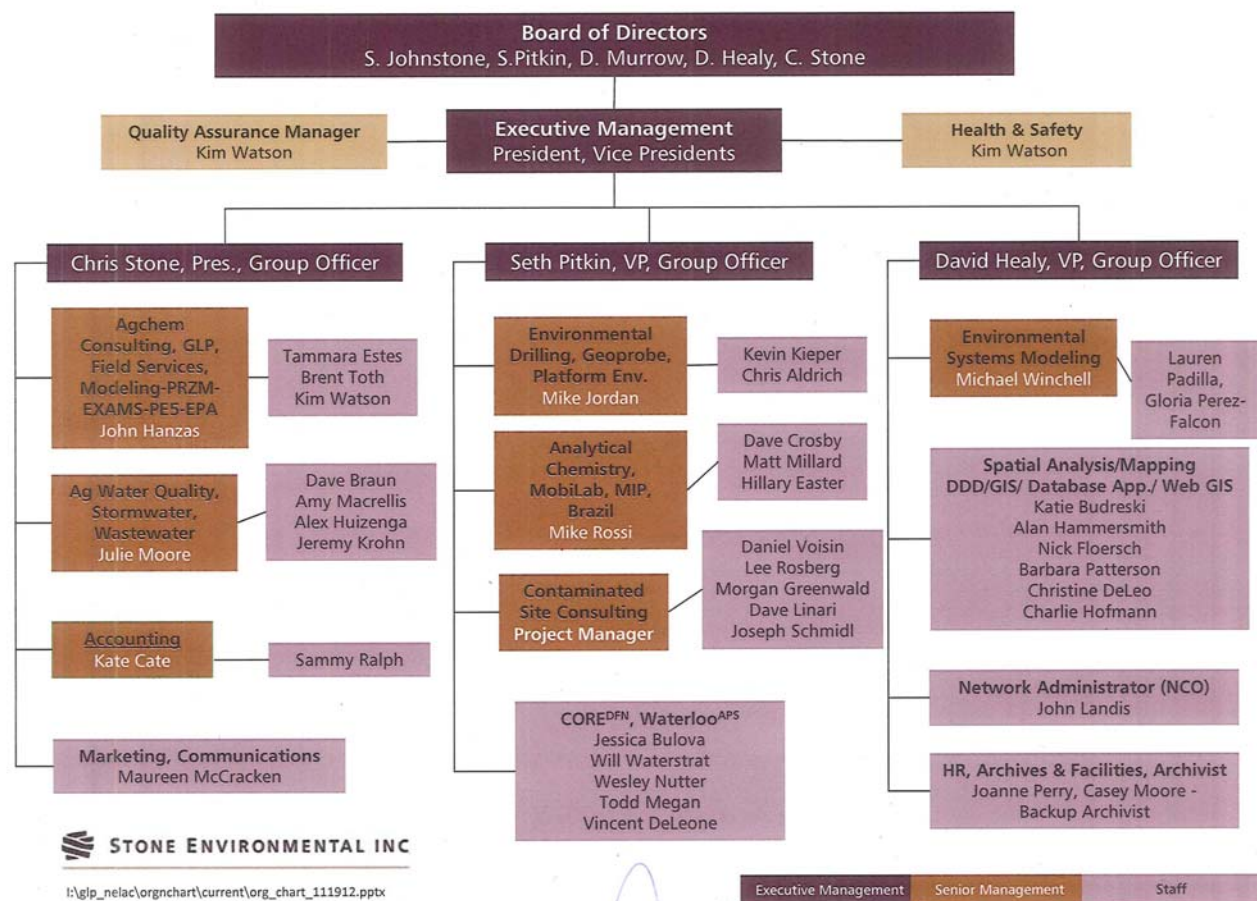


Figure 5. Organizational Chart

APPENDIX H

Forms:

SEI Procedure Specific Training Log

Laboratory Start-Up Form

Field Activities I&R Project Field Team Information Form

Demonstration of Capability Certification Statement

Non-Conformance Form (NCR) Form

Ethics Agreement

Stone Data Integrity Audit Checklist

STONE ENVIRONMENTAL, INC. PROCEDURE SPECIFIC TRAINING LOG

PERSONNEL: _____

Nature of Duties, Training or Instruction	SOP Followed (if applicable)	Date	Location	Instructor (s)	Initials

COPIES OF ALL CERTIFICATES, DIPLOMAS, TRANSCRIPTS OR OTHER DOCUMENTATION SHOULD BE ATTACHED.
ORIGINAL FILED IN THE INDIVIDUAL'S TRAINING RECORD LOCATED IN THE ADMINISTRATION DEPARTMENT.

I:\GLP_NELAC\FORMS\TrainingForms\ProcSpecTrainLog.doc

Stone Environmental, Inc.

Mobile Lab

Project Start Up

Stone Project Number:	_____	
Project ID:	_____	
Client:	_____	Client Representative: _____
Location:	_____	
Stone Project Manager:	_____	
Stone Field Leader:	_____	Stone Analyst: _____
Stone Data Manager:	_____	Additional Staff: _____

Form completed by:	_____	_____
Schedule Summary:	_____	
LIMS Filename:	_____	Date LIMS required by: _____

Lab:

☐ Stone Fixed Facility	☐ Tow vehicle:
☐ Mobile Lab 2	☐ On site power available (220/240V, 50A, Single Phase)?
	☐ Lab Generator - work out weekend refills of diesel
	☐ Other Generator - fill in details

Instruments:

☐ SIM	
☐ Scan	
☐ GC/MS Instrument:	_____
☐ GC/FID Instrument:	_____
☐ GC/ECD Instrument:	_____

Matrix:

☐ Water	Samples per day:	_____
☐ Soil	Samples per day:	_____
☐ Air	Samples per day:	_____
☐ Wipes	Samples per day:	_____

CoC Requirements:

- | |
|--|
| ☐ Mobile Laboratory Sample Login Form (on site) |
| ☐ LIMS Login Summary |
| ☐ Completed by Field Sampling Staff |

QA/QC Requirements:

☐ Field Duplicates	Frequency: _____
Selected by: _____	Naming Convention: _____
Treated as "N" Sample? _____	
☐ Matrix Spike / Duplicates	Frequency: _____
Selected by: _____	Naming Convention: _____
☐ Lab Duplicates required (beyond MS/D pairs)	Frequency: _____
☐ MB and LCS matrix sensitive?	
☐ Project Specific QAPP?	
Summary of specific QAPP details:	

REPORTING REQUIREMENTS - Please Assign below

- ☐ **Level I** - in field answers only
- ☐ **Level II** - Results; Surrogates; Form Is only; Minimal; No narrative or formal report
- ☐ **Level III** - Results; Surrogates; Form 1s for samples and blanks; QC summaries - Form 3 - LCS/LCSD/MS/MSD
- ☐ **Level IV** - Results; Surrogates; Form 1s for samples and blanks; QC summaries - Form 3 - LCS/LCSD/MS/MSD; Raw Data (see Analyst Guide)

Reporting Results Frequency:

- ☐ More than daily Frequency: _____
- ☐ Daily (end of day)
- ☐ Final Only
- ☐ Batching required? # Batches: _____ Frequency: _____

Report Results to:

Preliminary report date: _____
Final report due date: _____

EDD Requirements:

- ☐ Equis Ready
- ☐ ERPIMS
- ☐ Custom (attach example)

Client Contact for EDD: _____
EDD Format Due By: _____

Analytes - Check off to include.						
Parameters	CAS No	SOIL - SIM		Water - SIM		SCAN MDLS are 2.5 X?
		MDL	RL		RL	
☐ Fluorobenzene (IS)	462-06-6					Fluorobenzene (IS)
☐ Bromofluorobenzene (SS)	460-00-4	16.57	48	1.14	2	Bromofluorobenzene (SS)
☐ Chloromethane	74-87-3	55.03	120	2.51	5	Chloromethane
☐ Bromomethane	74-83-9					
☐ Vinyl Chloride	75-01-4	14.20	48	0.36	2	Vinyl Chloride
☐ Chloroethane	75-00-3	27.33	48	1.11	2	Chloroethane
☐ 1,1,2-Trichloro-1,2,2-trif	76-13-1	22.97	48	0.80	2	1,1,2-Trichloro-1,2,2-trif
☐ 1,1-Dichloroethene	75-35-4	15.14	48	0.88	2	1,1-Dichloroethene
☐ Carbon Disulfide	75-15-0	17.28	48	0.67	2	Carbon Disulfide
☐ Methylene Chloride	75-09-2	28.91	48	1.05	2	Methylene Chloride
☐ t-Butyl-methyl ether	1634-04-4	12.86	48	1.27	2	t-Butyl-methyl ether
☐ trans-1,2-Dichloroethene	156-60-5	19.01	48	0.95	2	trans-1,2-Dichloroethene
☐ 1,1-Dichloroethane	75-34-3	12.48	48	0.75	2	1,1-Dichloroethane
☐ cis-1,2-Dichloroethene	156-59-2	12.38	48	0.44	2	cis-1,2-Dichloroethene
☐ Chloroform	67-66-3	15.44	48	0.44	2	Chloroform
☐ 1,1,1-Trichloroethane	71-55-6	12.70	48	0.25	2	1,1,1-Trichloroethane
☐ Cyclohexane	110-82-7	16.22	48	0.27	2	Cyclohexane
☐ Carbon Tetrachloride	56-23-5	14.45	48	0.18	2	Carbon Tetrachloride
☐ Benzene	71-43-2	11.58	48	0.11	2	Benzene
☐ 1,2-Dichloroethane	107-06-2	19.00	48	0.77	2	1,2-Dichloroethane
☐ Trichloroethene	79-01-6	11.73	48	0.42	2	Trichloroethene
☐ Methyl Cyclohexane	108-87-2	19.75	48	0.88	2	Methyl Cyclohexane
☐ 1,2-Dichloropropane	78-87-5	10.24	48	0.27	2	1,2-Dichloropropane
☐ Bromodichloromethane	75-27-4	15.07	48	0.57	2	Bromodichloromethane
☐ cis-1,3-Dichloropropene	10061-01-5	17.14	48	0.36	2	cis-1,3-Dichloropropene
☐ Toluene	108-88-3	11.48	48	0.56	2	Toluene
☐ trans-1,3-Dichloropropene	10061-02-6	16.42	48	0.44	2	trans-1,3-Dichloropropene
☐ 1,1,2-Trichloroethane	79-00-5	20.29	48	0.67	2	1,1,2-Trichloroethane
☐ Tetrachloroethene	127-18-4	16.45	48	1.11	2	Tetrachloroethene
☐ Dibromochloromethane	124-48-1	16.95	48	0.51	2	Dibromochloromethane
☐ 1,2-Dibromoethane	106-93-4	20.45	48	0.75	2	1,2-Dibromoethane
☐ Chlorobenzene	108-90-7	14.09	48	0.76	2	Chlorobenzene
☐ Ethylbenzene	100-41-4	14.92	48	0.93	2	Ethylbenzene
☐ m+p-Xylenes	136777612	32.72	96	1.86	4	m+p-Xylenes
☐ o-Xylene	95-47-6	15.59	48	0.82	2	o-Xylene
☐ Total - Xylene	1330-20-7	15.59	48	0.82	2	Total - Xylene
☐ Styrene	100-42-5	15.39	48	0.78	2	Styrene
☐ Bromoform	75-25-2	17.88	48	0.76	2	Bromoform
☐ Isopropylbenzene	98-82-8	21.70	48	0.73	2	Isopropylbenzene
☐ 1,1,2,2-Tetrachloroethane	79-34-5	16.87	48	1.40	2	1,1,2,2-Tetrachloroethane
☐ 1,3-Dichlorobenzene	541-73-1	23.45	48	0.76	2	1,3-Dichlorobenzene
☐ 1,4-Dichlorobenzene	106-46-7	24.35	48	0.76	2	1,4-Dichlorobenzene
☐ 1,2-Dichlorobenzene	95-50-1	23.63	48	0.49	2	1,2-Dichlorobenzene
☐ 1,2-Dibromo-3-chloropropane	96-12-8	20.43	48	1.16	2	1,2-Dibromo-3-chloropropane
☐ 1,2,4-Trichlorobenzene	120-82-1	33.46	48	0.54	2	1,2,4-Trichlorobenzene
Other Compounds: Please List.						
☐						
☐						
☐						
☐						
☐						
☐						
☐						
☐						
☐						

☐ Reporting "J" values ☐ Extra Standards Needed ☐ MDL's For Extra Compounds	Order by Date: _____ Completed by Date: _____

Comments:

Stone Environmental, Inc. Field Services Quote

Client Name: 0

Project: 0

Project No. 0



Date: 1/0/1900

Scope of Work:

EXAMPLE MOBE/DEMOBE TEXT: Mobilize/demobilize one MIP data acquisition truck with operator from Montpelier, VT to XYZ

GC/MS Scope: Laboratory will conduct soil and groundwater analyses via EPA SW846 Method 8260 (gas chromatography/mass spectrometry (GC/MS)) with solid phase microextraction technique for volatile organic compounds (VOCs); for this program the analyte list is expected to be comprised of tetrachloroethene, trichloroethene, 1,2-dichloroethene (both isomers) and vinyl chloride. Stone is NELAC certified for the methods to be used for this program and can provide our certification documents upon request. Percent solid measurements will also be made subsequent to these analyses and the data will be used to report these results on a dry weight basis. Laboratory productivity rate is approximately 25-30 samples per day for the soil and groundwater programs. Detection limits for the groundwater and soil analyses will be 2 ug/L and 80 ug/Kg, respectively. If the sample productivity rate is above approximately 25, Stone recommends that an additional laboratory staff be added to the program. Pricing for this staff is shown below.

EXAMPLE Level II Lab Reporting: Laboratory deliverables include a Level II data package which includes a project narrative and tabulated analytical results with surrogate recoveries. Preliminary results will be presented as tabulated excel files as they are generated in the field. Final Level II data package will be generated within two weeks of the end of the project. Stone will also provide an EDD in a format to be determined. Stone standard EDD format is an "equis easy" format.

EXAMPLE Level III Lab Reporting: Laboratory deliverables include a Level III data package which includes a project narrative, tabulated analytical results with surrogate recoveries and QA/QC summaries (includes summaries of laboratory control samples, continuing calibration verification samples, blanks and matrix spike/matrix duplicate samples). Preliminary results will be presented as tabulated excel files as they are generated in the field. Final Level III data package will be generated within two weeks of the end of the project. Stone will also provide an EDD in a format to be determined. Stone standard EDD format is an "equis easy" format.

EXAMPLE Level IV Lab Reporting: Laboratory deliverables include a Level IV data package which includes all of the elements of the Level III data package plus all raw data, sufficient for independent, third-party data validation. Preliminary results will be presented as tabulated excel files as they are generated in the field. Final Level IV data package will be generated within two weeks of the end of the project. Stone will also provide an EDD in a format to be determined. Stone standard EDD format is an "equis easy" format.

Subproj	Phase	ITEM	RATE PER UNIT	UNITS	AMOUNT	SUBTOTAL
Onsite GC/MS Laboratory Services						
MLB	1.1	Mobilization/Demobilization	\$0 / day	0	\$0	
	1.2	DOT Down Day	\$591 / day	0	\$0	
	2.1	Onsite GC/MS Laboratory	\$1,770 / day	0	\$0	
	2.2	Overtime (over 10 hrs/day)	\$177 / hour	0	\$0	
	2.3	Weekend Travel	\$986 / weekend	0	\$0	
	2.4	Weekend Per Diem/Car Rental	\$363 / weekend	0	\$0	
	2.5	Level II Data Management/Reporting	\$160 / day	0	\$0	
	2.6	Level III Data Management/Reporting	\$214 / day	0	\$0	
	2.7	Level IV Data Management/Reporting	\$336 / day	0	\$0	
	2.8	EDD Development	\$0 / ls	1	\$0	
	2.9	Standby	\$960 / day	0	\$0	
Subtotal						\$0
Project Total						#DIV/0!

TERMS OF QUOTE

- Refusal will be determined by STONE. If the CLIENT wishes to continue, any broken tooling will be charged to the CLIENT
- "Dig Safe" and other utility clearances will be accomplished by others.
- Work days are 10 hrs from arrival on site to departure from site. Hours over 10 per day will be billed at the rates shown above. Stone policy forbids work days in excess of 12-hours unless authorized by Stone management.
- DOT Mandated down days are presented above; they assume 10 hr work days and factor in travel times specific to the project. If project schedule changes are necessary (i.e. overtime hours or Saturday work), DOT down day requirements may change.
- Access to all drill sites with rubber-tired trucks is unimpeded or will be provided by others. All sites will be workable level. Suitability of access is at the sole discretion of STONE.
- Potable water for use during the project will be made available on site for use by STONE at no charge.
- It is assumed that explorations will take place in natural soils. No drilling through man-made or man-placed materials is anticipated or required.
- Management and disposal of investigation derived waste will be performed by others. This waste includes spent environmental samples. If Stone is of possession of these samples at the end of the project, Stone will discard these samples in 30 and 120 days for groundwater and soil samples, respectively.
- It is understood that the property owner will allow STONE to leave our equipment on site overnight while on this project, in a safe and secure area of their choice.
- Unless otherwise noted in the scope of work delineated above, there are no provisions nor any costs included for the restoration of any property which may be damaged due to the drilling operation; i.e., lawns, shrubs, sidewalks, etc.
- All waste materials, e.g., empty cement or bentonite bags, empty bentonite pails, and other waste products generated will be disposed of on site in a refuse vessel provided by others, or will be neatly consolidated at one area on site at no cost to STONE.
- Acquisition of any permits which may be required are the responsibility of others.
- This Quote is valid for 60 days from the date indicated above.

 **STONE ENVIRONMENTAL INC**

DEMONSTRATION OF CAPABILITY**CERTIFICATION STATEMENT**

Date:

Laboratory Name: **Stone Environmental, Inc. Mobile Laboratory**

Laboratory Address: 535 Stone Cutters Way, Montpelier, VT 05602

Analyst Name:

Matrix:

Method number: _____ SOP #: _____

Analyte, or Class of Analytes or Measured Parameters:

We the undersigned CERTIFY that:

1. The analyst identified above, using the cited test method, which is in use at this facility for the analysis of samples under the National Environmental Laboratory Accreditation Program, has met the Demonstration of Capability.
2. The test method was performed by the analyst identified on this certification.
3. A copy of the test method and the laboratory-specified SOPs are available for all personnel on-site.
4. The data associated with the demonstration capability are true, complete and self-explanatory (1).
5. All raw data (including a copy of this certification form) necessary to reconstruct and validate these analyses have been retained at the facility, and that the associated information is available for review by authorized assessors.

Laboratory Manager

Signature

Date

Quality Assurance Manager

Signature

Date

- (1) True: consistent with Supporting data. Accurate: Based on good laboratory practices consistent with sound scientific Principles/practices. Complete: Includes the results of all supporting performance testing. Self-Explanatory: Data properly labeled and stored so that the results are clear and require no additional explanation.



STONE ENVIRONMENTAL, INC
QUALITY MANAGEMENT

NON-CONFORMANCE REPORT - (NCR) CORRECTIVE ACTIONS

To: _____

NCR Number: _____

Issue Date: _____

Closing Date (by QAM): _____

This Non-Conformance Report refers to the following:

Project Number: _____ Specification: _____

Plan, Feature or Area of Work: _____

Description of Deficient Condition:

(Include additional information, sketches, etc. as necessary)

Signature: _____
Quality Assurance Manager (QAM) or Designee

Date: _____

Recommended Corrective Action:

Recommended by: _____

Date: _____

Actual Corrective Action:

(Note: Preventive Actions taken here, use attached sheet if necessary)

Corrective Action Approved:

Timeframe:

Signature: _____

Signature: _____

Title: _____ Client/Other/USACE

Title: _____ Stone Environmental, Inc.

Reinspection Required: _____ Yes _____ No

Copy to: _____

Performed on: _____ Date: _____

Acceptable: _____ Yes _____ No

File: _____



It is the policy of Stone Environmental, Inc. (Stone) to incorporate the highest standard of quality and confidentiality with all analytical and field programs by adhering to the following practices:

Stone will only offer analytical procedures for which it can consistently demonstrate compliance with high quality, traceable and legally defensible performance standards. Stone Environmental staff is committed to the practice of complete honesty in the production and reporting of data. Staff who may be aware of misrepresentation of facts or data manipulation to bypass established quality assurance (QA) and quality control (QC) requirements, are required to immediately inform their supervisor or any member of management. In addition, any and all information which is not in the public domain that an employee acquires through the course of his or her employment at Stone, whether the information is owned by Stone or a client or potential client, is to be held in strictest confidence and not disclosed orally or in writing to any person other than a Stone employee or the client.

All employees are asked to sign a copy of the statement below upon their first day of employment.

I, _____ (print name) understand that high standards of integrity are required of me with regard to the duties I perform and the data I report in connection with my employment at Stone. I agree that in the performance of my duties at Stone:

I will not intentionally report data values that are not the actual values obtained;

I will not intentionally report dates, times, sample or QC identifications, or method citations of data analyses that are not the actual dates, times sample or QC identifications, or method citations;

I will not intentionally misrepresent another individual's work; and

If a supervisor or a member of Stone management requests me to engage in or perform an activity that I feel is compromising data validity or quality, I will not comply with the request and report this action immediately to a member of the upper management, up to and including the President of Stone Environmental, Inc.

I will not intentionally report data values that do not meet established quality control criteria as set forth in the Method and/or Standard Operation Procedures, or as defined by Stone Policy.

I agree to inform my Supervisor of any accidental reporting of non-authentic data by me in a timely manner. I agree to inform my Supervisor of any accidental or intentional reporting of non-authentic data by other employees. I have read this Ethics Agreement and understand that failure to comply with the conditions as stated above will result in disciplinary action, up to and including termination from the Stone.

Compliance with this agreement of business ethics and conduct is the responsibility of every Stone employee. Disregard or failing to comply with this standard of business ethics and conduct could lead to disciplinary action up to and including possible termination of employment and criminal action.

Signature: _____ Date: _____

Witness by: _____

STONE ENVIRONMENTAL, INC DATA INTEGRITY AUDIT CHECKLIST

Date: _____ **Conducted by:** _____ **Audit #:** _____

Method/Sample ID(s): _____

Personnel/Section Audited: _____

Are all samples accounted for and are sample IDs recorded correctly?

Is the sample sub-sampled without bias?

Is the appropriate QC (duplicates, spikes, LCS, etc.) being analyzed and accurately recorded?

Are blank samples being analyzed and accurately recorded?

Are unusual sample characteristics or method deviations noted?

Is temperature accurately recorded? Are correct temperatures being adhered to?

Are instrument times (clocks) accurate? Are critical dates and times of analysis accurately recorded?

Are records of holding times accurate?

Are duration times correctly recorded and do they meet method requirements?

Are dilutions accurately recorded and correctly calculated?

Are all results recorded in ink onto authorized bench sheets?

Is the correct SOP being followed accurately?

Verify all spiking activities

Verify standard and reagent expiration dates and usage

Verify calibration accuracy and acceptability

Verify a manual integration

Verify a sample calculation

Is the analyst of record correct?

Select one result on a final report and trace back to raw data – record findings:

Record any necessary Corrective Actions and corresponding report numbers (NCR Form):

Are any of the findings due to a personnel integrity issue (were any of the findings more than ‘mistakes’)?
If so, detail further actions (e.g. notification of laboratory management, further investigations, final resolution, etc.)

Appendix D

FLUTe Liner Installation and Groundwater Sampling SOPs

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FLUTe Blank Liner Installation and Removal Procedure

**(Note: A DVD is available teaching the installation procedure.
Call 1-888-333-2433 and request a copy)**

Rev. July, 2005

Blank liner installation and removal procedure

(note the starred items may not apply to the simple installation)

The blank liner installation is quite simple when performed in the following sequence:

1. Form the split hose over the top of the casing to protect the liner. Trim the hose to the proper length to cover the entire top edge of the casing. Tape the lower edge of the hose to the casing to hold it in place.
2. Set up the shipping reel on the reel stands with the large axle flange on the side marked “vent” inside the edge of the reel flange*. Make sure the arrow on the protective liner cover points over the top of the reel toward the wellhead. The reel should be about 10 ft from the wellhead.
4. Remove the protective wrapper on the liner. Don’t use a sharp knife. Unwrap it.
5. Tag the water level.
6. Assure that the depth of the hole is known and that the hole has not caved, bridged, or otherwise become blocked.
7. Set up the wellhead roller next to the wellhead, well supported (see the attached drawings). Leave room to attach the liner to the casing. Then reposition the roller as shown.
8. Install the air vent tube to the water table in the borehole and make sure that the air vent tube is well tied off with a pipe hitch to prevent its falling down the hole. The air vent tube should be opened with a small scallop of the tube about every 20 ft. to allow easy air flow into the tube. The top of the vent tube should be open to allow the air to flow out of the tube. The tube is usually supplied with the liner. **
9. Cut off the liner about 5 inches above the “GS” mark on the liner (be careful to not cut off the ¼” bubbler tube). Invert about 5 ft of the blank liner as it comes off the shipping reel. (The GS mark will be at the top of the casing.) Slit the liner and the sleeve next to the bubbler tube for about 6 inches.
10. Fold the everted portion of liner lengthwise and slide it down the casing until 5 inches of the top edge is sticking above the casing. Fold the liner over the casing, tape it in place, and clamp the liner to the casing securely. The vent tube must pass through the slit on the liner with the bubbler tube**. The liner is now ready to be installed. The liner is only routed over the large roller for installation, and not under the smaller roller.
11. ***Connect the bubbler tube to the upper right quick connect of the Tagler (bubbler monitor). It is necessary to attach the quick connect fitting to the nut and ferrule on the tube before inserting it into the quick connect on some Taglers. Insert a pressure gauge with a pressure range of about half the depth to the water table in psi (e.g., 30 psi for a 60 ft water table. However, there is no need for a pressure gauge greater than about 30 psi, unless the bubbler is open to the liner far below the water table in the formation.) The bubbler pressure minus $0.433 \times (\text{bubbler depth} - \text{water table depth})$ is the excess pressure inside the liner. That should not exceed about 10 psi. The bubbler depth should be equal to or greater than the water table in the formation. The pressure source from the nitrogen bottle (set at about 50 psi) is plugged into the bottom quick connect on the Tagler. The needle valve is set for a flow of about 2 SCFH. Make sure that that flow rate is maintained. (in shallow water table situations, there is usually no need for a bubbler).
12. Add water to the interior of the liner until there is about 5-10 lb of tension on the liner. Then, lower the liner slowly down the hole so as to allow the air to vent from beneath the

liner**. When the liner reaches the water table, the tension will drop to zero as the water slug in the liner descends beneath the water table. If the depth marks on the liner do not correspond to the water table depth, it may be necessary to add more water to cause the liner to descend to the water table. It should not be necessary to fill the liner with more than 10 ft of water to cause it to reach the water table (about 10 gallons for a 5 in. diameter liner). – more water in an angled hole.

13. Once the liner has reached the water table, add water to the interior of the liner, driving the liner down the hole. Note, the bubbler reading will not be correct until the liner has descended to the depth of the bubbler on the liner. (The bubbler pressure on the gauge is the sum of the water height in the liner above the water table in the formation, plus the depth of the bubbler below the water table in the formation. A bubbler is not needed for modest water table depths of about 30 ft.)

14. When the end of the liner comes off the reel, stop the liner. Allow the air trapped in the end of the liner to vent through the check valve on the tether. The liner may need to be squeezed by hand to vent the air. Once the air has been vented from the liner, allow the liner to then continue down the hole. (**Note**, the drawing shows a vacuum pump as used by FLUTe. The pump is not needed for the ordinary installation.)

15. Maintain a modest tension on the liner and then on the tether (about 3-4 lb.) as the liner descends. The tension should be sufficient to prevent the liner from sliding down the hole of its own weight and to be able to easily detect the progress of the eversion as the liner descends.

16. Monitor the bubbler pressure and be careful to not exceed the pressure of 10 psi as calculated in no. 11 above. If one is not adding water, the bubbler pressure will drop as the liner descends. That is a good check that the liner is descending correctly.

17. Let the blank liner descend until its descent velocity has dropped to about 0.1 ft per minute. At that velocity, there is not much remaining transmissivity below the liner. The tether (or the liner wrapped with a kellum strap) should be tied to an anchor that will prevent its further descent. Allowing the liner to descend further will prolong the removal.

Removal of the liner

The removal procedure starts with the wellhead roller situated as shown in the attached drawings. This is the same as the installation geometry, except the tether/liner is routed under the small roller on the back side of the wellhead roller (opposite the well). This routing under the small roller will prevent the roller from tipping over when tension is applied to the tether. The axle of the small roller is removable to allow easier routing of the tether under the small roller.

The wellhead roller must also be anchored to the casing or other secure anchor to prevent the roller from being dragged by the lateral force of the tether as the liner is pulled from the hole.

The procedure is as follows (see the drawings attached):

1. Set up the wellhead roller as shown. Anchor the frame of the roller low to prevent its being dragged away from the wellhead by the tension on the small roller.

2. Set up the winch plate about 50 ft away from the wellhead. Lay out a protective sheet of heavy plastic film between the wellhead roller and the winch to prevent abrasion or thorn/stubble damage to the liner as it is pulled out of the hole.
3. Anchor the winch plate using the cable and the aluminum plate provided. A vehicle can be parked with a tire on the aluminum plate to serve as a good anchor. Make sure that the tire will not be rotated with a 1000 lb force on the cable. A side pull on the tire is more secure for a front wheel.
4. Route the tether as shown and wrap the tether about 4 wraps, clockwise on the capstan of the winch. Then insert the handle and apply a tension to the tether. The tail of the tether, where it comes off the winch, must have some tension on it to prevent slipping on the capstan of the winch. It is usually easier if someone “tails” the tether while someone else cranks the winch. The winch has two directions of travel. The easier direction to turn is geared about 1.6 above the direct gearing of the harder direction. Don’t crank too hard on the winch (i.e., the limit of your ability). Just develop a good tension in the tether, which stretches the liner. Then wait as the liner contracts and pulls itself out of the hole. Retighten the tether as needed to remove the liner. As the liner rises in the hole, it will proceed more rapidly as more flow paths are uncovered.
5. In order to pull a blank liner from a hole with a deep water table (>10-15 ft), it is necessary to pump the water out of the liner as the liner rises.
6. **Lower a Grundfos II, or similar pump, to a point no lower than 10-15 ft above the water level in the formation. It is essential that the pump can not pump the water level in the liner lower than that value.** If the liner is over pumped, it may buckle instead of inverting, and become jammed in the hole. That is very awkward and difficult to fix. Turn the pump on while a good tension is applied to the tether, and let the pump run until it stops flowing (i.e., the water level in the liner has dropped to the pump).
7. Increase the tension on the tether. As the liner inverts, the water level in the liner will rise and the pumping can continue. By setting the pump speed to the approximate rate to match the water level rise in the hole as the liner inverts, the pump can run nearly continuously. Wrap the tether neatly onto the shipping reel as the tether comes off the winch. The shipping reel should be positioned between the winch and wellhead, nearer the winch, to later accept the liner as it is pulled out of the hole.
8. **When the liner is at the water table, the pump should be stopped and removed.** This will leave a sufficient amount of water in the liner to allow it to be inverted to the surface. If the pump is not stopped when the liner reaches the water table, there may be insufficient water left in the liner to cause it to invert nicely, and it may again jam in the hole.
9. When the liner follows the tether out of the hole, and over the roller, the liner can be pulled until it reaches the winch and no further. The liner will not go onto the winch. At that time, the Nylon straps provided should be wrapped in the diagonal fashion demonstrated, next to the wellhead roller, so that they operate as a Chinese finger trap or kelling and grip the liner without damaging the coating on the liner. The straps should alternate over and under each other so that they are woven onto the liner. If the straps look like one strap was wrapped on first and the second strap was then wrapped over it for its entire length, it was not properly woven onto the liner.
10. A carabiner is then clipped into the near end of the kelling and connected to a long rope provided to extend to the winch. The tether is then unwrapped from the capstan, and the rope connected to the kelling is wrapped onto the capstan. If the liner has a great deal of tension,

it may be necessary to wrap a kelling onto the liner near the winch, and tie that kelling off to an anchor (the cleat on the winch plate), so that the tether tension can be relaxed without the liner descending back down the hole. Then the rope from the wellhead kelling is wrapped onto the winch capstan.

11. As the wellhead kelling is drawn toward the winch, the slack liner is rolled onto the shipping reel as shown. (In fact, the tether should also be wrapped first on the shipping reel as the tether is withdrawn with the winch.) When the kelling nears the winch, a second short rope is tied into the carabiner to anchor the near kelling while the next kelling is attached to the liner near the wellhead. As the tether is unwrapped from the winch, the anchor rope takes up the liner load until the long rope is again wrapped on the winch. (note, only one rope and carabiner is required, since each time that the anchor rope is allowed to take the load, the rope and carabiner can be connected to the kelling at the wellhead.) In this manner, the liner is pulled length after length from the hole. It is obvious that the further the winch is from the wellhead, the less often a kelling must be reattached to the liner.

12. When the liner rises out of the water table in the hole, it can usually be pulled by hand from the borehole by one or more people, saving the time of reattaching kellings. Be sure that the pump is stopped and removed before pulling the liner from the water table. The liner should always be rolled onto the shipping reel as it is pulled from the borehole to prevent damage to the liner and its coating.

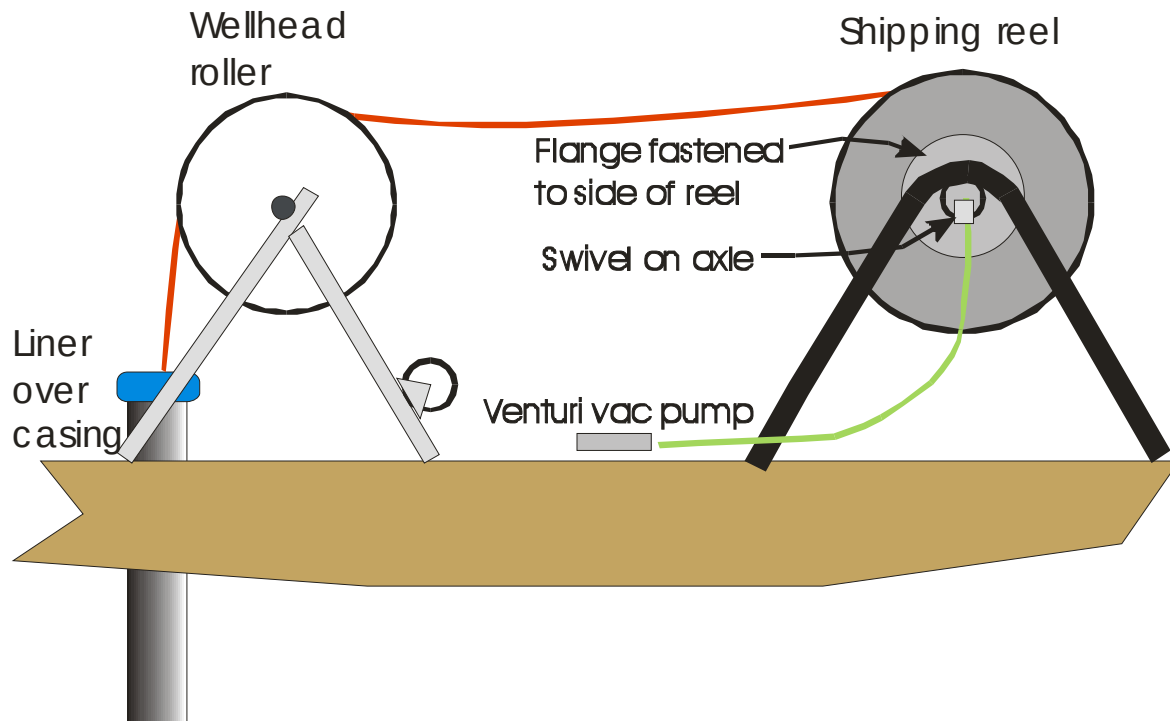
Questions? Call FLUTE at 888-333-2433 or 505-883-4032.

* This detail is only relevant to a reel stand with a vacuum axle. It is not typically used.

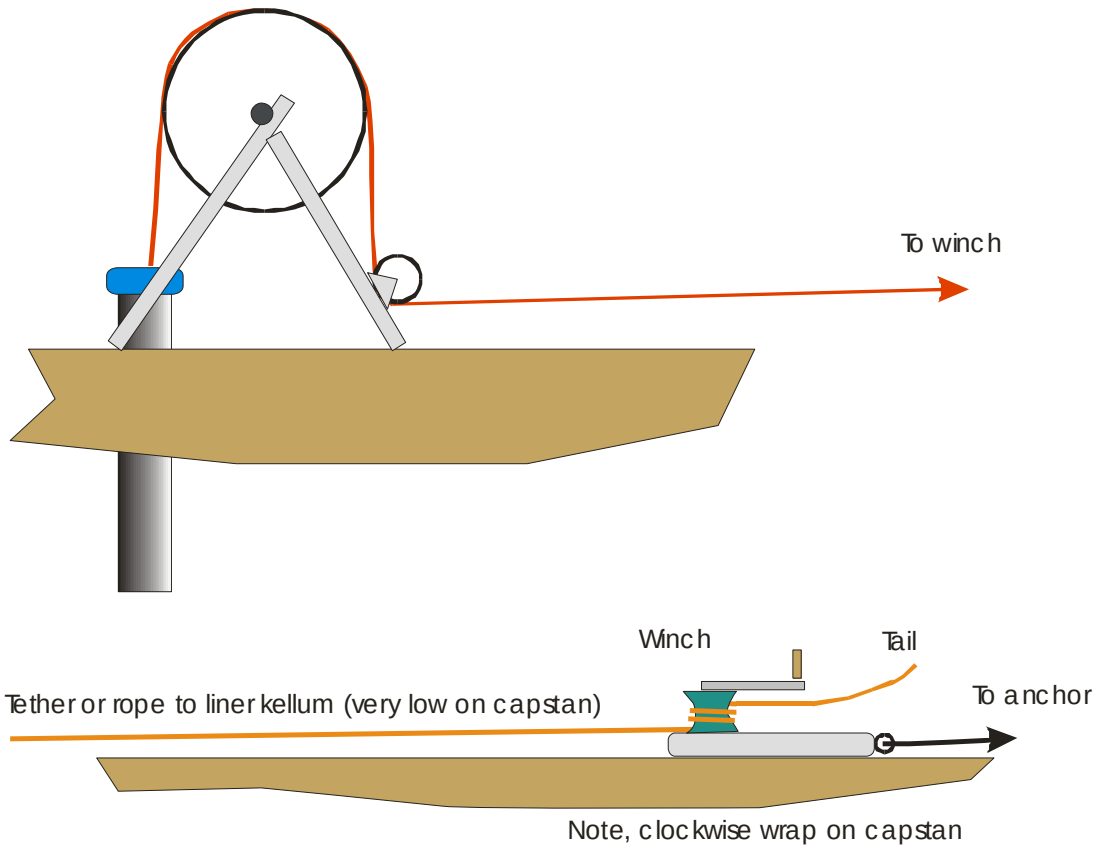
** The air vent tube is needed if the casing extends to the water table and there is no flow path in the vadose zone to vent the air trapped beneath the liner.

*** The bubbler tube is a useful monitoring method for the water level in the liner, but much less useful for installations into holes primarily above the water table.

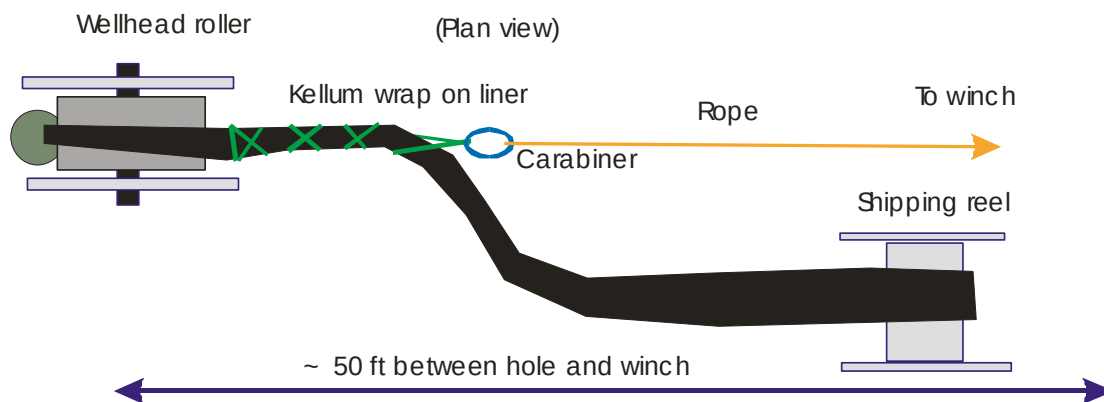
Installation geometry



Blank liner removal geometry



Winching geometry for the liner



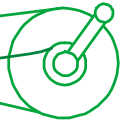
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Brief Description of Installation Procedure for Water FLUTes

Installation procedure for Water FLUTes

Purpose

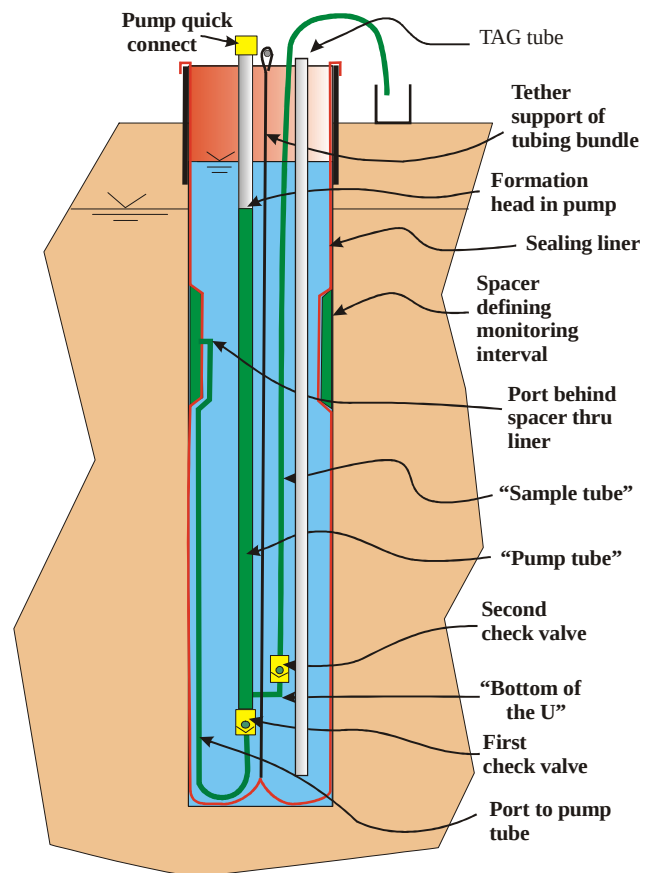
This is intended as a brief general description of the procedure and the equipment used for the Water FLUTE installation method.

The Water FLUTE system

The Water FLUTE system is a multi level ground water sampling system as is described in detail in Cherry, et al¹. The system consists of a flexible borehole liner composed of a urethane coated nylon fabric with attachments for the purpose of drawing water from the formation and for measurement of the depth of the water table at each sampling interval. Figure 1 depicts the liner as fully installed in a borehole with only one sampling interval shown for clarity. The external annular spacer defines an interval of the borehole that is not sealed by the liner. The ground water sample is drawn from that interval and conducted to the pump system shown in the center of the borehole. The long pump tubing allows a relatively large (~1 gal.) sample to be displaced to the surface by nitrogen gas pressure. The pumping procedure allows a thorough purge of the pumping system and a water sample can then be obtained with essentially no risk of aeration of the sample. The water level at the port is measured with a manual electric tag liner lowered into the pump tube. Pressure transducers are often incorporated into the system to allow a continuous recording of the head variations in the formation.

Fig. 1. Water FLUTE pump system

(Single port system shown for clarity)



The installation procedure

The Water FLUTE system is everted into the borehole as is normally done for many flexible liner systems. Figure 2 shows the main components of the installation procedure (the pumping system is omitted from the drawing). The liner is positioned on a shipping reel near the wellhead. The liner is inside-out relative to its final state in the borehole.

¹ *A New Depth-Discrete Multilevel Monitoring Approach for Fractured Rock*, Ground Water Monitoring & Remediation 27, no. 2/ Spring 2007/pages 57–70.

An air vent tube is first located in the borehole to allow the air above the water table to escape as the liner is installed. A second tube called a pump tube is lowered to the bottom of the hole to allow the water to escape beneath the liner as the liner is everted into the hole (eversion is the opposite procedure to inversion). The top end of the liner is fastened to the surface casing with a large hose clamp. Then the liner is pushed into the casing by hand for a depth of ~3 ft to form an annular pocket. Water is added to the annular pocket which pressurizes the liner and drives it down the hole, pulling itself off the shipping reel. The liner passes through itself and is said to be everting down the borehole. The water level inside the liner is well above the water level in the formation so that the liner interior pressure is higher than the formation pressure, causing a seal of the borehole. As the liner descends, it pushes the borehole water into the formation. If the formation is of low transmissivity, the water must be pumped from beneath the liner via the pump tube. When the liner reaches the bottom of the hole, the tether supporting the pump tubing is tied to a strong bar at the wellhead to prevent any further descent of the tubing bundle.

Fig. 2. Typical Water FLUTe Liner Installation

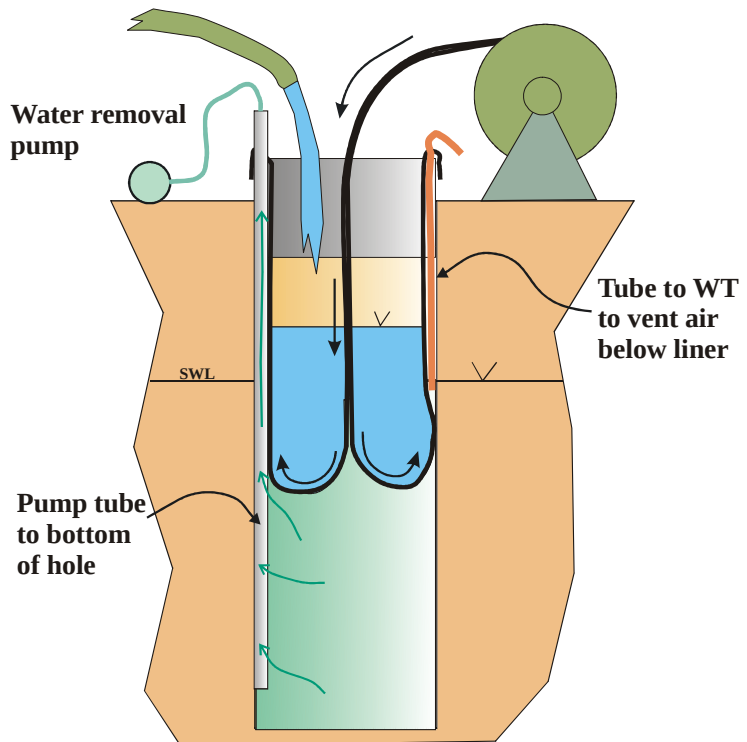


Figure 1 shows the liner fully everted and sealing the borehole. The individual pumping systems are tested to assure that they are fully functional before the pump tube is removed. In order to remove the pump tube, a pump is lowered inside the liner and the water is removed from the liner until the liner begins to collapse. (Sometimes a large tube built into the tubing bundle, called a tag tube, is used as an air lift pump to remove the water from the interior of the liner.) The pump tube is then pulled out of the hole and the liner is refilled to a level about 10 ft above the water table in the formation so as to pressurize the liner and seal the borehole. The sealing liner isolates each sampling interval in the hole to allow a discrete water sample to be drawn from that interval defined by the length of the annular spacer on the exterior of the liner.

The quick connect fittings are added to the top of the pump tubing for connection of the gas source. A nitrogen bottle is used to expel the water from the pumping system as shown in Figure 3.

Special circumstances

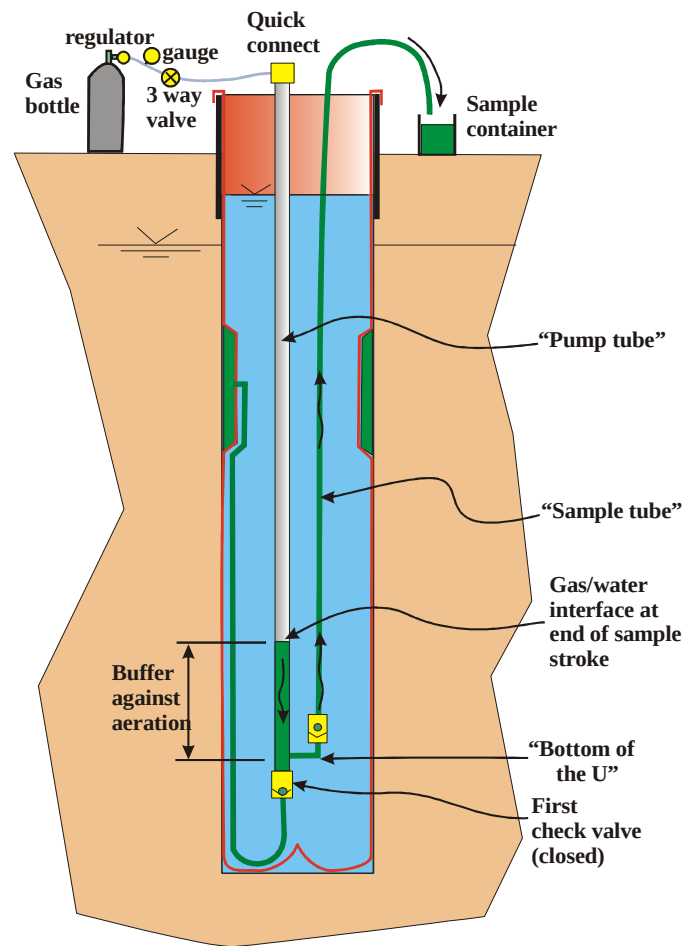
If the water table is very near the surface, a temporary extension of the casing is added to develop a higher driving pressure for the installation of the liner. When the liner is fully

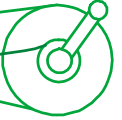
installed, a weighted mud is used as a filling of the liner from the bottom to the top to better pressurize the liner. The mud still allows the liner to be removed by the reverse of the installation process.

In karst formations, a device called an eversion aid can be used inside the bottom end of the liner to cause it to propagate more nearly vertically than a liner driven with water alone. This allows the liner to propagate through large caverns intersected by the borehole.

Water FLUTe liners can be installed equally easily in angled holes or even horizontal holes using the same eversion procedure.

Fig. 3. Pumping Procedure





FLUTe hydraulic conductivity profiling procedure

Purpose:

The FLUTe hydraulic conductivity profiling procedure, called Profiling for short, is a method invented by FLUTe for obtaining the transmissivity distribution in a borehole while installing a blank sealing liner made of urethane coated nylon. The technique measures the liner installation rate very carefully and from that measurement produces a transmissivity distribution.

The method:

The blank liner installation drives the water from the borehole through all the transmissive features in the borehole. As the liner descends, by the eversion process, it seals the transmissive zones sequentially from the top to the bottom of the hole. When a transmissive zone is sealed, the remaining transmissivity beneath the liner is reduced and that results in an immediate drop in the liner velocity. The velocity change multiplied by the cross section of the hole is the flow rate into that transmissive feature. In that manner, the entire transmissivity of the borehole is mapped in a period of 1-2 hours.

The procedure consists of the careful measurement every half second of the driving pressure in the liner (the excess head above the formation water table), the liner velocity, the tension on the liner at the surface, the pressure in the borehole beneath the liner, and the time of each recording. The procedure requires that the liner tension and the driving pressure in the liner be maintained relatively constant. A recording transducer is positioned at the bottom of the hole to measure the pressure beneath the descending liner.

The procedure

The blank liner is positioned at the wellhead. The profiling machine is set up over the top of the wellhead and the liner is passed through the machine and attached with a clamp to the top of the casing. The liner is pushed into the casing to form an annular space which is then filled with water. For a very shallow water table, a weighted mud may be added to the liner. The profiling machine controls the tension, measures the tension, and measures the velocity and position of the liner. A bubbler is built into the liner to monitor the level of the water inside of the liner (the driving pressure).

The recording system is connected to the profiling machine. The data is recorded into a laptop computer as the liner descends. The liner descent is driven by the addition of water to the inside of the liner from a nearby water storage tank. The water flow rate is controlled by a valve to maintain a constant water level inside of the liner. As the liner is pulled through the machine by the water pressure in the liner, the operator assures that the

data is being well recorded and that the water addition is appropriate. A vacuum line is connect to the interior of the liner on the shipping reel via a hollow axle inside the reel in order to remove any air trapped inside the liner that would otherwise become trapped in the end of the liner and interfere with its free descent.

As the end of the liner passes into the borehole (this occurs when the liner has traveled half the liner length), the liner is followed by a tether attached to the end of liner. This tether in passing though the profiling machine continues the velocity recording process.

When the liner has sealed most of the flow paths in the borehole, the liner velocity slows to a very low rate. When the rate drops to less than 0.001 ft/second, the installation is halted because the hole has been effectively sealed and there is little value in continuing the slow rate of measurement. From the final velocity the conduct/transmissivity of the remainder of the borehole can be calculated.

The liner tether is secured to an anchor at the wellhead to prevent further descent of the liner, and to maintain an excess head in the liner to provide a good seal of the borehole. The removal time for the liner is very similar to the installation time.

The data reduction

The data recorded are entered into a data reduction program which allows various tests of the data validity and then the data are used to calculate the transmissivity distribution in the borehole. The velocity and transmissivity data are plotted versus hole depth and are also provided to the customer in digital form to allow his assessment and use of the transmissivity distribution in the formation intersected by the borehole.

Further information

Numerous technical papers have been published on this procedure and its comparison with the more traditional transmissivity measurements such as straddle packers. Those papers are available from FLUTe at info@flut.com. The main advantage of the method is the low cost of the data beyond the cost of installing a sealing liner, the short amount of time required to perform the measurement, and the high spatial resolution of the transmissivity distribution. When the measurement is completed, the borehole is sealed by the liner.

Questions on this procedure should be addressed to Carl Keller at carl@flut.com.

Sampling guidelines for *Water FLUTe* systems installed after May, 2009

Rev. April, 2010

Water level in the liner.

The liner water level should be ~10 ft above the highest formation water level to provide a good seal of the liner in the hole (5 ft minimum excess head). The formation water level can be measured via the “pump tube” for each port. The water level inside the liner should be tagged in the ½ x 5/8” tube labeled “TAG” adjacent to the sampling tubes. If the water level inside the liner is measured in the liner, outside the Tag Tube, lower the weighted tag line very slowly to avoid damage to the liner. Water can be added to the liner by simply pouring water into the liner or through the TAG tube, whichever is easier. Do not fill the liner more than 10 ft above the highest formation water level. The water level in the liner should be checked prior to each sampling episode. (Beware that filling the liner with de-ionized water can give a false water level reading.) It is not recommended to manually tag water levels more than 200 ft below the surface. The wet film adhesion may prevent the removal of the tag line. A special Teflon coated tag line can be used to extend that limit.

Water flow

The water flow into the pumping system is shown in Fig. 1. Water flows from the formation through the spacer pore space, through the port tube, through the first check valve, and fills the “pump tube”. The “sample tube” is also filled at the same time. The water level rises in the pump tube to the water table for that port.

Setting up the gas pressure source

The water is pumped with gas pressure. The FLUTe pump design is such that there is very low risk of aeration of the sample. The gas source is usually a nitrogen bottle with a regulator for setting the prescribed driving pressure. The arrangement of the FLUTe gas drive system is shown in Fig. 2. The regulator is set to the proper gas pressure defined later by closing the three way valve to prevent gas flow out of the quick connect fitting. The

pressure gauge on the FLUTe pump driver is much more sensitive than the regulator for setting the regulator pressure. The FLUTe pump driver must be securely connected to the regulator at the normal ¼" NPT connection on the regulator outlet.

The regulator is first attached to the top fitting on the gas bottle (a special nitrogen regulator fitting connects to a nitrogen bottle). Tighten the nut securely. Turn the pressure regulator handle counter-clockwise until it moves freely (the no pressure position). Rotate the main valve on the regulator (nearer the bottle) clockwise to fully closed. Open the valve on the bottle (counter clockwise). The main bottle pressure gauge on the regulator will rise to the bottle pressure. Close the regulator valve (clockwise) until the pressure starts to rise on the pressure gauge on the FLUTe pump driver (three way valve closed with no flow out of the quick connect). Adjust the regulator to the desired pressure for purging, provided by FLUTe. Connect the quick connect to the top fitting of the pump tube (see Fig. 2). Open the three way valve to drive the water out of the pump.

Purging

Water is pumped from the tubing by applying the gas pressure to the interface at the static water level in the pump tube (Fig. 1 and 2). The water is driven down in the pump tube and up through the second check valve to the surface via the sample tube. By driving the water with a sufficient gas pressure (the "recommended purge pressure") to drive all of the water in the pump tube and the sample tube to the surface, the water in the pump tubing is nearly all expelled. The purge stroke (~1 gal. of water) is complete when gas is expelled from the sample tube following the water flow. The pressure in the system must then be vented (i.e., dropped to atmospheric by turning the three way valve to the vent position), to allow the pump tube to refill by flow via the port tube. The recharge flow from the port tube consists of the port tube water, the water in the pore space of the spacer, and water from the medium. Because of the relatively large volume in the pump tube, most of the recharge is from the medium. The recharge will take about as long as the first purge stroke. However, a low conductivity medium will require more time.

Purging the pump tube a second time will remove any of the water that has resided in the spacer and port tube volume. That is highly recommended, since the water resident in the tubing and spacer is probably not typical of the formation water. If the refill has been prompt, the second purge water

volume will be similar to the first stroke. Two more purge strokes, for a total of four purge strokes, are recommended to remove water that may have been in long contact with the liner or spacer. (Note, systems manufactured before May, 2009 use larger pumps and were only stroked twice. The purge volume is slightly larger for this new procedure and takes about the same time as the two stroke system. This new system stresses the liner less at the spacer and has numerous other advantages.)

Sampling

The sampling flow is best driven on the fifth cycle using a “recommended sampling pressure” which is less than that needed to drive gas through the bottom of the pump tube. The pressure recommended is that which will drive the water to near, but not out of, the bottom of the large tube. That recommended pressure, “the sampling pressure,” is calculated in the spreadsheet provided with each system. The pressure regulator is set to the sample pressure, which is lower than the purge pressure. Opening the three way valve will now apply the sample pressure to the system causing flow from the sample tube.

The first flow of the sampling cycle sweeps along droplets of water left in the tubing from the purge cycle. That residual water is depleted of volatile components. Tests have shown that the first tube volume of the sample flow should be discarded as depleted in volatiles (the “discard volume” is also calculated in the spreadsheet). Thereafter, the samples can be collected from the sample tube outflow. The volume to be discarded is shown in the spreadsheet as “discard volume”. The sample tube water flow rate will start fast, then slow, and finally stop. That occurs as the water column being driven approaches the applied pressure/head. The typical sampling pressure drives to within 25 ft. of the bottom of the pump tube (the U). The large buffer zone remaining in the pump tube assures against aeration of the sample.

This procedure should provide an ample sample (~3 liters) of good quality drawn directly from the formation. If a larger sample volume is needed, simply drop the pressure (i.e., vent the three way valve again), let the pump refill and apply the pressure again. No discard is needed for subsequent sampling flows.

Caution: If the pumping system refills very slowly, there may not be sufficient water in the pump to fill the “sample tube” to the surface when the stroke is performed. In that case, there will be spitting of gas from the sample water and it will be followed by a flow of gas only. The sample water should never show “spitting” and the sample stroke should never end with gas flow from the sample tube. The proper sample flow will slow until it stops flowing. Should this evidence of insufficient recharge be observed, allow the pump to refill for a longer time and repeat the sample stroke. One can tag the water level in the large tube, as described in the head measurement procedure, to assure that the pumping system has been sufficient refilled.

Measuring the head in the system

The water level at each port can be manually measured by removing the plug from the top of the pump tube and lowering a slender (~1/4”) electric water level meter until it contacts the water level in the pump tube. It is not recommended to manually tag water levels more than 200 ft below the surface. The wet film adhesion may prevent the removal of the tag line. A special Teflon coated tag line can be used to extend that limit.

The water level in the large tubes may not be the current water level. After sampling, if there is any leakage of the second check valve (sand in the tube, etc...) the water in the sample tube can backflow into the larger tube, adding to the water that fills the large tube during the recharge. Also, if the water level in the formation is dropping between head measurements, the water level in the pump tube will not follow the descent if the first check valve is a good seal. For these two reasons, and for the freezing concern below, it is best to finish the sampling stroke by raising the pressure to the “purge pressure” value to purge the pumping system of all water. Then upon refilling, the level is the current head for each port. If head measurements are made between sampling events, each port’s pumping system should be first be purged one stroke to allow the tubing to refill to the current head value. Always replace the plugs in the top of the pump tubes when finished sampling.

If the water might freeze in the sampling tubing near the surface, purge the entire volume of water from each sampling line, after sampling, before leaving it. Use the recommended purge pressure to remove all water, not the sampling pressure. **Each line should be blowing gas when the purge is**

complete. If the tubes were purged after sampling prior to head measurements, that is sufficient.

Since the Water FLUTe uses PVDF tubing, the purge of the entire system after sampling should not be neglected, even if head measurements are not to be made. This removes the water column in the sampling tube. For deep water tables, the long term pressure of the standing water in the sampling tube might lead to excessive creep of the tubing which is susceptible to “cold flow”, a characteristic of Teflon like materials. (This is not a concern except for very deep water tables (>300 ft).

In most cases, the performance of a final purge of the system after sampling is useful, even if not essential.

Simultaneous purge and sampling of all tubes

The FLUTe pumping system for each port is essentially identical in length, pump volume and elevation in the hole. This allows all ports to be purged and sampled simultaneously for a great saving in sampling time. The only difference for simultaneous sampling is that the pressure source must include a tube to each port fitting at the wellhead. FLUTe offers a manifold pump driver system at extra cost (the single port driver is provided with the Water FLUTe). The recommended purge and sample pressures are the same as used for single port sampling.

In some cases, the buoyancy of the sampling system is so great when emptied of water during the simultaneous purge that the tubing bundle can cause the liner to invert. The sampling volume spreadsheet provided with the liner notes whether the system can be purged simultaneously. This is only a problem for smaller hole diameters, many ports, and a small excess head in the liner. The new pump design allows simultaneous sampling in most situations.

A short summary is provided as the following checklist:

Check List

1. Check/restore the water level in the liner.
2. Connect the gas driver source to the gas drive (pump) tube for the port.

3. Set the regulator to the recommended purge pressure.
4. Turn the three way valve and expel the tube water at the suggested purge pressure. Collect the purged water volume for verification of a good purge. Note the water flow time of the purge stroke (~4 min.).
5. Allow the tubing to refill. Repeat the purge. Collect the purge volume to assure the amount removed is at least the “port tube volume”. Was the refill long enough?
6. Purge a total of four times, more if desired.
7. Allow the tubing to refill for the sample stroke.
8. Reduce the driving pressure to the “sampling pressure”. Apply the pressure and collect the first flow to measure the discard volume. Discard that water. Collect the samples.
9. Perform a final purge of the water out of the sampling lines by raising the driving pressure to the purge pressure value.
10. When the sampling system has refilled, tag the water level, if desired, for the current water table. If a port system is refilling very slowly, tag it at a later time.

See the spreadsheet provided with each *Water FLUTe* for the recommended purge and sampling pressures. Those are the pressures that can also be used for a simultaneous purge of the several ports. The spreadsheet flags the condition where all ports should not be purged simultaneously. In most cases, several, to all, of the ports can be purged simultaneously.

Optimum sampling procedure:

Since it is often desirable to minimize the amount of time that the sample water resides in the pumping tubing, it is useful to note the actual time that is required for the recharge of the system. Since the fill rate slows dramatically for the last portion of the recharge, it is not necessary to wait for a complete refill. For most formations, the recharge is dominated by the tubing pressure drop. In that case, the time required for the purge stroke to be completed is about the same time required for the refill. (The exception is for a tight formation that recharges the tubing very slowly.) Hence the second purge can be started after waiting the same length of time as the first purge endured. If the second purge is of a similar volume (usually somewhat less) than the first purge volume, the refill time was long enough. After the same delay, the sampling stroke can be initiated. This timing of the strokes allows one to reduce the retention time in the pumping system. For the very large sample volumes produced, the refill time can be shortened

even more, as long as the sample volume is adequate after the discard of the first flow.

In some situations, the retention time is still too long. FLUTe can often increase the sample tube and port tube diameters for greater flow rates. However, the standard design is well matched for to a wide range of hole diameters, depths, and water table elevations. For very deep wells, the tubing may need to be of higher pressure capacity for the required driving pressures. For water table depths below 700 ft., this may be a concern. FLUTe initiated a design change from Nylon 11 to PVDF tubing in the Water FLUTe systems in 2002 to avoid any concern about tubing interaction with the sample water. However, the prescribed purge is sufficient for the use of Nylon tubing systems.

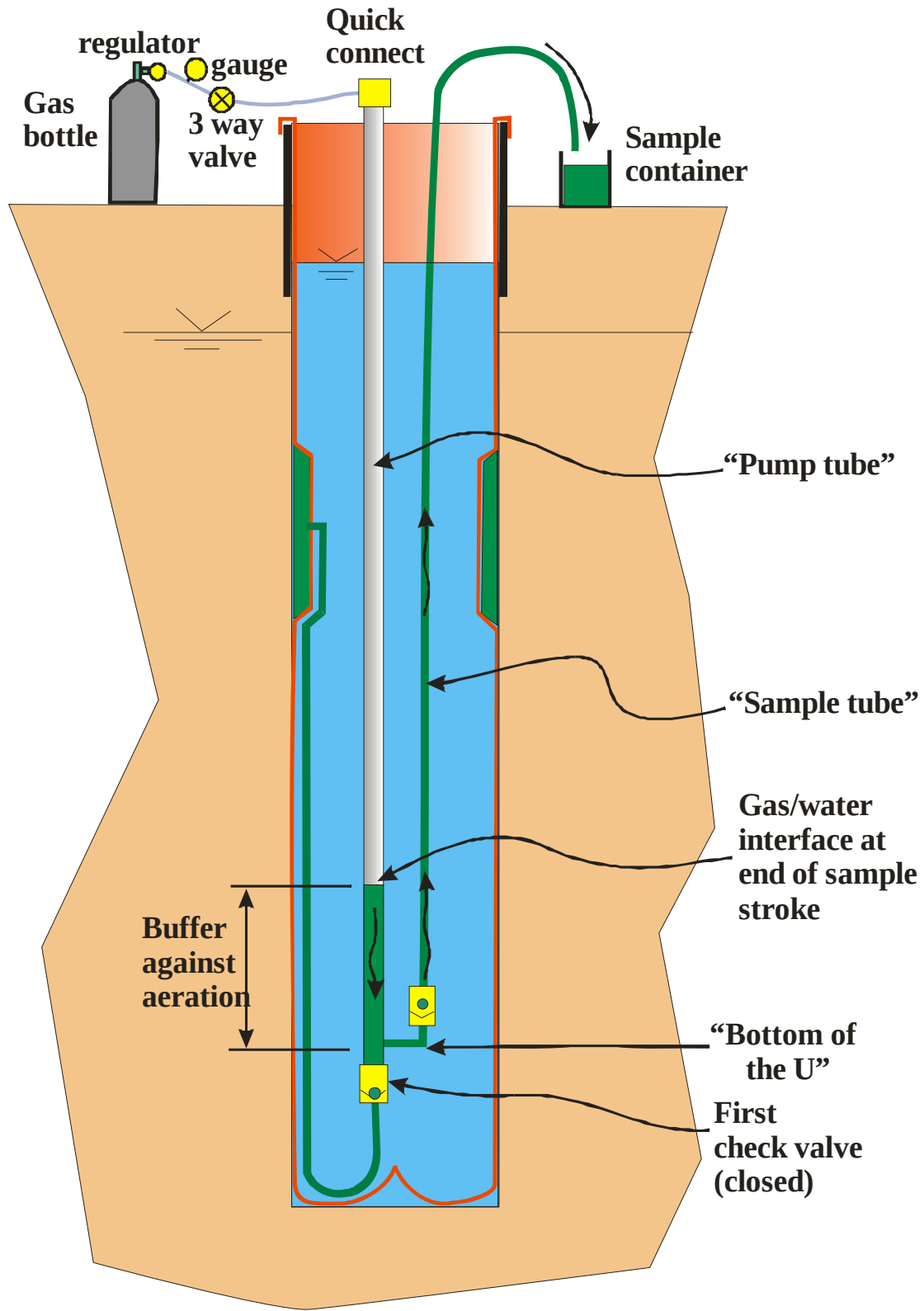
For special situations such as a very large difference (>50 ft) between the water tables at the ports or large fluctuations in the water table, the pumping system may be extended to greater depths. However, the sampling procedure above is sufficient for that situation also.

Questions: Call 888-333-2433 and ask for Carl Keller, or a field engineer.

(Single port system shown for clarity)



Fig. 2. Pumping Procedure



Sampling guidelines for *Water FLUTe* systems installed prior to May, 2009

Rev. April, 2010

Water level in the liner.

The liner water level should be 10 ft above the highest formation water level to provide a good seal of the liner in the hole (5 ft minimum excess head). The formation water level can be measured via the “pump tube” for each port. The water level inside the liner should be tagged in the ½” id tube labeled “TAG” adjacent to the sampling tubes. If the water level inside the liner is measured in the liner, outside the Tag Tube, lower the weighted tag line very slowly to avoid damage to the liner. Water can be added to the liner by simply pouring water into the liner or through the TAG tube, whichever is easier. Do not fill the liner more than 10 ft above the highest formation water level. The water level in the liner should be checked prior to each sampling episode. (Beware that filling the liner with de-ionized water can give a false water level reading.)

Water flow

The water flow into the pumping system is shown in Fig. 1. Water flows from the formation through the spacer pore space, through the port tube, through the first check valve, and fills the “pump tube”. The “sample tube” is also filled at the same time. The water level rises in the pump tube to the water table for that port.

Setting up the gas pressure source

The water is pumped with gas pressure. The FLUTe pump design is such that there is very low risk of aeration of the sample. The gas source is usually a nitrogen bottle with a regulator for setting the prescribed driving pressure. The arrangement of the FLUTe gas drive system is shown in Fig. 2. The regulator is set to the proper gas pressure defined later by closing the three way valve to prevent gas flow out of the quick connect fitting. The pressure gauge on the FLUTe pump driver is much more sensitive than the regulator for setting the regulator pressure. The FLUTe pump driver must be securely connected to the regulator at the normal ¼” NPT connection on the regulator outlet.

The regulator is attached to the top fitting on the gas bottle (a special nitrogen regulator fitting connects to a nitrogen bottle). Turn the pressure regulator handle counter-clockwise until it moves freely (the no pressure position). Rotate the main valve on the regulator (nearer the bottle) clockwise to fully closed. Open the valve on the bottle (counter clockwise). The main bottle pressure gauge on the regulator will rise to the bottle pressure. Close the regulator valve (clockwise) until the pressure starts to rise on the pressure gauge on the FLUTe pump driver (three way valve closed with no flow out of the quick connect). Adjust the regulator to the desired pressure for purging, provided by FLUTe. Remove the plug of each pump tube and connect the quick connect to the top fitting of the pump tube (see Fig. 2). Open the three way valve to drive the water out of the pump.

Purging

Water is pumped from the tubing by applying the gas pressure to the interface at the static water level in the pump tube (Fig. 1 and 2). The water is driven down in the pump tube and up through the second check valve to the surface via the sample tube. Drive the water with a sufficient gas pressure (the “recommended purge pressure”) to drive all of the water in the pump tube and the sample tube to the surface, the water in the pump tubing is nearly all expelled. The purge stroke is complete when gas is expelled from the sample tube following the water flow. The pressure in the system must then be vented (i.e., dropped to atmospheric by turning the three way valve to the vent position), to allow the pump tube to refill with flow via the port tube. The recharge flow from the port tube consists of the port tube water, the water in the pore space of the spacer, and water from the medium. Because of the relatively large volume in the pump tube, most of the recharge is from the medium. The recharge will take about as long as the first purge stroke. However, a low conductivity medium will require more time.

Purging the pump tube a second time will remove any of the water that has resided in the spacer and port tube volume. That is highly recommended, since the water resident in the tubing and spacer is probably not typical of the formation water. If the refill has been prompt, the second purge water volume will be similar to the first stroke. If in doubt, or if in a sedimentary formation or screened well, a third purge stroke is recommended to remove water that may have been in long contact with the liner or spacer.

Sampling

The sampling flow is best driven on the third (or fourth) cycle by a “recommended sampling pressure” which is less than that needed to drive gas through the bottom of the pump tube. The pressure recommended is that which will drive the water to near, but not out of, the bottom of the large tube. That recommended pressure, “the sampling pressure,” is calculated in the spreadsheet provided with each system. The pressure regulator is set to the sample pressure, which is lower than the purge pressure. Opening the three way valve will now apply the sample pressure to the system causing flow from the sample tube.

The first flow of the sampling cycle sweeps along droplets of water left in the tubing from the purge cycle. That residual water is depleted of volatile components. Tests have shown that the first tube volume of the sample flow should be discarded as depleted in volatiles (the “discard volume” is also calculated in the spreadsheet). Thereafter, the samples can be collected from the sample tube outflow. The volume to be discarded is shown in the spreadsheet as “discard volume”. The sample tube water flow rate will start fast, then slow, and finally stop. That occurs as the water column being driven approaches the applied pressure/head. The typical sampling pressure drives to within 25 ft. of the bottom of the pump tube (the U). The large buffer zone remaining in the pump tube assures against aeration of the sample.

This procedure should provide an ample sample of good quality drawn directly from the formation.

Caution: If the pumping system refills very slowly, there may not be sufficient water in the pump to fill the “sample tube” to the surface when the stroke is performed. In that case, there will be spitting of gas from the sample water and it will be followed by a flow of gas only. The sample water should never show “spitting” and the sample stroke should never end with gas flow from the sample tube. The proper sample flow will slow until it stops flowing. Should this evidence of insufficient recharge be observed, allow the pump to refill for a longer time and repeat the sample stroke. One can tag the water level in the large tube, as described in the head

measurement procedure, to assure that the pumping system has been sufficient refilled.

Measuring the head in the system

The water level at each port can be manually measured by removing the plug from the top of the pump tube and lowering a slender (~1/4") electric water level meter until it contacts the water level in the pump tube. It is not recommended to manually tag water levels more than 200 ft below the surface. The wet film adhesion may prevent the removal of the tag line. A special Teflon coated tag line can be used to extend that limit.

The water level in the large tubes may not be the current water level. After sampling, if there is any leakage of the second check valve (sand in the tube, etc...) the water in the sample tube can backflow into the larger tube, adding to the water that fills the large tube during the recharge. Also, if the water level in the formation is dropping between head measurements, the water level in the pump tube will not follow the descent if the first check valve is a good seal. For these two reasons, and for the freezing concern below, it is best to finish the sampling stroke by raising the pressure to the “purge pressure” value to purge the pumping system of all water. Then upon refilling, the level is the current head for each port. If head measurements are made between sampling events, each port’s pumping system should be first be purged to allow the tubing to refill to the current head value. Always replace the plugs in the top of the pump tubes when finished sampling.

If the water might freeze in the sampling tubing near the surface, purge the entire volume of water from each sampling line, after sampling, before leaving it. Use the recommended purge pressure to remove all water, not the sampling pressure. **Each line should be blowing gas when the purge is complete.** If the lines were purged after sampling for head measurements, that is sufficient.

If the Water FLUTe uses PVDF tubing, the purge of the entire system after sampling should not be neglected, even if head measurements are not to be made. This removes the water column in the sampling tube. For deep water tables, the long term pressure of the standing water in the sampling tube might lead to excessive creep of the tubing which is susceptible to “cold flow”, a characteristic of Teflon like materials. (This is not a concern except for very deep water tables (>300 ft).

In most cases, the performance of a final purge of the system after sampling is useful, even if not essential.

Simultaneous purge and sampling of all tubes

The FLUTe pumping system for each port is essentially identical in length, pump volume and elevation in the hole. This allows all ports to be purged and sampled simultaneously for a great saving in sampling time. The only difference for simultaneous sampling is that the pressure source must include a tube to each port fitting at the wellhead. FLUTe offers a manifold pump driver system at extra cost (the single port driver is provided with the Water FLUTe). The recommended purge and sample pressures are the same as used for single port sampling.

In some cases, the buoyancy of the sampling system is so great when emptied of water during the simultaneous purge that the tubing bundle can cause the liner to invert. The sampling volume spreadsheet provided with the liner notes whether the system can be purged simultaneously. This is only a problem for smaller hole diameters, many ports, and a small excess head in the liner. However, increasing the excess head in the liner to overcome the buoyancy of the tubing can be a hazard to the liner.

A short summary is provided as the following checklist:

Check List

1. Check/restore the water level in the liner.
2. Connect the gas driver source to the gas drive tube for the port.
3. Set the regulator to the recommended purge pressure.
4. Expel the tube water at the suggested purge pressure. Collect the purged water volume for verification of a good purge. Note the water flow time of the purge stroke.
5. Allow the tubing to refill. Repeat the purge. Collect the purge volume to assure the amount removed is at least the “port tube volume”. Was the refill long enough?
6. Purge a third time, if desired.
7. Allow the tubing to refill for the sample stroke.

8. Reduce the driving pressure to the “sampling pressure”. Apply the pressure and collect the first flow to measure the discard volume. Discard that water.
9. Reduce the pressure, if needed, to slow the flow and collect the samples.
10. Perform a final purge of the water out of the sampling lines by raising the driving pressure to the purge pressure value.
11. When the sampling system has refilled, tag the water level, if desired, for the current water table. If a port system is refilling very slowly, tag it at a later time.

See the spreadsheet provided with each *Water FLUTe* for the recommended purge and sampling pressures. Those are the pressures that can be used for a simultaneous purge of the several ports, but be sure that the buoyancy of the tubing will not lift the tubing, and the wellhead. The spreadsheet flags the condition where all ports should not be purged simultaneously. In most cases, several, to all, of the ports can be purged simultaneously.

Optimum sampling procedure:

Since it is often desirable to minimize the amount of time that the sample water resides in the pumping tubing, it is useful to note the actual time that is required for the recharge of the system. Since the fill rate slows dramatically for the last portion of the recharge, it is not necessary to wait for a complete refill. For most formations, the recharge is dominated by the tubing pressure drop. In that case, the time required for the purge stroke to be completed is about the same time required for the refill. (The exception is for a tight formation that recharges the tubing very slowly.) Hence the second purge can be started after waiting the same length of time as the first purge endured. If the second purge is of a similar volume (usually somewhat less) than the first purge volume, the refill time was long enough. After the same delay, the sampling stroke can be initiated. This timing of the strokes allows one to reduce the retention time in the pumping system. For very large sample volumes produced, the refill time can be shortened even more, as long as the sample volume is adequate after the discard of the first flow.

In some situations, the retention time is still too long. FLUTe can often increase the sample tube and port tube diameters for greater flow rates. However, the standard design is well matched for to a wide range of hole diameters, depths, and water table elevations. For very deep wells, the

tubing may need to be of higher pressure capacity for the required driving pressures. For water table depths below 700 ft., this may be a concern. FLUTe initiated a design change from Nylon 11 to PVDF tubing in the Water FLUTe systems in 2002 to avoid any concern about tubing interaction with the sample water. However, the prescribed purge is sufficient for the use of Nylon tubing systems.

Questions: Call 888-333-2433 and ask for Carl Keller, or a field engineer.

Figure 1. Water FLUTe pump system

(Single port system shown for clarity)

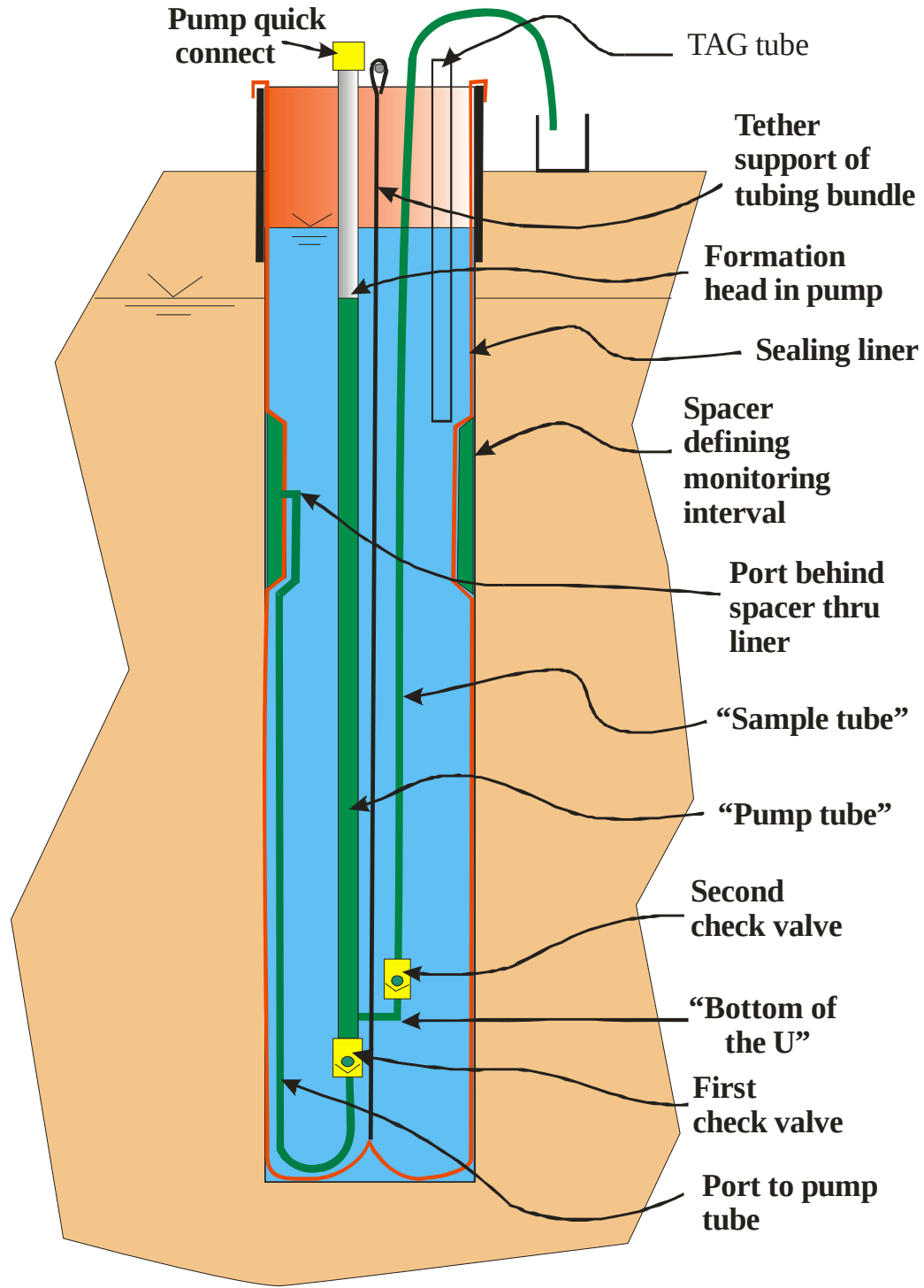
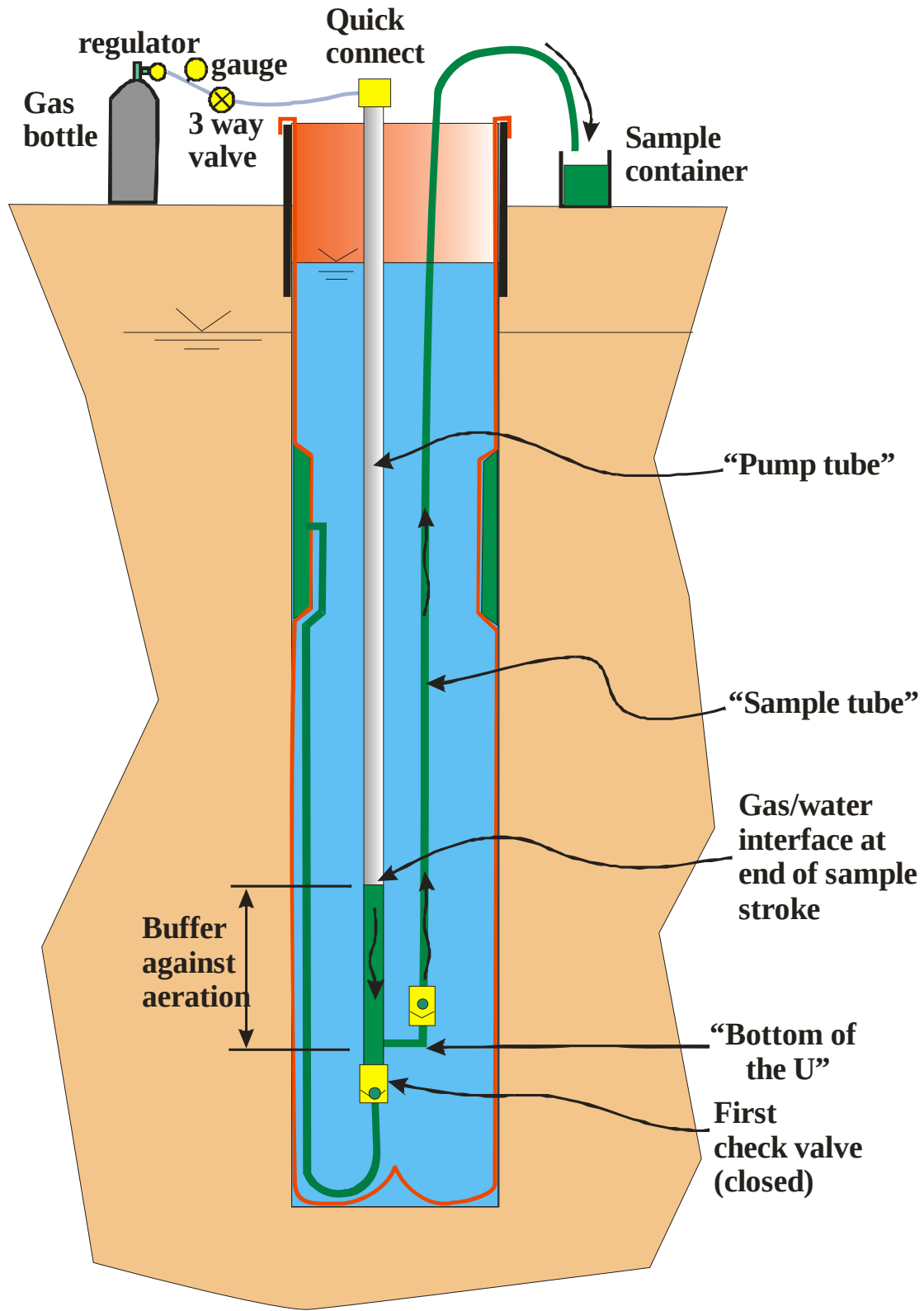
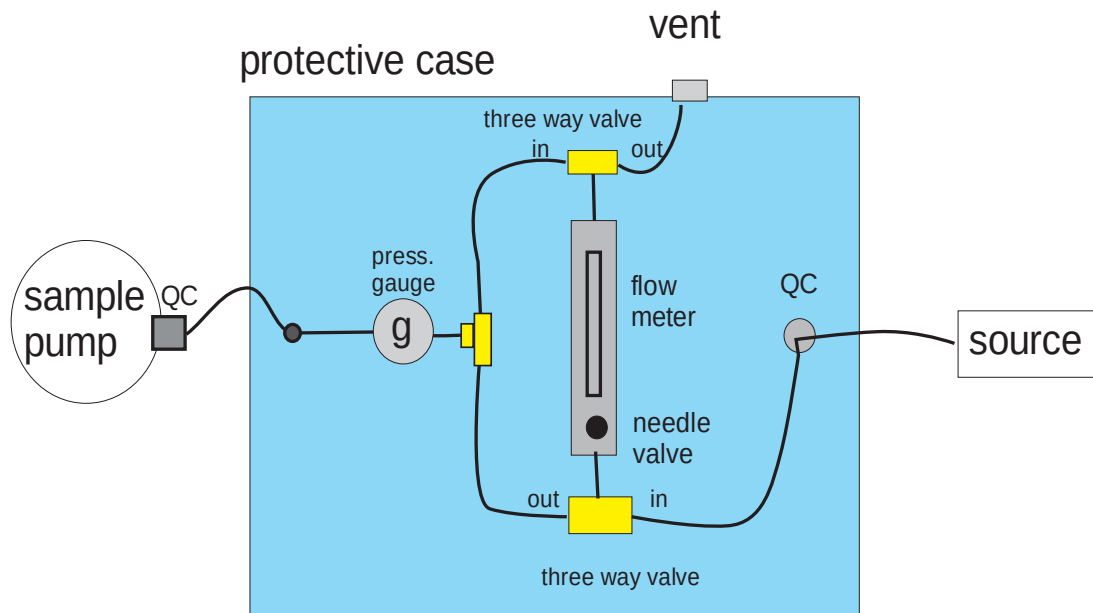


Fig. 2. Pumping Procedure



Flow Control system for Water FLUTe



Price: \$855

Flow rates for microseeps flow controller

enter numbers in bold outlined cells only

depth of pump

130

volume of pump tube

0.17726 cubic ft.

time to refill

5 min.

time to flow through cell

20 min

water table

30

1.329449 gal.

Flow rate to refill

flow rate to flow through cell

pressure in pump

0.135755

0.033939

4.829252 bars abs.

8.145271 SCFH

2.036318 SCFH

gauge press.

3.829252 bars

Appendix E

Hager-Richter Borehole Geophysical Logging SOPs

HAGER-RICHTER GEOSCIENCE, INC. BOREHOLE GEOPHYSICAL LOGGING STANDARD OPERATING PROCEDURES

Equipment

General. A Mount Sopris Matrix portable digital logging system is used with a 4MXA-1000 winch for the borehole geophysical logging. Data are recorded in digital format using a PC. Data are displayed in real time in the field and are processed in the office using WellCAD v4.4, commercially licensed software.

Optical Televiewer. An ALT OBI-40 optical televiewer (OTV) probe will be used for this project. The OTV acquires a high resolution, effectively continuous, magnetically oriented, 360° image of the borehole wall. The image can be used to detect bedrock structures such as fractures, foliation, and bedding and to provide information about lithology. The probe includes a 3-axis magnetometer and three accelerometers to orient the image and to provide borehole deviation data that are used to correct structure orientations from apparent to true orientations.

Acoustic Televiewer. An ALT ABI-40 acoustic televiewer (ATV) probe will be used for this project. The ATV acquires a high resolution, effectively continuous, magnetically oriented, 360° image of the borehole wall using the reflected signal of sound waves in the ultrasonic frequency range. Both amplitude and travel time of the reflected signal are recorded and can be used to detect bedrock structures such as fractures, foliation, and bedding. The probe includes a 3-axis magnetometer and three accelerometers to orient the image and to provide borehole deviation data that are used to correct structure orientations from apparent to true orientations.

ATV travel time data can also be used to calculate an acoustic caliper log. The acoustic caliper log provides the average borehole diameter as a function of depth. The acoustic caliper log is derived from the acoustic travel time data and the velocity of the acoustic signal in water. The acoustic caliper log is determine the diameter of the borehole, to detect open fractures and voids, and to aid in the interpretation of other borehole geophysical logs.

Fluid Temperature. A Mount Sopris 2SFB-1000 fluid resistivity/temperature probe will be used for the temperature logging. The temperature sensor is a semiconductor device for which the voltage output is linearly related to temperature. Temperature logs record the temperature of the borehole fluid with depth and are useful for detecting flow into or out of a borehole. If fluid temperature contrasts are present between the borehole fluid and individual fractures and fracture zones, the fluid temperature logs are also useful indicators of flow into and out of the borehole.

Fluid Resistivity. A Mount Sopris 2SFB-1000 fluid resistivity/temperature probe will be used for the fluid resistivity logging. The probe uses an electrically shielded Wenner array to measure the capacity of the borehole fluid to transmit electric current with depth and can be an

indicator of salinity and water quality. If fluid resistivity contrasts are present between the borehole fluid and individual fractures and fracture zones, the fluid resistivity logs are also useful indicators of flow into and out of the borehole.

Resistivity is the physical property that relates electric current density to potential gradient and is defined as:

$$\tilde{n} = (A / L) * (V / I) \qquad \text{Eq. 1}$$

where:

$\tilde{n}$	is resistivity
A	is cross-sectional area of a homogeneous tube
L	is length of the tube
V	is potential
I	is current

Natural Gamma Ray. A Mount Sopris 2PGA-1000 poly-gamma probe will be used for the natural gamma ray logging. The probe uses a sodium iodide crystal that produces a pulse of light when struck by a gamma ray. The variation of radioactivity naturally occurring in rocks and sediments makes the natural gamma ray log an excellent indicator of changes in lithology. Radioactive minerals tend to accumulate in clays with the practical result that layers with higher clay content are commonly expressed in the natural gamma ray log as relatively higher counts per second (cps). Clean sands, which are normally low in radioactivity, produce low count rates.

Spontaneous Potential and Single Point Resistance. A Mount Sopris 2PGA-1000 poly-gamma probe will be used for the spontaneous potential (SP) and single point resistance (SPR) logging for this project. The SP and SPR logs are types of electric logs. The electric logs are calculated from combinations of voltage and current measurements made with various combinations of a fixed electrode at the surface and one or more electrodes mounted on a downhole probe.

SP measures the voltage that occurs between the borehole fluid and the surrounding materials. Spontaneous potentials occur in the earth due to chemical and physical differences between rock types and saturating fluids. The SP data are the difference in potential (or voltage) between a fixed electrode at the surface and a single moving electrode in the borehole. SP logs are commonly used to identify changes in lithology, bed thickness, and salinity of formation fluid under some conditions.

SPR measures the electric resistance of the material surrounding the borehole and saturating fluid with depth. The SPR measurement is made by passing an alternating current between a surface electrode and an electrode on the probe. The resistance is calculated using the voltage between the two electrodes and Ohms Law, which is defined as:

$$R = E / I \qquad \text{Eq. 2}$$

where: R is resistance
 E is potential
 I is current

SPR data are useful in the determination of qualitative lithologic information, water quality, and location of fractures/fracture zones. The SPR values increase with increasing grain size and decrease with increasing borehole diameter, fracture density, and with higher concentrations of dissolved solids in the borehole fluid.

Heat Pulse Flow Meter. A Mount Sopris HFP-2293 heat pulse flow meter (HPFM) will be used for the HPFM logging. The HPFM measures the vertical rate and direction of fluid flow in a borehole at discrete depths and is designed to be used for boreholes with flow rates less than one gallon per minute (gpm). A heating grid heats a thin sheet of water in a short time interval (less than 0.05 seconds), and, if vertical flow is present, the sheet of water moves along the borehole in the direction of flow. Temperature sensors located at known distances above and below the heating grid monitor the differential temperature of the borehole fluid. The time required for the sheet of heated water to reach one of the sensors is measured, and, based on factory calibrations, the time is used to calculate the vertical flow rate in the borehole. Depths where water flows into and out of the borehole can be interpreted based on changes in the vertical flow rate and/or direction. HPFM measurements can be made under ambient and stressed (pumping or injection) conditions.

Measurement depths are selected based on information provided by other borehole geophysical data such as OTV, ATV, fluid temperature, and fluid resistivity. To make a measurement, the probe is positioned at a selected depth and the probe is stabilized by the friction between the centralizers and diverter petal on the probe and the borehole wall. When the borehole fluid has stabilized after the disturbance caused by the probe being moved to the measurement depth, the heating grid is fired, and a measurement cycle starts.

Borehole Geophysical Logging Field Procedures

Data Acquisition. Standard data acquisition parameters are as follows:

Data Acquisition Parameters

Log	Sampling Interval	Logging Speed	Logging Direction (Initial and Repeat)
OTV	0.01 feet	5 feet per minute	down
ATV & Acoustic Caliper	0.01 feet	8-10 feet per minute	down and up
Fluid Temperature & Fluid Resistivity	0.10 feet	8-12 feet per minute	down and up
Natural Gamma Ray	0.10 feet	10-15 feet per minute	down and up
SP & SPR	0.10 feet	10-15 feet per minute	down and up
HPFM	HPFM data are acquired at discrete depths under ambient and injected conditions.		

Equipment Decontamination. The downhole equipment is decontaminated prior to first use and after logging each borehole. The cable and downhole probes will be decontaminated by washing with an Alconox and water solution and then rinsing with potable water and/or deionized water.

Equipment Calibration and Standardization

Depth Encoder. Adequate tension is maintained with the logging cable during the borehole geophysical logging and the depth encoder is cleaned after each logging run in order to maintain accurate depth measurements. Repeat sections are acquired to verify depth consistency. In addition, at the beginning and end of a logging run, a fiducial depth (top of casing or ground surface) is measured and checked for consistency. Recorded depths of fixed features in the borehole (i.e. reported casing lengths and reported borehole depths) are also checked for depth consistency.

Optical TelevIEWer and Acoustic TelevIEWer. The orientation sensors, which provide azimuth and tilt data, in the OTV and ATV probes are checked using a compass and a calibration tube prior to and after the field operations. To verify consistency of the ATV data, logs are acquired while logging down and up the full length of the borehole. In addition, the borehole orientation data from the OTV and ATV are compared for consistency. Acoustic caliper data are compared with known casing and borehole diameters.

Fluid Temperature and Fluid Resistivity. To verify consistency, repeat logs are acquired for the full length of the borehole. The fluid temperature and fluid resistivity sensors are factory calibrated by Mount Sopris Instrument Company, Inc. (MSI).

Performance tests are conducted on the fluid temperature sensor in the field by checking the temperature of test water measured with the logging probe compared to the temperature of the test water measured using a thermometer. Performance tests are also conducted on the fluid resistivity sensor by observing the response in time mode of fluid resistivity measurements in tap water and in a salt water solution in the field.

Natural Gamma Ray. To verify consistency, logs are acquired while logging down and up the full length of the borehole. Natural gamma ray readings for interfaces in the borehole (cased to open-hole, water-filled to air-filled) are monitored to evaluate the performance of the probe and probe sensors. Natural gamma ray data are compared to normal resistivity, SP, and SPR data to check for consistent observations of lithologic variation.

Spontaneous Potential and Single Point Resistance. To verify consistency, logs are acquired while logging down and up the full length of the borehole. Normal resistivity, SP, and SPR readings for interfaces in the borehole (cased to open-hole, water-filled to air-filled) are monitored to evaluate the performance of the probe and probe sensors. Normal resistivity, SP, and SPR data are compared to natural gamma ray data to check for consistent observations of lithologic variation. The SP and SPR probe's factory calibrations are checked using a Mount Sopris 4RSP-1000 calibration box prior to and after the field operations.

Heat Pulse Flow Meter. To verify consistency, a minimum of three measurements are made at each sample depth. The HPFM was factory calibrated by MSI and the calibrations are checked in a calibration tube prior to and after the field operations. Multiple performance checks on the heating grid are also conducted during data acquisition.

To ensure reliable HPFM measurements, the borehole water level is monitored and recorded during HPFM data acquisition. To ensure consistent water pumping rates during HPFM data acquisition, pumping rates are continuously monitored with a rotameter flow meter. The factory calibrations for the rotameter flow meter are checked prior to and after the field operations in the same calibration tube used for the HPFM calibration tests.

Appendix F

ALS Temperature Logging Procedure



TECHNICAL MEMORANDUM

To: Dr. Dan Folan (*Dan.folan@aecom.com*)**Cc:****From: Peeter Pehme**, Ph.D., P.Geo.**Date: Sept 27th, 2013.****Subject: Standard Operating Procedures: Active Line Source (ALS) testing**

It has long been recognized that temperature profiles in open boreholes measured in rock offer insights about fractures with flow (e.g. Trainer, 1968; Bidaux and Drogue, 1993; Robinson et al., 1993); however, temperature has generally been used only minimally in fractured rock investigations at contaminated sites. Two recent advances provide impetus for temperature profiling to become much more important. The first is the greatly improved sensor resolution for temperature measurement (on the order of 0.001°C) and the second concerns measurement of temperature profiles in holes sealed using impermeable flexible liners produced by FLUTE (<http://www.flut.com>) to prevent cross flow between fractures (i.e. hydraulic cross connection). Using these two advances for measuring temperature profiles under ambient flow conditions, Pehme et al. (2010) identified numerous hydraulically active fractures in boreholes in dolostone and sandstone. The number of fractures identified by this method was much larger than the few identified when the holes were unsealed (i.e. open-hole conditions). Identification of all of the fractures in which active groundwater flow occurs is important in contaminated site investigations because the nature of contaminant plumes is very different between dense and sparse networks (Parker, 2007).

Although the use of high precision temperature probes in the static water columns of lined holes enables the identification of numerous hydraulically active fractures (Pehme et al., 2010), this approach has a depth limitation. Fractures are preferentially identified close to ground surface where groundwater flow transports heat perturbations from surface imparted by the atmosphere (i.e. surface temperature variations due to weather) and urban infrastructure. These surface-imparted temperature disequilibria are attenuated at depth due to thermal conduction in the rock mass. The maximum depth to which this thermal disequilibrium can be used to identify fractures varies considerably depending on both geology (i.e. thickness and nature of overburden, degree of bedrock fracturing etc.) and hydrogeologic conditions (i.e. degree of vertical and lateral flow, recharge vs. discharge etc.).

The Active Line Source (ALS) method applied in lined boreholes described by Pehme et al. (2013) eliminates the depth limitation for use of temperature profiling in lined holes to identify ambient flow through fractures. In this method, the static water column in the lined hole is heated continuously along the entire length of the hole to rapidly create strong thermal disequilibrium around the borehole and then temperature profiles are measured as the heat in the water column dissipates.

Equipment and Method**Data Collection**

The essential equipment used in the field includes five components: the temperature probe (the tool), a winch, heating cable, generator and computer. For the data presented in this paper, two temperature probes were used; early data were collected with a rented probe (a single sensor BMT-01 manufactured by IFG corporation, Brampton, Ontario, Canada), and the later results with a prototype probe. Both probes have a specified operating range of 0-50°C, sampling rate of 2Hz, a specified resolution of 10⁻⁴ °C (although our data supports 10⁻³ °C).

The heating cable is a Chromalox/Etirez Constant Wattage Heater Cable (CWM 8-2CT / PCN 392171, Medium Temperature - 392 deg. F exposure - power off with a Fluoropolymer jacket - 8 W @ 240 VAC)

(total resistance ~20ohm) that, when powered at 220volts, produces 26W/m uniformly along its length.

The hole is sealed with a Flute™ liner in a manner described by Keller et. al (submitted) and the water allowed to thermally stabilize before the three stages (Table 1) of the ALS are initiated. The term “passive” is used to refer to any temperature log collected without prior heating. In the ALS procedure, the ‘background’ condition is considered to be as observed with the passive temperature profile preferably collected just before the beginning of the heating stage, usually the prior afternoon. The borehole is heated for as long as logistically practical (typically 4 to 6 hours). The ‘active log’ is a temperature profile measured during the borehole heated stage just prior to the heater being turned off. The hole is typically logged three times during the cooling stage as the applied heat in and around the borehole dissipates and the system gradually cools towards background temperatures, as summarized in Table 1. The first cooling log (C1), is started within an hour after the heater is turned off, the second log (C2) is started 4-6 hours after the heating ceases (timed to start at approximately the same time into thermal recovery as the duration of heating) and the last cooling log (C3), is typically collected 18 hours after heating (early the following morning).

The logging rate used for the data collection is varied based on a compromise between resolution and the need to minimize both the time spent logging in the middle of the test and disturbance of the water column. Data are typically collected at a rate of 0.5-0.7m/min for the passive, C2 and C3 logs, and 1-1.5 m/min for the active and C1 logs when adequate time must be allowed for the effects of logging to dissipate prior to collection of subsequent data. It is worth noting that all background (passive) temperature logs (both open and lined hole) are collected at a nominal data interval of 0.005-0.007m. A critical factor in assessing the reliability of aberrations in temperature profiles is that the shape of features that span 10 to 20 cm are defined by many readings (14-20 when collected as specified) so depth resolution due to run speed is a critical factor.

Table 1: Details of data collection steps in the ALS process

Stage		Details	Purpose/Comments
1	Background	Ambient temperature of the fluid column in the borehole is measured prior to the addition of heat. P - a “passive” log is collected at a slow rate of decent (0.5-0.7 m/min)	Provides base against which to assess: amount of heat added target values of thermal recovery basis for confirming overall borehole thermal stability (see C3) optimally completed the afternoon prior to heating
2	Heating	Energy is introduced with a line heater (typically at 26 W/m for 4-6 hrs) uniformly down borehole A – “Active” log is collected (1.5-2 m/min) which measures temperature prior to turning off the heater	Used to estimate amount of heat added: data tends to be noisy, presumed to be primarily caused by small changes in the distance between the heat source and sensor(s) power depends on heater(s) used and voltage applied timed to end near end of heating cycle
3	Recovery	C1 – Log collected during cooling, starting approx. ½ hour after heater turned off (1-1.5 m/min)	Heater may be removed depending on logistical considerations provides indication of the early stages of cooling most variable of the recovery logs
		C2 – Cooling log started at approximately the same length of time after the heater is turned off as total heating (i.e. usually ~5½-6½ hrs after end of heating), (0.8-1m/min)	Designated as start of “late” time good indicator of flow zones theoretical start of linear decay (Beck et. al. 1971, Pehme et al 2007a), used to estimate thermal conductivity
		C3 – logged the next day (approx. 24hrs after the start of heating) at 0.5-0.7 m/min	Well into late stage recovery used in estimation of thermal conductivity compared against P log to access recovery process and overall thermal stability

Procedure for Identification of Flow from Temperature Logs

The identification of fractures showing active groundwater flow using temperature logs in lined holes is primarily based on an analysis of a processed version of the data referred to here as the 'thermal deviation log'. This procedure for processing temperature logs is described in detail by Pehme et al. (2013).

References:

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- Robinson R., S. Stilliman and C. Cady, 1993, Identifying Fracture Interconnections between Boreholes Using Natural Temperature Profiling: II. Application to fractured Dolomite, *Log Analyst* 34, no. 1 pp. 69-77
- Trainer, F.W. 1968. Temperature profiles in water wells as indicators of bedrock fractures. Professional Paper 600-B Washington DC: USGS.

Appendix G

Golder Associates - Rock Core Diffusion Testing Procedure

THEORETICAL DESCRIPTION OF THE DIFFUSION TEST

A schematic drawing of the diffusion cell used for this study is presented in Figure 1. A source solution consisting of de-ionized water spiked with sodium chloride was placed on one side of an intact rock core specimen and a collector solution consisting of de-ionized water was placed on the opposite side. The source solution constituents (i.e. sodium and chloride) were then allowed to diffuse through the rock core sample and into the collector solution compartment over a period of 134 days. During this period, the collector solution compartment was periodically sampled in order to monitor the chloride concentration variation with time.

Assuming that the chloride concentration decrease with time in the source solution is due only to diffusion through the rock core (i.e. no short circuiting of chloride along the contact between the rock and cell wall), the boundary condition representing the chloride concentration in the source solution can be written as (e.g. see Rowe and Booker, 1985):

$$c_s(t) = c_{os} - \frac{1}{H_s} \int_0^t f_s(t) dt \quad [3]$$

- where: $c_s(t)$ = chloride concentration in the source solution at time t [M/L³],
 c_{os} = initial chloride concentration in the source solution [M/L³],
 H_s = equivalent height of source solution, calculated as the source solution volume divided by the cross-sectional area of the rock core sample perpendicular to the direction of diffusion [L], and
 $f_s(t)$ = mass flux across the rock sample/source solution interface [M/L²/T]

The mass flux across the sample/source solution interface $f_s(t)$, can be further related to the chloride concentration gradient across this interface $(\partial c / \partial z)_s$ by Fick's first law, viz.:

$$f_s(t) = -n' D \left(\frac{\partial c}{\partial z} \right)_s \quad [4]$$

where n' is the effective porosity of the rock matrix.

The boundary condition representing the species concentration in the collector solution ($c_c(t)$) is given by:

$$c_c(t) = \frac{1}{H_c} \int_0^t f_c(t) dt - \frac{q_c}{V_c} \int_0^t c_c(t) dt \quad [5]$$

- where: $c_c(t)$ = chloride concentration in the collector solution at time t [M/L³],
 V_c = volume of the collector solution [L³],
 $f_c(t)$ = chloride mass flux into the collector solution [M/L²/T],
 q_c = average rate of sampling of the collector solution [sample volume/average sampling frequency] [L³/T], and
 H_c = equivalent height of collector solution, calculated as the collector

solution volume divided by the cross-sectional area of the rock core specimen, perpendicular to the direction of diffusion [L]

The mass flux into the collector $f_c(t)$ can be further expressed in terms of the concentration gradient across the sample/collector solution interface $(\partial c / \partial z)_c$, viz.:

$$f_c(t) = -n'D \left(\frac{\partial c}{\partial z} \right)_c \quad [6]$$

For these flux controlled boundary conditions, a semi-analytical solution to the one-dimensional diffusion equation,

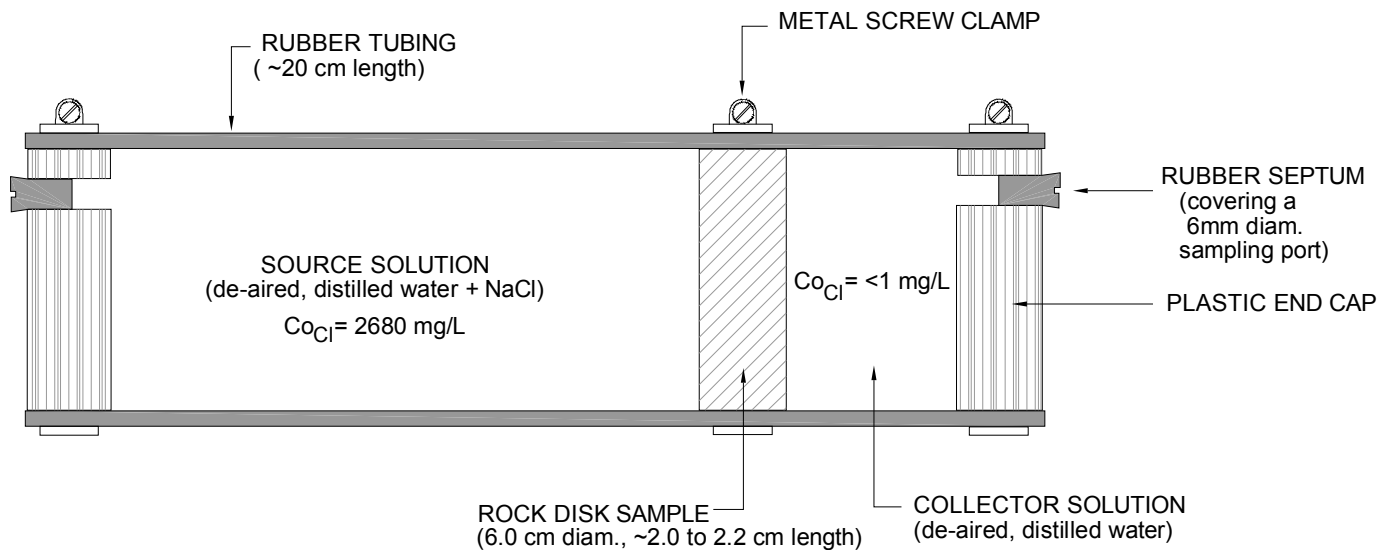
$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial z^2} \quad [7]$$

has been implemented in the computer program POLLUTE (Rowe et. al., 1994). Using different values for the chloride diffusion coefficient, theoretical curves for the chloride concentration variation with time in the collector solution were generated using POLLUTE and then compared to the experimental concentration data. The diffusion coefficient that gave the best fit “by eye” to the experimental data was chosen as the experimental value. For all samples, the effective porosity, n' , was taken as the total porosity.

EXAMPLE DIFFUSION TEST PROCEDURES

The following outlines the general procedures used in the set-up and monitoring of the diffusion tests for the measurement of matrix diffusion coefficient for chloride. Note that the diffusion tests were conducted at room temperature ($\sim 23^{\circ}\text{C}$).

- (1) A core specimen measuring approximately 2.0 cm to 2.2 cm in thickness and 6.0 cm in diameter was cut from each of the submitted core samples using a tungsten tip saw and tap water as the cutting fluid.
- (2) A thin layer of silicone grease was spread around the outer perimeter of each core specimen and the specimen was pushed into an approximately 20 cm long section of rubber tubing having an unstretched inner diameter slightly smaller than the core specimen. The core specimen was positioned as shown in Figure 1.
- (3) A screw clamp was slid over the outer part of the rubber tubing and tightened directly over the core specimen to ensure a good seal between the specimen and the rubber tubing. Plastic end caps were then positioned as shown in Figure 1 and clamped in a similar manner as the core specimen.
- (4) With the cell in a near horizontal position, distilled water was injected into the collector compartment through the injection port located on the end cap. Care was taken to minimize the air space remaining in the compartment. The total volume of distilled water injected into the collector compartment ranged from 109 mL to 116 mL. The measured chloride concentration in the distilled water stock solution was approximately <1 mg/L.
- (5) With the apparatus in a vertical position (collector compartment at the bottom), the source solution consisting of distilled water spiked with 2.68 g/L sodium chloride was injected into the source compartment. Care was taken to minimize air space remaining in the compartment. The total volume of sodium chloride source solution injected into the source compartment ranged from 304 mL to 326 mL.
- (6) Immediately after inserting the source solution, the cell was placed in a horizontal position and the start time for diffusion (i.e. $t = 0$) was recorded.
- (7) A 3 mL sample of the collector was taken periodically (approximately once per 19 days) through the sampling port. Once each sample was taken, an equal volume of fresh collector solution (i.e. distilled water) was re-injected into the collector compartment.
- (8) One control sample was set up and tested in the same manner as the rock core samples to ensure that there was no short circuiting of the chloride solution across the core sample via diffusion through the rubber tubing.
- (9) All collector solution samples, including those for the control sample were analyzed for chloride by ion chromatography at Maxxam Analytics, Mississauga, Ontario.



SCALE	N.T.S.
DATE	June 22, 2011
DESIGN	FSB
CAD	FC
CHECK	SR
REVIEW	FSB

TITLE

SCHEMATIC DRAWING OF THE CHLORIDE DIFFUSION CELL

FILE No. 1011110230AA001.DWG

PROJECT No. 10-1111-0230

REV. A

CHLORIDE DIFFUSION TESTING

FIGURE

1

GOLDER ASSOCIATES LTD.
MISSISSAUGA, ONTARIO
GEOTECHNICAL LABORATORY
QUALITY ASSURANCE MANUAL

REVISION: 9

Approved by:

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1.0 DEFINITIONS

Quality Assurance Manual - A document stating the quality policy, quality system, and quality practices of an organization. Guideline to overall quality of the laboratory, specifically the organizational structure, responsibility, procedures, process, and resources for implementing quality management.

Standard Operating Procedures - Specific directions unique to our laboratory in performing a specific test on a repetitive basis (supplements published standards).

GAL Employee Handbook - Overall company policies and employee's rights to know, and guidelines.

ASTM Test Methods - Nationally established test procedures.

Project Files - Site and client specific project files.

Proposal Files - Proposals for Laboratory Testing.

Report - The factual data presented by Golder Associates Ltd. and received by our client.

Audit Team – An Internal Team required to audit the Quality Assurance of CCIL Accredited Labs at the Canadian Golder Associates Laboratories. Refer to 2.3 and 15.1 for a list of Auditors and their responsibilities.

All of the above stated material is located in the Golder Associates Mississauga laboratory.

2.0 MANAGEMENT RESPONSIBILITY

2.1 Quality Policy

Golder Associates (Golder) policy and objectives for the Geotechnical Laboratory are to provide our clients with high quality laboratory testing services that are responsive to the needs of the client.

2.2 Organization

The geotechnical laboratory is a legal and integral part of Golder. A current business license for Golder is posted in the foyer of our office.

The laboratory is located in the office of Golder in Mississauga, Ontario. The laboratory is equipped to provide a variety of testing services of soil materials (gravel, sand, silt & clay), rock, concrete, mine tailings and other geotechnical materials. Testing can be performed on undisturbed and disturbed samples.

Golder has been involved in providing our clients with geotechnical laboratory testing services for more than forty years.

Golder actively participates in the Ministry of Transportation, Ontario (MTO) Aggregate and Soil Proficiency Sample Program and is approved by MTO for high complexity geotechnical laboratory testing, Canadian Council of Independent Laboratories (CCIL) for Type “C” and Type “D” Aggregate Quality Testing Laboratory and the lab is also CSA certified for concrete testing within the classification of Category II. Golder’s Mississauga Office is ISO 9001:2000 certified since December 2007. Golder keeps abreast of the changes that occur in the industry, in terms of calibrations, tests, equipment and technology.

2.3 Management and Staff

The Golder geotechnical laboratory has a management staff with appropriate authority and resources needed to carry out the assigned duties. An organizational chart of the management of the laboratory is located in the Quality Assurance Manual and is indicative of the supervision exercised and received. The laboratory management staff is typically comprised of the following personnel:

Brian Conlin, P.Eng. President
Sean McFarland, P.Eng. Office Manager
Frank S. Barone, Ph.D. P.Eng. J. Paul Dittrich, Ph.D. P.Eng. Quality Managers
John Watkins GTA Laboratory Group Manager
Marijana Manojlovic, B.Sc. Laboratory Manager
Rui Oliveira Angela Hunwicks Lina Han Larry Zhou Albert Lam Xiangyue Meng Laboratory Technicians
Lucy Gutta Administrative Assistant
One – two Seasonal/part time employees
Jim MacDonald Quality Assurance Lab Health & Safety
Emily Worden Kwok Chris Sewell Jim Mac Donald Audit Team
Sue Crozier GAIMS Internal Audits

The President of the Canadian Operations is a Principal of Golder and is responsible for overseeing the Office Manager.

The Office Manager is a Principal of Golder and is responsible for overseeing the office, issues such as sales and marketing, and final approval of hiring and dismissal.

The Quality Managers are Professional Engineers and employees of Golder and are responsible for overseeing the laboratory; providing administrative support in final review of reports and proposals, overall quality and resolving technical issues for the Laboratory.

The Laboratory Manager has the primary responsibility for general laboratory operation, supervision and training of personnel, implementing the Quality System, authorizing the purchase of equipment, and preparing short and long-term goals. The Laboratory Manager is assisted by other members of the management staff as required for specific needs as they arise.

The Laboratory Technicians are responsible for receiving, preparation, testing, calibration, maintenance, storage, and disposal of samples. They also report faulty operations of equipment.

2.4 Organizational Freedom

Golder assures that laboratory personnel, as employees of the company, have suitable training to allow them to perform the duties assigned by the Laboratory Manager. Laboratory personnel may perform their duties without specific detailed knowledge regarding the client, project, or material manufacturer. The Laboratory Manager provides the laboratory personnel with training for the specific duties assigned in the laboratory.

Golder policy and procedures to ensure the protection of the client's confidential and proprietary rights are stated in the Golder Employee Handbook. The laboratory regulations supplement the Golder Employee Handbook. The laboratory regulations also describe typical laboratory requirements including project scheduling, housekeeping, safety, sickness, storage of food, and tardiness.

2.5 Golder References and Resumes

Resumes (Curricula Vitae) detailing the educational and employment history of individual Golder employees that work in the laboratory and/or are associated with the laboratory are located in the Statement of Qualifications (SOQs) and are on file with the Golder Marketing Coordinator.

2.6 Resources

Golder Associates, Mississauga Laboratory has the resources necessary to conduct its business in a manner consistent with the level of care and skill ordinarily exercised by members of this profession. The resources include but are not limited to people, equipment and space. The equipment and personnel are listed in the Quality Assurance Manual.

2.7 Management Representative and Review

Internal audits are conducted by the Golder Associates Audit Team as defined in the Organizational Chart on page 5.

Golder Associates Integrated Management Systems (GAIMS) conduct annual Project Management and Calibration & Equipment Audits. Quality Assurance Inspections are performed monthly to determine compliance to equipment calibration, maintenance schedules and testing procedures.

External audits are conducted on the lab by CSA, CCIL, MTO, and ISO and the outcome of these audits are presented to the Quality Managers. The Canadian Food Inspection Agency audits the laboratory once every two years for facility offshore testing compliance.

In addition to the annual internal audits and external audits, the Laboratory Manager compiles a report of Non-Conformances, Opportunities for Improvement and client complaints and provides this to the Quality Managers for review.

3.0 QUALITY SYSTEM

3.1 Quality Assurance Manual (QAM)

The Golder Laboratory objective is to provide our clients with high quality laboratory testing service. This quality system is achieved through our policy, QAM, independent audits, membership in technical organizations (CCIL), standard operating procedures, and training.

A QAM is maintained by the Laboratory Manager and is kept in the Laboratory. The Quality Assurance Manual is reviewed and updated as necessary by the Laboratory Manager and the Quality Managers.

The QAM and other quality documentation are available to laboratory personnel for reference. Laboratory personnel are responsible for adhering to the requirements of the QAM.

3.2 Quality System Procedures

The laboratory QAM contains documented plans and procedures pertaining to Management Responsibility; Project Identification and Traceability; Testing; Reporting; Inspection, Measuring and Test Equipment; Test Status; Control of Nonconforming Product; Handling; Storage; Disposal; Packaging and Delivery; Quality Records; Training; and Statistical Techniques.

3.3 Quality Planning

The laboratory conducts an internal inspection once per year by the Audit Team to verify that its operations continue to comply with the requirements set forth in the Accreditation Programs.

The Quality Managers review the results of both the internal and external audits during their Management Review. Appropriate improvement measures are implemented as soon as practical as required based on the results of the audits.

3.4 Standard Test Methods

The majority of standard test methods and procedures pertaining to material tests performed by the laboratory are ASTM (American Society of Testing and Materials) standards. Copies of the appropriate ASTM test methods are located in the laboratory and/or the Golder library.

Copies of other standards such as MTO and Standard Methods for the Examination of Water and Waste Water, CSA – A23.2 Methods of Testing and Standard Practices for Concrete are located in the laboratory and/or in the Golder library.

4.0 CONTRACT REVIEW

The established and maintained procedures for project contract review (where applicable) are as follows:

The Laboratory Manager reviews, approves, accepts, and signs the contract if appropriate.

The contract review will typically be carried out with a view to identify whether the contract contains defined and documented requirements for laboratory testing; the contract is written to accommodate changes and revisions; and that the laboratory is capable of performing all contractual requirements.

Contractual requirements can take the form of a verbal authorization from the client (followed by a written confirmation, facsimile and e-mail), purchase order, letter of intent, chain of custody, transmittal letter, or a formal contract.

Once authorization is received from the client, Golder submits project information such as client, project, site, etc. to our accounting department for processing the billing information for invoices. Any changes that may occur are also forwarded to accounting. Records of contract reviews are maintained in files. Authorization to provide services, scope of work, general terms and conditions are kept in a separate folder in the lab.

4.1 Purchasing

Laboratory supplies are purchased at the following companies for reasons of proximity, dependability, reputation, and adherence to applicable Standards. Sartell Instrumentation also assists with repairs and modifications of lab equipment. These listed companies will continue to be our suppliers unless there are specific reasons to effect change (such as: poor service, excessive prices increases, poor quality standards, and inexperienced sales personnel).

Sartell Instrumentation

225 Traders Blvd. E. Mississauga, On. 905.890.1090

VWR International

2360 Argentia Rd. Mississauga, On. 1.800.932.5000

Hoskin Scientific

4210 Morris Dr. Burlington, On. 905.333.5510

Fisher Scientific

111 Scotia Court Whitby, On. 1.800.234.7437

4.2 Management Review

Management review will be carried out annually to ascertain the suitability of policy and procedures, discuss reports from managerial/supervisory personnel, review recent internal and external audits and to take the necessary corrective and preventative actions.

Results from the inter laboratory proficiency tests and client feedback will be discussed.

Results of these meetings are recorded, dated, and implemented and kept in the Quality Manual.

5.0 DOCUMENT AND DATA CONTROL

Purpose

The purpose of this procedure is to control documents and data that are used to convey information concerning the quality system and material testing and to ensure that this information is available to all pertinent staff.

Scope

Documents and data controlled by this procedure are listed in the table on the following page.

Responsibility

The responsibility for the review and approval of technical documents is described in the document control matrix on the following page. The matrix lists all controlled documents as well as the custodian, method of retrieval, method of highlighting change, and location of the master. Laboratory Quality Manual, work instructions and training records are reviewed and approved by the Group Leader before issue. The purpose of the review is to ensure the adequacy of the information included in the document. The custodian is responsible for maintaining the master and keeping all issued documents current. The custodian is not necessarily the author or approver.

Method

The documents listed in the matrix have been deemed to be controlled documents. The following describes the classification of the types of controlled documents kept in the Mississauga laboratory:

Public Documents - Available to general public and clients

Restricted Documents - Available to Mississauga laboratory staff only

Private Documents - Available to staff designated by Group Leader.

A copy of Public controlled documents is maintained on the bookshelf in the Triaxial lab. The Laboratory Manager maintains Restricted controlled documents. The location of Private controlled documents is determined according to office policy or by the Group Leader.

A master document is maintained for each listed document. This master is used as reference to determine the current issue.

Obsolete documents are removed from the work place by the custodian and will be retained as a quality record. Obsolete documents retained for knowledge preservation will be permanently marked obsolete.

Changes to documents are reviewed and approved by the individuals listed in the responsibility clause of this procedure. To identify the changes in the document for the benefit of the user

several different techniques are used. These techniques are stated in the 'Method of Identifying Change' column of the attached table.

Documents from external sources are also listed in the document matrix. Although the contents of external documents are not controlled by the laboratory, they are maintained in a current status by the custodian. The document source is contacted periodically to determine if the existing version has been changed or re-issued. A history of these contacts is kept as a quality record.

All documents generated by the laboratory shall be reviewed annually to determine if they reflect current practices and are correct. All documents generated by the laboratory shall be uniquely identified by the date of issue or revision number and the approver.

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QUALITY ASSURANCE MANUAL

DOCUMENT AND DATA CONTROL MATRIX

Document	Location of Master	Obsolete Document Custodian	Method of Identifying Change	Custodian	Public	Restricted	Private
Quality Manual	LM	LM	Revision or Date	LM	x		
Internal Audit Checklists	LM	LM	Revision or Date	LM		x	
Training records	LM	LM	Revision or Date	LM		x	
Nonconformance Reports	LM	LM	Revision or Date	LM		x	
Corrective Action Reports	LM	LM	Revision or Date	LM		x	

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Document	Location of Master	Obsolete Document Custodian	Method of Identifying Change	Custodian	Public	Restricted	Private
Supplier Assessment Records	LM	LM	Revision or Date	LM		x	
Supplier Lists	LM	LM	Revision or Date	LM	x		
Proposals	Office File	File Storage	Revision or Date	LM	x		
Transmittals	Office File	File Storage	Revision or Date	LM	x		
Lab File	Office File	File Storage	Revision or Date	LM	x		
Sample Control DB	Lab	LM	Revision or Date	LM	x		
Internal Audits	LM	LM	Revision or Date	LM		x	
Test records	Office File	File Storage	Revision or Date	LM		x	
External Testing Procedures	Office	LM	Revision or Date	LM	x		
MSDS Forms	LM	Dispose	Revision or Date	LM	x		
Inventory List	LM	Dispose	Revision or Date	LM		x	

OM = Office Manager
 GL = Group Leader
 LM = Laboratory Manager
 LS = Laboratory Supervisor
 HR = Human Resources

5.1 Laboratory Documents

The laboratory has established and maintains a checklist to control documents identified in the Quality Assurance Manual. To control data, a project number is marked on every page. As appropriate, other information that is pertinent such as project short title, sample number, material and/or date are also recorded.

A unique Golder internal number is assigned to each new project. This unique project number is placed on all samples and documents associated with the project.

Changes to documents are initiated, reviewed, and approved by the Laboratory Manager.

Documents are re-issued after revisions are made. Laboratory documents are kept for ten years prior to disposal.

Obsolete documents are removed from laboratory circulation by either recycling or waste disposal.

Document and Data Control Matrix is in Appendix A.

5.2 Laboratory File Format

A laboratory Test Schedule page (see Appendix A) is included in each new project file. The Schedule page(s) list the sample number and material type for each specimen and test specified.

The summary page or data page of test results notes the particular reference test standard used and any modifications to the methods.

The data and summary page(s) indicate the month and year that the testing was conducted or started.

The data and summary pages indicate the project number and client.

If provided, the data and summary page(s) indicate the specific project by name, city, province, and/or country.

5.3 Environmental/Accommodation

Environmental/Accommodations are documented in the QAM. This includes; but is not limited to; the humidity room, the curing room and the Triaxial lab. The annual fume hood calibration and the yearly inspection of the ventilation system are documented. Stickers are placed on the fume hood and the dust extractor indicating the calibrations and maintenance dates.

5.4 & 5.5 Equipment and Calibration

The Mississauga Laboratory adheres to Golder Associates Integrated Management Systems (GAIMS) GP3 Calibration & Equipment Best Practices. This ensures that measurement equipment is identified, protected, verified, calibrated, adjusted and repaired in order to ensure the validity of test results. Calibration records are kept in binders located in the Triaxial Lab, the Hydrometer Lab and the Concrete Lab.

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Sieves that are being used for laboratory testing are recorded with the serial number and each sieve is labeled with a sticker indicating the date checked and the person who inspected the sieve and the date of the next inspection.

6.0 CONTROL OF CUSTOMER-SUPPLIED PRODUCT: SUBCONTRACTING

6.1 Accredited Laboratories

When subcontracting tests, Golder selects an accredited (if applicable) laboratory for the test required. The subcontractor is contacted to discuss the test, sample size and the cost. The sample is sent with a transmittal identifying the test required. Accompanying the transmittal, a unique project number is used as a purchase order for payment of the test.

When reporting test results and upon the client's request, subcontractor test results are identified/acknowledged in the report or submitted directly to the client on subcontractor letter head.

7.0 IDENTIFICATION AND TRACEABILITY

Upon initial receipt of the material (sample) at our laboratory, identifying numbers are recorded on the appropriate laboratory documentation (log-in schedule form). An identification tag with the sample number is attached to the sample.

Laboratory personnel have the responsibility to identify samples and individual specimens during all stages of delivery, testing and storage by means of a log and physical markings on the sample and specimens or appropriate containers containing the sample and specimens.

The sample and specimen numbering system as outlined in 13.1 is implemented using the “Sample Control Database.” The number of test specimens is entered in a clear, logical and sequential fashion.

Records containing sample identification are maintained and kept by the Laboratory Manager and are referred to for further clarification of the specific sample to be tested.

Report identification and traceability is managed through the unique Golder internal project number which is on every page of the report and other pertinent information such as client, sample number, material and date.

8.0 INSPECTION AND TESTING

8.1 Incoming Material

All incoming material is initially examined by laboratory personnel upon arrival in the laboratory and before sample/specimen preparation. This typically consists of an initial examination for damaged samples (and tubes), or insufficient quantity of sample. If there are non-conforming samples, the Project Manager or Client is notified.

8.2 In Process

The samples to be tested are identified by using tags, labels or other suitable means established by the laboratory. (See Section 7.0)

The identification system (as discussed in Section 7.0) is intended to ensure that no confusion occurs regarding the identity of the sample and its replicate specimens during inspection, testing and storage.

After receiving the schedule sheet, Laboratory personnel consult the Laboratory Manager before proceeding with testing if the need arises.

A comment / remarks section is included on our data forms and log-in schedule form and this information may be included in the transmittal section of the project file.

Inspection of samples and specimens for testing includes identifying preparation requirements before testing.

8.3 Review of Test Results

Final review of test results is routinely conducted by the Laboratory Manager before issuing results to the client and is confirmed by signature. Additional input/review of the test results is available from the other members of the laboratory and management staff as required. The review consists of checking the project number, sample number, technician (initials), typographic errors, the data and results.

GOLDER ASSOCIATES LTD.
QUALITY ASSURANCE MANUAL

The Golder laboratory acts as an independent testing service that performs and reports the factual results of testing in accordance with the methods provided at the time of testing. Typically, our clients reserve the right to interpret the test results and decide whether the results pass or fail to meet their project requirements. The pass/fail decisions are made by specifically identified client personnel such as the project manager, design engineer, etc.

9.0 INSPECTION, MEASURING AND TESTING EQUIPMENT

9.1 Equipment

All equipment required to perform the laboratory testing to the ASTM, CSA, and MTO requirements are listed and kept in the Equipment Files of the Golder laboratory.

The laboratory equipment is properly and regularly maintained. The Inventory List and maintenance schedule are located in Appendix B.

References for pertinent measuring and test equipment (where available from the manufacturer) are maintained in an equipment inventory list included in Appendix B of the Quality Assurance Manual. This information includes the type and name of the piece of equipment, manufacturer's name and model number (where appropriate), serial and identification numbers, and the date when the equipment was received and placed into service.

The manufacturer's instructions for the equipment are kept on file in the Laboratory Manager's office. In addition, the Laboratory Manager maintains documented instructions on the use of measuring and test equipment.

When newly acquired equipment is placed into service, it is calibrated prior to use if necessary and at the next required interval. Equipment that is defective or out-of-service and cannot be corrected is disposed of or replaced with a new piece of equipment.

9.2 Equipment Calibration and Precision

Records and documentation for equipment calibration are maintained and are located in a calibration file in the Laboratory Manager office. A calibration checklist for the required equipment is included in Appendix B of the Quality Assurance Manual and is reviewed monthly to ensure equipment calibration is kept current.

Precision and accuracy records, for the pertinent test equipment are assessed by use of statistical test methods, nationally traceable standards, and established manufacturers target values. For commercial testing; where required, a quality control statistical test is performed on a sample of reference material prior to the start of testing each week or each month as required.

A Statement of Qualifications of the external calibration firms is maintained in the specific manufacturers / equipment file. (e.g. Hoskins Scientific; Fischer Scientific; Circuit Scale)

The Laboratory Manager and laboratory personnel are responsible for ensuring that the laboratory test performed is consistent with the test standards and accuracy that is required within the context of the prescribed methods for the specific test being conducted.

9.3 Computer and Automated Data Acquisition Equipment

The computers and automated data logging equipment used in the laboratory have proven to be effective for the recording, processing, manipulation, reporting, storage, and retrieval of data. The computer and other automated equipment are maintained by both laboratory personnel and, as appropriate, by an independent servicing firm.

The computer and automated equipment is situated in a controlled environment necessary to maintain proper functioning of the equipment and the integrity of the test data.

Computer software appropriate for the testing application is employed. Golder keeps a copy of the software license on file.

Data obtained for an individual test that is not data acquisition automated are manually written on the appropriate laboratory forms and, in some instances, recorded mechanically from the automated equipment (i.e. graphic plots). Hand written data from the laboratory forms are manually entered into a computer, and saved to a unique project specific computer file. Hand written forms are archived in a secure file cabinet in the laboratory. Data entry into the computer and the hand written forms are crosschecked for accuracy. A hard copy of the computer-generated data is also included in the project file.

Golder has a computer network system that maintains all software and electronic files. Only Golder employees have access to this network system. The network files are backed-up each night by the information technology (IT) staff.

10.0 INSPECTION AND TEST STATUS

Inspection of samples and specimens for testing includes identifying preparation requirements (including specific client's preparation instructions) prior to testing of materials.

The laboratory assignment (log) sheet identifies the status of all test samples and it is located in the project file. An example of the log sheet is included in Appendix A of the Quality Assurance Manual.

11.0 CONTROL OF NONCONFORMING TEST RESULTS

11.1 Nonconforming Testing

Nonconforming test results that may arise from poor sample preparation, inadequate environment, a visually identifiable flaw, insufficient size or amount of material or wrong test procedures are recorded on the nonconformance report sheet and placed in the laboratory file. An example of the nonconformance report sheet is included in Appendix A of the Quality Assurance Manual.

11.2 Nonconforming Sub-contracting Testing

Nonconforming testing performed by a sub-contractor shall be treated using the same procedure as the internal nonconforming testing. The Laboratory manager is responsible for verifying that the nonconformance has been corrected and closed.

11.3 Nonconforming Equipment, Material, Consumables and Client Complaints

When the nonconforming equipment, material or consumables are received the Lab Manager will investigate the nonconformance and record on a nonconformance report and follow up with the corrective action where required. Client complaints will be recorded on a nonconformance report. Laboratory manager will contact the customer and be responsible for the resolution of the complaints.

The nonconformance report provides details of the nonconformance including the prime cause, description of the nonconformance and possible disposition.

12.0 CORRECTIVE ACTION

Any nonconformance during testing or with the equipment as well as customer complaints are immediately reported to the Laboratory Manager who initiates appropriate corrective actions and preventive actions to remedy the problem. A corrective action form is filled out (example in Appendix A of the Quality Assurance Manual). The problem is identified and the cause of the problem (if known) is noted. A corrective and preventive action to solve the problem is outlined and initiated. The form is signed and dated. At the end of the year, a summary of the number of Non-Conformances and Opportunities for Improvements, the problems, and resolutions are reviewed by the Quality Managers and presented to the Office Manager in the quality records report. Examples of major problems include air compressor malfunctions, power failures, calibrations overdue, broken load cells, damaged sieves requiring replacement, etc.

13.0 HANDLING, STORAGE, DISPOSAL, PACKING AND DELIVERY

13.1 Handling

Golder requests that samples be packed and shipped to the laboratory in such a manner as to prevent damage during shipping. However, Golder can only provide recommendations for appropriate shipping procedures. Golder cannot dictate to its clients the method and conditions of shipment of the product material. As noted in Section 8.1, Golder does perform an examination of the samples upon receipt in the laboratory.

When samples arrive at the Golder Mississauga facility they are taken to the lab receiving area. Schedule sheets are processed which identifies the samples and the form is given to the engineer who will then schedule the testing. Once scheduled; the samples are then given a unique identification number which consists of a 2 digit number representing the year followed by a four digit number representing the ascending sample numbers. This is implemented through the software program called the “Sample Control Database”. This database keeps records of all samples placed into the system and projects and samples numbers can easily be recalled and listed. The unique number is placed on the sample with marker to ensure proper identification.

The Laboratory Manager or designate as required are the only authorized persons to implement placement and removal of samples into and out of storage.

Temperatures in the laboratory are monitored and recorded using a data logger and are controlled with our heating, ventilating and air conditioning (HVAC) unit. This data is available upon request.

A separate room (Humidity Room) equipped with an air-conditioner and a humidifier is used for the storage of undisturbed samples. An inventory of the samples in this room is part of the laboratory sample storage record.

13.2 Storage

All material is stored to preserve and segregate all samples from the time of receipt until the laboratory's responsibility for sample storage ceases as stated in the sample storage policy in the Quality Assurance Manual. (13.1)

Soil samples from foreign countries, lands, or sources other than continental North America are disposed of according to the Canadian Department of Agriculture Regulations located in the laboratory manager's office, or returned to client.

The laboratory maintains a sample archive storage area which consists of a heated and ventilated indoor warehouse space equipped with fluorescent lighting.

13.3 Disposal

Soil samples that are contaminated are identified with a red adhesive label clearly stating "Contaminated Soil". When the Project Manager signs off for disposal of the sample; Regulation 347 permits up to 5kg a month of contaminated wastes can be disposed of in a regular disposal bin. If the samples weigh more than the allowable amount, Clean Harbors Environmental Services or an alternate service provider picks up the soil and disposes them according to the Provincial Regulations.

13.4 Packaging

All specimens tested in the laboratory are properly identified and segregated while in the possession of the laboratory.

13.5 Delivery

The test results produced in the laboratory are accompanied by either a letter report or are submitted as a summary report of the test results.

The report of the test results presents accurate, unambiguous, objective information in compliance with the specified test method. The level of detail provided in the report complies with the client's requirements at the time of testing.

Test results are identified by the name and address of our laboratory.

The report contains the name and address of the client.

The report describes and identifies the number of items (samples and specimens) tested.

As a matter of routine, the sample scheduling form indicates the date of receipt of each sample. The laboratory test data form indicates the date that the test was performed. The report presented to our client does not typically state the dates of receipt and performance of the tests due to the potential confusion it could cause. Samples are typically subjected to several tests, which may not be performed on the same date. Conversely, one test may take several days.

The record of each sample indicates the test method used and an unambiguous description of any non-standard methods or modifications.

If necessary, the report contains appropriate tables, graphs, and photographs.

The report is signed, titled, and dated by the Laboratory Manager and Quality Managers as appropriate.

Golder laboratory reports typically do not contain a disclaimer stating that the results relate only to the items tested. As an independent commercial laboratory, the scope of services provided contains an implicit understanding that the reported test results apply only to the sample tested. The interpretation of the results is the responsibility of our client or his designated representative.

The Golder laboratory report typically does not contain a warning regarding reproducing the report without the written approval of the laboratory and the client. This issue is commonly covered as part of the legal agreement between Golder and our client.

14.0 QUALITY RECORDS

The laboratory has established and maintained procedures for identification, indexing, filing, storage maintenance, and disposal of quality records, and project records. An assigned project number in increasing numerical order organizes the project records. A typical lab project file consists of:

- Sample scheduling form
- Computer generated hard copy of results (Summary Sheets and Data Pages) and invoices.
- Laboratory test data forms (hand-recorded results) along with appropriate graphs and charts.

All quality records and project records are held secure and in confidence to the client by the Laboratory Manager and as stated in the Employee Handbook.

The quality records such as Non-Conformances, Opportunities for Improvement, internal audits, external audits and proficiency testing are summarized in the Quality Management Meeting Minutes. The final report is then presented to the Office Manager as required, in a concise report by the Laboratory Manager.

15.0 QUALITY AUDITS – INTERNAL & EXTERNAL

15.1 Internal

An internal audit is performed once a year by the Audit Team that is independent of the direct responsibility of the laboratory. The results of the audit are maintained in the Quality Assurance Manual. Any deficiencies and corrective actions are noted and discussed with the Laboratory Manager. The Quality Managers and the Laboratory Manager set a timely resolution. After, the set time, a follow-up is conducted by the Quality Managers and noted. The results of the audit are compiled and presented to the Office Manager in the quality records report (see Section 14.0).

15.2 External

Independent external audits are done by CCIL, MTO, CSA and ISO to verify and accredit that the Golder Associates Mississauga Laboratory operations continue to comply with the requirements of the quality system.

15.3 Deficiencies

Deficiencies identified by the internal and/or external audits and proficiency testing are corrected as soon as practical. When deficiencies occur either from an on-site audit or through proficiency testing, the following procedures are followed.

On-Site Audit Deficiencies

1. Reviews of the deficiencies are examined.
2. A plan of action is devised for correcting the deficiencies.
3. If deficiencies are found within the quality system, the Quality System Manual is updated following a meeting held with the laboratory personnel on the change that has occurred such that they are made aware of the changes that could affect their work.

4. If deficiencies are found with laboratory equipment, the equipment is calibrated, repaired, replaced, or removed from service.
5. Once the deficiencies are resolved, the auditing firm and Quality Managers are notified.

Proficiency Testing Deficiencies

1. A review of the deficiencies are examined and discussed between the Laboratory Manager and Quality Managers.
2. The laboratory test results (computer and hand written) are reviewed for possible transcription errors.
3. The laboratory technician performing the test is questioned in regards to the procedure that was followed.
4. The equipment is checked for calibration and for any malfunctions that may have occurred.
5. If an error in the reporting or transcription is discovered, it is corrected.
6. If an error is found in the equipment or procedure, the test is repeated with fully functioning and calibrated equipment and the correct procedure is followed and witnessed by the Laboratory Manager.
7. The error is reported on the worksheet and kept in the laboratory file along with the new or updated test results.

16.0 TRAINING

The Laboratory Manager ensures that the laboratory staff have the necessary education, training, technical knowledge, and experience to perform the assigned tasks in the laboratory.

The Laboratory Manager ensures that the laboratory staff receives initial training and that this training record is kept up to date through exposure of personnel to the various tests conducted, through supervision, and through exchange of information and ideas. The Laboratory Manager is also responsible for attending seminars and relaying any pertinent information and pamphlets to the laboratory files and to the laboratory personnel.

17.0 STATISTICAL TECHNIQUES

The laboratory maintains consistency with precision and bias statements (where applicable) outlined in the specific ASTM test method for the test performed, by statistical data developed from laboratory testing of reference material and/or manufacturer's published data.

In-house Reference Material is used as part of Quality Control (QC). The QC allows us to check that the personnel is preparing and testing a specimen correctly and to check that our instruments used during testing are operating properly. This QC is performed monthly. Currently in-house reference material is available for hydrometers and Atterberg limits testing. Specific gravities and wash sieves are performed on a monthly basis.

QC is also used to supplement the specified schedule of calibrations that are performed on our instruments to insure that accuracy and precision are not sacrificed. The results from the QC are compared to the results as tabulated from previous and ongoing testing. The results are stored in a database to generate statistical information such as average and standard deviations that are presented for comparison with guidelines with the particular method.

QC testing is carried out on two types of material to offer a high and low range of statistical results.

Appendix H

Example Field Records

- o Soil Boring/Rock Coring Log
- o Monitoring Well Construction Record
- o Monitoring Well Development Record
- o Water Quality Instrument Calibration Record
- o Low Flow Groundwater Collection Record
- o Water Level Record
- o EPL LNAPL Gauging Record
- o Slug Testing Record
- o MassDEP Indoor Air Quality Building Survey
- o Sub-Slab Vapor Sample Collection Record
- o IDW Inventory Log
- o Project Photograph Log
- o AECOM Chain of Custody Form
- o Spectrum Analytical Chain of Custody Form
- o Alpha Analytical Chain of Custody Form
- o Microbial Insights Chain of Custody Form
- o Isotech Chain of Custody Form

							Client:		BORING ID:			
							Project Number:					
							Site Location:					
							Coordinates:		Elevation:		Sheet: 1 of	
							Drilling Method:				Monitoring Well Installed:	
							Sample Type(s):		Boring Diameter:		Screened Interval:	
Weather:							Logged By:		Start Date/Time:		Depth of Boring:	
Drilling Contractor:									Finish Date/Time:		Water Level:	
Depth (ft)	Geologic sample ID	Sample Depth (ft)	Recovery (inches)	Headspace (ppm)	Moisture	U.S.C.S	MATERIALS: Color, size, range, MAIN COMPONENT, minor component(s), moisture content, structure, angularity, maximum grain size, odor, and Geologic Unit (If Known)					Lab Sample ID (Depth)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
NOTES:									Date/Time	Depth to groundwater while drilling		
Checked by _____									Date: _____			

VISUAL IDENTIFICATION OF ROCK CORES

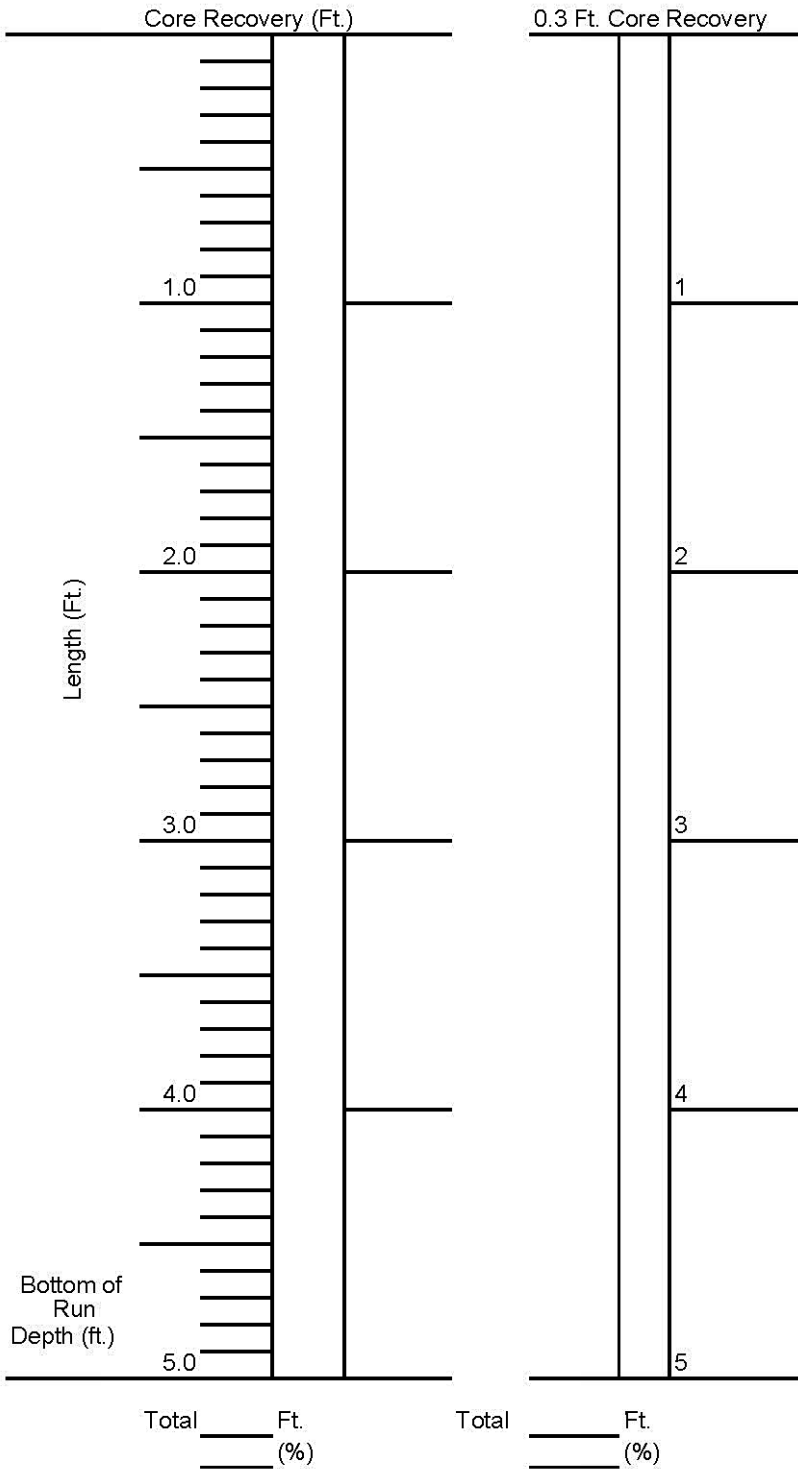
Boring ID: _____

Sheet _____ of _____

Client	Project Number	Location	Date
Logged By	Sample	Core Dia. (In.)	Depth (Ft.)
Core Length (Ft.)	Core Recovery (Ft.)	RQD %	Rock Quality
Driller	Drill Equipment	Start Time	Finish Time

Top of Run
Depth (ft.)

Rock Description and Identification
(include fracture dip & description, bedding
planes, and other geologic features.)





Client:	
Project Number:	
Site Location:	
Well Location:	Coords:
Method:	

WELL ID:
Date Installed:
Inspector:
Contractor:

MONITORING WELL CONSTRUCTION DETAIL

		Depth from G.S. (feet)	Elevation(feet) Datum _____
	Top of Steel Guard Pipe	_____	_____
Measuring Point for Surveying & Water Levels	Top of Riser Pipe	_____	_____
	Ground Surface (G.S.)	0.0	_____
Cement, Bentonite, Bentonite Slurry Grout, or Native Materials	Riser Pipe:		
	Length _____		
% Cement _____	Inside Diameter (ID) _____		
	Type of Material _____		
% Bentonite _____			
% Native Materials _____	Bottom of Steel Guard Pipe	_____	_____
	Top of Bentonite	_____	_____
	Bentonite Seal Thickness _____		
	Top of Sand	_____	_____
	Top of Screen	_____	_____
	▲ Stabilized Water Level	_____	_____
	Screen:		
	Length _____		
	Inside Diameter (ID) _____		
	Slot Size _____		
	Type of Material _____		
	Type/Size of Sand _____		
	Sand Pack Thickness _____		
	Bottom of Screen	_____	_____
	Bottom of Tail Pipe:	_____	_____
	Bottom of Borehole	_____	_____
	Borehole Diameter: _____		
	Approved: _____		
Describe Measuring Point:	Signature _____	Date _____	

Well ID:

Well/Piezometer Development Record

Client: _____ Site Location: _____
Project No: _____ Date: _____ Field Staff: _____

WELL/PIEZOMETER DATA

Well ☐ Piezometer ☐ Diameter: _____ Material: _____
Measuring Point Description _____ Geology at Screen Interval _____
(if known) _____
Depth to Top of Screen (ft.) _____
Depth to Bottom of Screen (ft.) _____ Time of Water Level Measurement _____
Total Well Depth (ft.) _____ Calculate Purge Volume (gal.) _____
Depth to Static Water Level (ft.) _____ Disposal Method _____

Original Well Development ☐ **Redevelopment** ☐ Date of Original Development _____

DEVELOPMENT METHOD

PURGE METHOD

Field Testing Equipment Used: _____ Make _____ Model _____ Serial Number _____

Field Testing Calibration Documentation Found in Field Notebook # _____ Page # _____

Time	Volume Removed (gal)	Turbidity (NTUs)	Color	Odor	Other

ACCEPTANCE CRITERIA (from workplan)

Min. Purge Volume (___ well volumes) _____ gallons

Maximum Turbidity Allowed: ___ NTUs

Stabilization of parameters: **N/A**

Has required volume been removed

Has required turbidity been reached

Have parameters stabilized

If no or N/A explain below:

Yes No N/A

☐ ☐ ☐

☐ ☐ ☐

☐ ☐ ☐

Signature: _____ Date: _____



Lockheed Martin - Former General Electric Site - Wilmington, MA
Water Quality Instrument Calibration Record

Project No: _____

Personnel: _____

Date: _____

Parameter	Instrument		Standard		Std. Value @ 25 °C	Ambient Temp °C	Initial Value	Adjusted Value	Initials & Time	Comments	Post Cal Criteria
	Manf/Model	Serial No.	Manf/Model	SN/Exp. Date							
pH 10.00	YSI/ 556		US Environmental	lot:	10.00						
			exp.:				----		Post Cal	+/-0.3	
pH 7.00			US Environmental	lot:	7.00						
			exp.:				----		Post Cal	+/-0.3	
pH 4.00			US Environmental	lot:	4.00						
			exp.:				----		Post Cal	+/-0.3	
SpCond (1,000)			US Environmental	lot:	1,000 uS/cm						
			exp.:				----		Post Cal	+/- 5% or 10uS/cm	
DI Water (Check Conductivity)				lot:	0.00 uS/cm						
			exp.:				----		Post Cal	+/- 5% or 10uS/cm	
ORP	Zobell	lot:									
	exp.:				----		Post Cal	+/- 10mV			
DO	H ₂ O sat'd air	N/A	mg/L						BP =		
			°C			----		Post Cal	BP =	+/-0.5mg/L	
Zero DO (Check Only)	US Environmental	lot:							BP =		
			exp.:			----		Post Cal	BP =	<0.5mg/L	
Turbidity					0.00 NTU	N/A				Post Cal = NTU @	
					10.00 NTU					Post Cal = NTU @	+/-5%
All measured values must be corrected for temp. unless the instrument is operated in the ATC mode. DO measurements must also be corrected for barometric pressure.											
Temperature conversion °C = 5/9(°F-32)											
BP = Barometric Pressure (mmHg)											
NOTES:											

Well ID:

Low Flow Ground Water Sample Collection Record

Client: _____ Date: _____ Time: Start _____ am/pm
Project No: _____ Finish _____ am/pm
Site Location: _____
Weather Conds: _____ Collector(s): _____

1. WELL & WATER LEVEL DATA: (measured in feet from Top of Casing unless noted)

a. Total Well Length _____ c. Screen Length _____
b. Water Table Depth _____ d. Pump Intake _____
e. Calculated System Purge Volume _____ (calculation on page 2)

2. WELL PURGE DATA

a. Purge Method: _____

b. Acceptance Criteria defined (see workplan)

- Temperature	3%	- D.O.	< 0.5 mg/L	- Drawdown	< 0.3 ft
- pH	± 1.0 unit		> 0.5 mg/L within 10%	- Turbidity	< 10 NTU
- Sp. Cond.	3%	- ORP	± 10 mV		> 10 NTU within 10%

c. Field Testing Equipment used: _____ Make _____ Model _____ Serial Number _____

Time (24hr)	Volume Removed (Liters)	Temp. (°C)	pH	Spec. Cond. (μ S/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Flow Rate (ml/min)	Drawdown (feet)	Color/Odor

d. Acceptance criteria pass/fail

	Yes	No	N/A	(continued on back)
Has required volume been removed	☐	☐	☐	
Has required turbidity been reached	☐	☐	☐	
Have parameters stabilized	☐	☐	☐	

If no or N/A - Explain below.

3. SAMPLE COLLECTION: Method: _____

Sample ID	Container Type	No.	Preservation	Analysis Req.	Time

Comments _____

Signature _____ Date _____

[illegible]



Weather: _____ Recorder(s): _____

Notes:	



Lockheed Martin - Former GE Site - Wilmington, MA

Building 3 EPL LNAPL Gauging Record

Date: _____

Weather: _____

Recorder(s): _____

Initial Gauging						
Well	Time	Depth to LNAPL (ft btoc)	Depth to Water (ft btoc)	Depth to DNAPL (ft btoc)	Depth to Bottom (ft btoc)	Comments
PZ-2S						
CW-1						
CW-2						
TRC-101R						
Confirmed product with bailer (Y/N)						
Product removed (Y/N)						
Note: If LNAPL is detected at thickness > 0.03 feet, insert absorbant wick and wire basket into well and secure tightly.						
Dispose of spent wicks in drum or 5 gallon bucket within treatment building.						
Post-Product Removal Gauging						
Well	Time	Depth to LNAPL (ft btoc)	Depth to Water (ft btoc)	Depth to DNAPL (ft btoc)	Depth to Bottom (ft btoc)	Comments
PZ-2S						
CW-1						
CW-2						
TRC-101R						
Gauging device used (Mnfr./Model No.):						
Notes:						

ft btoc = feet below top of PVC casing

Well ID:

HYDRAULIC CONDUCTIVITY TEST LOG

Client: _____

Date: _____

Time: Start _____ am/pm

Project No: _____

Finish _____ am/pm

Site Location: _____

Weather Conds: _____

Tester (s): _____

1. WELL INFORMATION

a. Ref. Point Elev. _____

e. Total Well Depth _____

i. Screen Length _____

b. Static Depth to GW _____

f. Gravel Pack Diameter _____

j. Geology of Screened Interval _____

c. Time of GW reading _____

g. Water Column Height _____ (e-b) _____

d. Static GW Elev. (Ho) _____ (a-b) h. Casing Diameter _____

2. SLUG INFORMATION (see back for volume calculation)

a. Slug Length _____

b. Slug Diameter _____

3. DATA COLLECTION

a. Method of Data Collection: Manual _____ Electronic _____
(see back)

b. Transducer Information

c. Data Logging Information

Make _____

Model _____

Serial Number _____

Offset _____

Linearity _____

Scale _____

Coefficient _____

Diameter/Length _____

Make _____

Model _____

Serial Number _____

Mode _____ (linear or logarithmic)

Ref. Point (designation) _____ (TOC, Ground Surface, actual elev.)

Ref. Point value (if elev.) _____

Positive numbers indicate increase or decrease in water level
(circle one)

4. HYDRAULIC TEST INFORMATION

Start Time	Test Type (rising, falling)	Electronic File Name	Comments	End Time
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

5. MANUAL WATER LEVEL READINGS (as needed for control)

Time	Location	Depth to Water	Time	Location	Depth to Water
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Signature _____

Date _____

6. EXPECTED WATER LEVEL DISPLACEMENT CALCULATION (optional)

- a. Diameter of Slug (in) _____
 b. Length of Slug (ft) _____
 c. Volume/Linear ft of Slug (gal/ft from chart) _____
 d. Volume of Slug (gal) _____ (b*c)
 e. Diameter of Well (in) _____
 f. Volume/Linear ft of Well (gal/ft from chart) _____
 g. Expected Change in Water Level _____ (d/f)

Volume / Linear Ft. of Pipe		
Diam. (in)	Gallon	Liter
0.25	0.0025	0.0097
0.375	0.0057	0.0217
0.5	0.0102	0.0386
0.75	0.0229	0.0869
1	0.0408	0.1544
1.25	0.0637	0.2413
1.5	0.0918	0.3475
2	0.1632	0.6178

Note: Water column height (1-g from front page) must be greater than transducer length plus length of slug.

7. MANUAL WATER LEVEL MEASUREMENTS

[illegible]

Indoor Air Quality Building Survey

Date: _____

ID#: _____

Address: _____

Building Contact: _____ Phone: Tel: () _____
 Cell: () _____
 Work: () _____

List of Current Occupants:

INITIALS	AGE	SEX (M/F)

Building Construction Characteristics:

(Circle, Highlight or Underline appropriate responses)

Single Family	Multiple Family	School	Commercial
Ranch	2-Family		
Raised Ranch	Duplex		
Cape	Apartment House		
Colonial	# of units _____		
Split Level	Condominium		
Colonial	# of units _____		
Mobile Home	Other (specify) _____		
Other (specify) _____			

General Description of Building Construction Materials: Wood, Brick, Stone, Metal, Other

How many occupied stories does the building have? _____

Has the building been weatherized with any of the following?

Insulation Storm Windows Energy-Efficient Windows Other (specify) _____

What type of basement does the building have?

Full basement Crawl space Slab-on-Grade Other (specify) _____

What are the characteristics of the basement?

Finished	<u>Basement Floor:</u>	<u>Foundation Walls:</u>	<u>Moisture:</u>
Unfinished	Concrete	Poured Concrete	Wet
Other (specify) _____	Dirt	Block	Damp
	Layed Up Stone	Dry	

Is a basement sump present? (Y/N) _____

Does the basement have any of the following characteristics (i.e., preferential pathways into the building) that might permit soil vapor entry:

Cracks	Pipes/Utility Conduits	Other (specify) _____
Foundation/slab drainage	Sump pumps	

Heating and Ventilation System(s) Present:

What type of heating system(s) are used in this building?

Hot Air Circulation	Heat Pump	Steam Radiation	Wood Stove
Hot Air Radiation	Unvented Kerosene heater	Electric Baseboard	Other (specify): _____

What type (s) of fuel(s) are used in this building?

Natural Gas	Electric	Coal	Other (specify): _____
Fuel Oil	Wood	Solar	

What type of mechanical ventilation systems are present and/or currently operating in the building?

Central Air Conditioning	Mechanical Fans	Bathroom Ventilation
Fan	Kitchen Range Hood	Open Windows
Individual Air Conditioning Units	Air-to-Air Heat Exchanger	Other (specify): _____

Sources of Chemical Contaminants:

Do one or more smokers occupy this building on a regular basis? _____

Has anybody smoked in the building in the last 48 hours? _____

Does the building have an attached garage? _____

If so, is the garage used for parking cars? _____

Do the occupants of the building frequently have their clothes dry-cleaned? _____

Was there any recent remodeling or painting done in the building? _____

Are there any pressed wood products in the building (e.g., hardwood plywood wall paneling, particleboard, fiberboard)? _____

Are there any new upholstery, drapes or other textiles in the building? _____

Has the building been treated with any insecticides/pesticides? If so, what chemicals are used and how often are they applied? _____

Which of these items are present in the building? (Check all that apply)

Potential VOC Source	Location of Source	Removed 48 hours prior to sampling ?(Yes/No/NA)
Paints or paint thinners		
Gas-powered equipment		
Gasoline storage cans		
Cleaning solvents		
Air fresheners		
Oven cleaners		
Carpet/upholstery cleaners		
Hairspray		
Nail polish/polish remover		
Bathroom cleaner		
Appliance cleaner		
Furniture/floor polish		
Moth balls		
Fuel tank		
Wood stove		
Fireplace		
Perfume/colognes		
Hobby supplies (e.g., solvents, paints, lacquers, glues, photographic chemicals)		
Scented trees, wreaths, potpourri, etc.		
Other		
Other		
Other		
Other		

Outdoor Sources of Contamination:

Do any of the occupants apply pesticides/herbicides in the yard or garden? If so, what chemicals are used and how often are they applied?

Is there any stationary emission source in the vicinity of the building?

Are there any mobile emission sources (e.g., highway, bus stop, high-traffic area) in the vicinity of the building?

Weather Conditions During Sampling:

Outside Temperature (°F):

Prevailing wind direction and approximate wind speed: _____

Describe the general weather conditions (e.g., sunny, cloudy, rain): _____

Was there any significant precipitation (0.1 inches) within 12 hours preceding the sampling event? _____

Type of ground cover (e.g., grass, pavement, etc.) outside the building: _____

General Comments

Is there any other information about the structural features of this building, the habits of its occupants or potential sources of chemical contaminants to the indoor air that may be of importance in facilitating the evaluation of the indoor air quality of the building?

Adapted from

NHDES (New Hampshire Department of Environmental Services). October, 1998. "Residential Indoor Air Sampling Form." *Draft Residential Indoor Air Assessment Guidance Document*. Waste Management Division. Site Remediation Programs.

NYSDOH (New York State Department of Health). 1997. "*Indoor Air Quality Questionnaire and Building Inventory*." Division of Environmental Health Assessment. Bureau of Toxic Substance Assessment.

VDOH (Vermont Department of Health). June, 1993. "*Indoor Air Study Questionnaire*."

FIGURE 6-2

Soil Gas Sampling Log Sheet

Sample ID _____

Client: _____
Project Name: _____
Project Number: _____
Date: _____
Sampler: _____

Location: _____
Canister Number: _____
Core Diameter: _____ Core Material: _____
Core Length: _____
Magnehelic Measurement: (Positive number indicates higher pressure in Core) _____
Depth of Hand Auguring: _____
Soil Type: _____
Method of Probe Advancement: _____
Depth of Probe Advancement: _____ Length Probe is Retracted: _____

Time of Purging	PID Reading	Time of Purging	PID Reading
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Starting Time: _____ Starting Pressure: _____
Finish Time: _____ Final Pressure: _____

Room Dimensions: Length: _____ Width: _____ Height: _____

Comments:

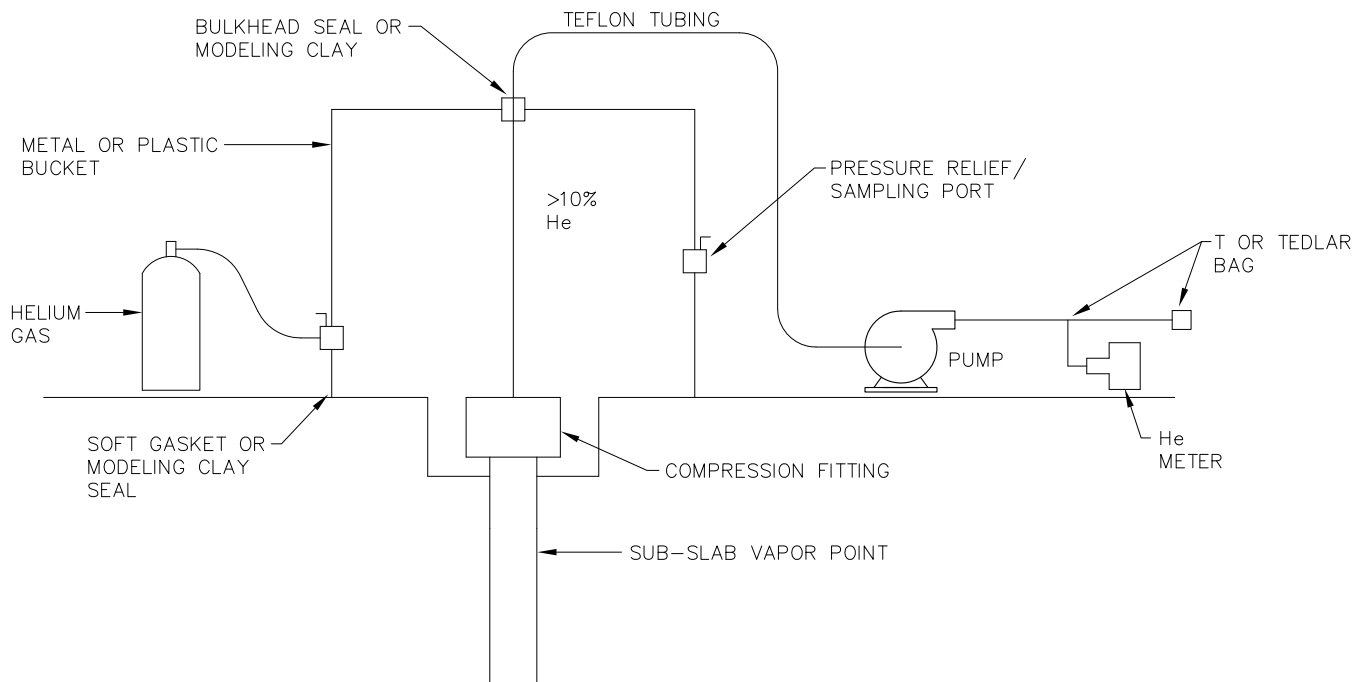
Indoor Air/Ambient Air Sample

Sample ID _____

Location: _____
Sample ID: _____
Canister Number: _____
Starting Time: _____ Starting Pressure: _____
Finish Time: _____ Final Pressure: _____

Comments:

General Weather Conditions: _____
Chemical Inventory: _____



NOTES:

1. USE BRASS FITTINGS FOR TEST CHAMBER. FITTINGS TO BE CLEANED PRIOR TO USE.
2. CHECK HOSE DIAMETERS OF HELIUM METER, PUMP, AND SUMMA CANISTERS PRIOR TO ARRIVING AT SITE.
3. USE WEIGHT ON TOP OF TEST CHAMBER TO HOLD IN PLACE.
4. FILL TEST CHAMBER TO AT LEAST 10% HELIUM.

FILENAME: 05510-106-05A.DWG

ENSR | AECOM

ENSR CORPORATION
 2 TECHNOLOGY PARK DRIVE
 WESTFORD, MASSACHUSETTS 01886
 PHONE: (978) 589-3000
 FAX: (978) 589-3100
 WEB: HTTP://WWW.ENSR.AECOM.COM

LEAK TEST SET-UP

FIGURE NUMBER:

2

DRAWN BY:
K.P.B.

DATE:
7/08

PROJECT NUMBER:
05510-106-0207

SHEET NUMBER:
1



Lockheed Martin
Former GE Site
50 Fordham Road - Wilmington, MA
2012 Site Wide Activities

Drum ID	Contents	Location(s) Generated	Date(s) of Generation	Lab Results Due Date	Date Transported Off-site	Transportation Firm	Place of Disposal	Date Final Disposal Paperwork Received
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Notes: _____



PHOTOGRAPHIC LOG

Client Name:
Lockheed Martin

Site Location:
Former GE Site – Wilmington, MA

Project No.
60267214

Photo No.

Date:

**Direction Photo
Taken:**

Description:

Photo No.

Date:

**Direction Photo
Taken:**

Description:



CHAIN OF CUSTODY RECORD

Page ____ of ____

Client/Project Name:			Project Location:						Analysis Requested										<u>Container Type</u> P – Plastic A – Amber Glass G – Clear Glass V – VOA Vial O – Other E – Encore		<u>Preservation</u> 1 – HCl, 4° 2 – H2SO4, 4° 3 – HNO3, 4° 4 – NaOH, 4° 5 – NaOH/ZnAc, 4° 6 – Na2S2O3, 4° 7 – 4°	
AECOM Project Number: AECOM PO Number:			Field Logbook No.:																<u>Matrix Codes:</u> DW – Drinking Water WW – Wastewater GW – Groundwater SW – Surface Water ST – Storm Water W – Water		S – Soil SL – Sludge SD – Sediment SO – Solid A – Air L – Liquid P – Product	
Sampler (Print Name)/(Affiliation):			Chain of Custody Tape Nos.:																Lab I.D.		Remarks	
Signature:			Send Report to:			TAT:																
Field Sample No./Identification	Date	Time	C O M P	G R A B	Sample Container (Size/Mat'l)	Matrix	Preserv.	Field Filtered														
Relinquished by: (Print Name)/(Affiliation)			Date:		Received by: (Print Name)/(Affiliation)					Date:		Analytical Laboratory (Destination):										
Signature:			Time:		Signature:					Time:												
Relinquished by: (Print Name)/(Affiliation)			Date:		Received by: (Print Name)/(Affiliation)					Date:												
Signature:			Time:		Signature:					Time:		Sample Shipped Via: Temp blank										
Relinquished by: (Print Name)/(Affiliation)			Date:		Received by: (Print Name)/(Affiliation)					Date:												
Signature:			Time:		Signature:					Time:												
												UPS FedEx Courier Other Yes No										



SPECTRUM ANALYTICAL, INC.
Featuring
HANIBAL TECHNOLOGY

CHAIN OF CUSTODY RECORD

Page ____ of ____

Special Handling:

- ☐ Standard TAT - 7 to 10 business days
- ☐ Rush TAT - Date Needed: _____
 - All TATs subject to laboratory approval.
 - Min. 24-hour notification needed for rushes.
 - Samples disposed of after 60 days unless otherwise instructed.

Report To: _____

Telephone #: _____

Project Mgr. _____

Invoice To: _____

P.O. No.: _____ RQN: _____

Project No.: _____

Site Name: _____

Location: _____ State: _____

Sampler(s): _____

1=Na₂S₂O₃ 2=HCl 3=H₂SO₄ 4=HNO₃ 5=NaOH 6=Ascorbic Acid 7=CH₃OH
8= NaHSO₄ 9= Deionized Water 10=H₃PO₄ 11= _____ 12= _____

List preservative code below:

QA/QC Reporting Notes:

* additional charges may apply

DW=Drinking Water GW=Groundwater WW=Wastewater
O=Oil SW= Surface Water SO=Soil SL=Sludge A=Air
X1= _____ X2= _____ X3= _____

Containers:

Analyses:

MA DEP MCP CAM Report: Yes ☐ No ☐
CT DPH RCP Report: Yes ☐ No ☐

QA/QC Reporting Level

- ☐ Standard ☐ No QC ☐ DQA*
- ☐ NY ASP A* ☐ NY ASP B*
- ☐ NJ Reduced* ☐ NJ Full*
- ☐ TIER II* ☐ TIER IV*

☐ Other _____

State-specific reporting standards:

G=Grab C=Composite

Lab Id:	Sample Id:	Date:	Time:	Type	Matrix	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic										

Relinquished by:

Received by:

Date:

Time:

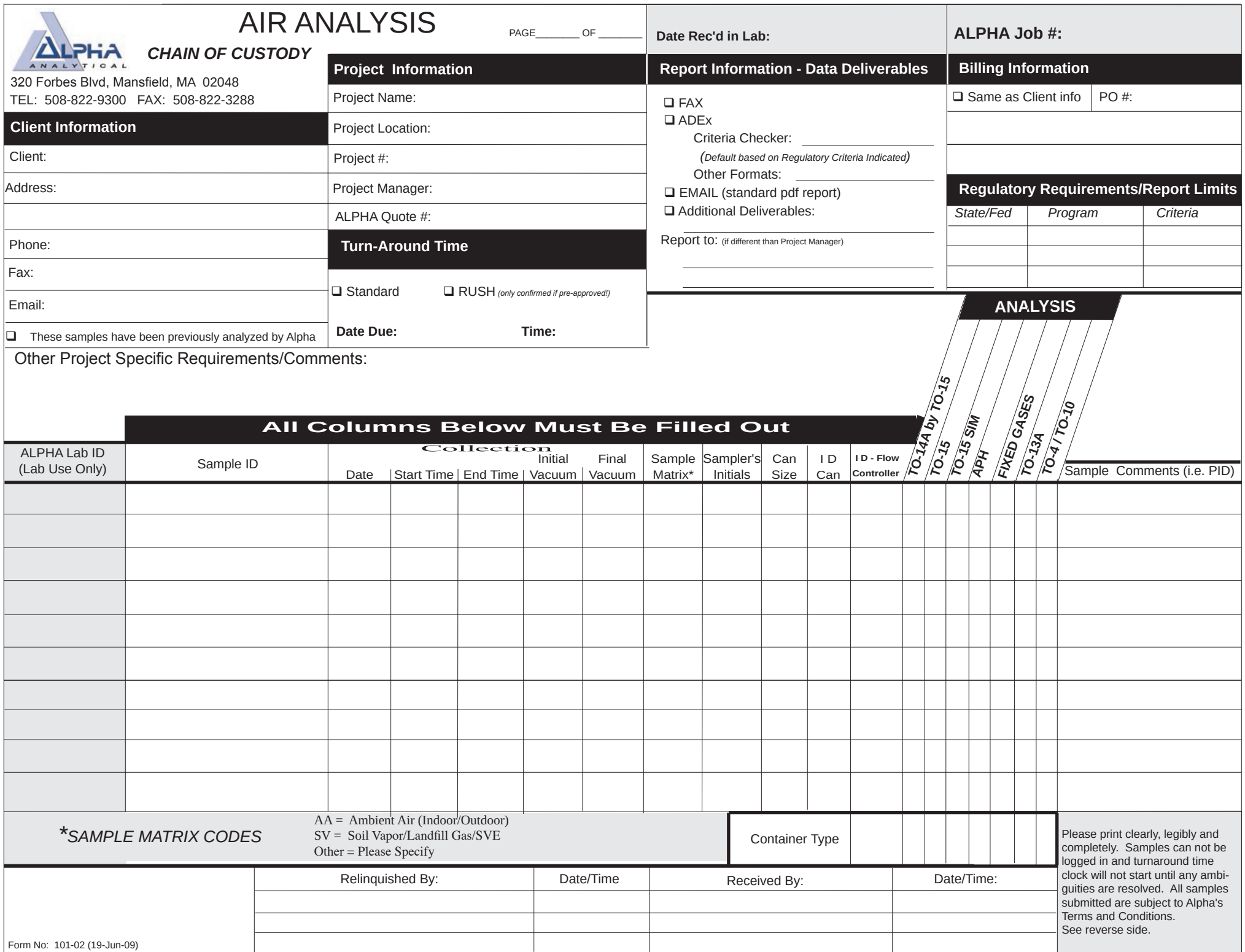
Temp°C

☐ EDD Format _____

☐ E-mail to _____

Condition upon receipt:

☐ Ambient ☐ Iced ☐ Refrigerated ☐ DI VOA Frozen ☐ Soil Jar Frozen



Name: _____

Company: _____

Address: _____

email: _____

Phone: _____

Fax: _____

Project Manager: _____

Project Name: _____

Project No.: _____

Name:	
Company:	
Address:	
email:	
Phone:	
Fax:	
Purchase Order No.	
Subcontract No.	



- ☐ More samples to follow
- ☐ No Additional Samples

Please contact us with any questions about the analyses or filling out the COC at (865) 573-8188 (9:00 am to 5:00 pm EST, M-F). After these hours please call (865) 300-8053.

****Saturday delivery: See sampling protocol for alternate shipping address.**

Send Data and Invoice to

Name: _____

Company: _____

 Address: _____

Phone: _____

Fax: _____

Email: _____

Project: _____

Purchase Order #: _____

Location: _____

Sampled By: _____

Circle one: Standard

Priority

Rush

Sample Description

				Analysis Requested			
Container Number	Sample Identification	Date Sampled	Time				Comments

Chain-of-Custody Record

Signature	Company	Date	Time
Relinquished by			
Received by			
Relinquished by			
Received by			
Relinquished by			
Received by			


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Appendix I

Waste Management Procedures and Forms

Subject: EESH Remediation Waste Management

- Ref: 1. Code of Federal Regulations, Title 40, Parts 260, 261, 262, 264, 265, 268, 761, and 763
 2. Code Federal Regulations, Title 49, Parts 100 through 180
 3. Corporate Functional Procedure No: ESH-06
 4. Corporate Functional Procedure No: ESH-08
 4. Corporate Policy Statement 527

1.0 Purpose

This procedure establishes practices for management and transportation of solid and hazardous waste (waste in this context also refers to DOT hazardous materials) generated at remediation project sites in a manner that complies with Subtitle C of the Resource Conservation and Recovery Act (RCRA), Department of Transportation (DOT) regulations, and similar state and/or host country waste regulations. Additionally, this procedure ensures waste disposal is managed in accordance with Corporate Functional Procedure ESH-06 and ESH-08, and records retained in accordance with Corporate Policy Statement 527.

2.0 Applicability

This procedure applies to the Energy, Environment, Safety and Health (EESH) Remediation Organization (the Organization) and to the remediation projects for which the Organization has waste management responsibility. Each member of the Organization, including IWTA, contractor staff and, where applicable, support organizations (e.g. Global Supply Chain Management), is responsible for execution of this procedure.

The materials to which this practice applies are solid wastes generated as a result of remediation project activities, including such things as investigation derived waste, environmental sampling, treatment of contaminated media, and routine operations and maintenance, unless such solid waste is exempt under applicable regulations.

3.0 Key National Agreement

Waste management requirements shall be included within the EESH Key National Agreements (KNA). The KNA establishes the requirements under which Remediation Contractors perform work for Lockheed Martin.

The KNA will stipulate that the Remediation Contractor shall comply with Lockheed Martin waste management, transportation, and disposal requirements and all applicable state, federal, and/or host country laws and regulations.

4.0 Statement of Work Requirements

4.1 Waste Management Plan

All remediation project statements of work that include the generation of solid waste, excluding office trash (e.g. food wastes, consumer packaging) that may be disposed of at a municipal solid waste facility, shall include a requirement for the waste management contractors (i.e. Remediation Contractors and/or Corporate Approved Waste Management Vendors) to submit a waste management plan to Lockheed Martin. A site specific waste management plan shall be prepared that identifies all potential solid waste streams that may reasonably be expected to be generated or discovered during project activities. The plan will address the required elements listed below; however, if the waste is determined to be non-hazardous following completion of Element A, then only the additions of Elements D and E are required.

Element A) Hazardous Waste Determination

- i) Listing assessment (See Attachment #1 – Waste Listing Assessment Form)
- ii) Characteristic determination

Hazardous waste determinations shall be made in accordance with 40 CFR 262.11 using a combination of process knowledge and/or analytical evaluation of waste sampling. Hazardous waste determinations shall be reevaluated whenever any of the following circumstances occur:

- A change in the process that produces the waste (e.g. a new chemical constituent is discovered, the treatment process changes);
- A change in the treatment media is made (e.g. new media vendor or media type);
- A waste was tainted by inadvertent mixing with another waste; or
- A change occurred to the hazardous waste regulations that apply to that waste.

Characteristic waste determinations based on analytical sampling shall be reevaluated at some reasonable frequency to verify the accuracy of the initial waste determination. The waste determination reevaluation frequency for ongoing remediation or treatment operations should be specified in the waste management plan and be profiled at least once a year.

Element B) Responsibilities and Training Requirements

- i) Contractor staff responsibilities with regard to waste management and training requirements necessary to comply with Section 6.0 and all state, federal, and/or host country laws and regulations. Contractor training certifications shall be provided electronically to the Lockheed Martin Project Lead.

Element C) Pre-Shipment Requirements

- i) Material identification and classification per DOT requirements
- ii) Packaging, storage, segregation, marking, labeling, and accumulation of waste
- iii) Waste shipment documentation
 - (1) Hazardous Waste Generator Identification Number

iv) Hazardous Material Transportation Plan

- (1) Hazardous material transportation risk identification, prioritization, and mitigation plan
- (2) Emergency Response (material information to be provided with shipments, actions to be taken in the event of an incident, staffing the emergency response phone number)
- (3) Hazmat Security Plan (as required based on thresholds outlined in 49 CFR §172.800)
- (4) Transportation and disposal logistics

Lockheed Martin Project Leads shall ensure the use of the Lockheed Martin Corporate Purchasing Agreements and the associated Corporate Approved Waste Management Vendors (WMV) for hazardous waste management and ensure that waste is transported to a treatment, storage, and disposal (TSD) facility on the Lockheed Martin Corporate Hazardous Waste Approved Vendors List as outlined in the ESH-06. Remediation contractors can contract directly with the WMV.

Additionally, hazardous waste manifests shall be signed only by a DOT trained and qualified Lockheed Martin employee or authorized designee (See Attachment #2 – Hazardous Waste Manifest Authorization Form). In addition to completing the Authorization Form, Project Leads shall verify that the designee is DOT trained and qualified to sign manifests and has adequate DOT experience. It is preferable to have contractors designated to sign that are involved in the waste characterization and oversight. For contractor personnel handling hazardous waste, appropriate hazardous waste handling training shall be provided by the contractor as outlined in Section 6.0 and complying with all state, federal, and/or host country laws and regulations.

Non-hazardous waste is not required to be managed by Corporate Approved Waste Management Vendors but shall be transported to an approved industrial waste disposal facility as outlined in ESH-06.

Within the United States, waste shall be characterized and disposed in accordance with the state regulations where it was generated unless the state requirements are less stringent than the federal requirements. For instance, California non-RCRA hazardous waste cannot be disposed of in a non-hazardous waste facility. Within a host country, waste shall be managed in accordance with the host country regulations; however, if the host country standards are less stringent than those of the US Environmental Protection Agency (EPA), then the EPA standards shall apply.

Element D) Shipping Requirements

- i) Manifest certification and accuracy verification of physical waste shipment against manifested waste shipment (for non-hazardous waste this may not be applicable)
 - (1) For hazardous waste, the contractor responsible for waste shipment shall utilize the Lockheed Martin Hazardous Material/Waste Shipment Checklist (see Attachment #3) during the preparation and pre-transport review of waste shipments and submit a completed electronic copy to the Lockheed Martin Project Lead with the shipping documentation.

- ii) For non-specification bulk containers (e.g. dump trucks and roll-offs), the contractor responsible for waste shipment shall adhere to the Lockheed Martin requirements for packing and closing (see Attachment #4). These requirements are meant to supplement the applicable regulations.

Element E) Post Shipment Requirements - Records

- i) Waste characterization, chain of custody, transportation, and destruction records shall be scanned and electronically submitted to the Lockheed Martin Project Lead for records retention. This shall include profile sheets, the Hazardous Material/Waste Checklist, the generator copy of the waste manifest, a copy of the TSD signed waste manifest, Land Disposal Restriction forms, and certificates of waste destruction where applicable. For finite-duration remediation projects, waste transportation and disposal records shall be submitted to the project lead at the completion of the project unless submittals are required by regulatory agencies on a more frequent basis. For recurring remediation project activities such as annual groundwater monitoring or groundwater treatment, these records shall be submitted for each year's waste generation activities in the first quarter of the following year or per the Project Lead's direction.

The waste management plan shall be submitted in a phased approach. The first section of the waste management plan will provide the hazardous listing assessment and the characteristic determination methodology (addressing Element A). This section of the plan shall be submitted in a timeframe that allows for Lockheed Martin's review prior to waste generation. Upon approval to proceed, the second section will document the waste profiling results and must be signed off on by a Lockheed Martin Project Lead. Additionally, it shall outline the logistics for waste handling, transportation and disposal (addressing Elements B through E). This section of the plan shall specify a reevaluation frequency for waste generated as a result of ongoing remediation or treatment operations.

Following the approval of the second section by the Lockheed Martin Project Lead, the waste management contractor shall implement the waste management plan. This plan shall be updated when the remedial treatment system process, waste stream, media, or regulations change.

4.2 Health and Safety Plan

For remediation sites managing waste, a section shall be included in the site Safety and Health Plan to address the safety and health requirements for managing the site specific waste.

4.3 Electronics and Scrap Metal Recycling

Where applicable and feasible, electronics and scrap metals shall be recycled or refurbished to the extent possible in accordance with ESH-06.

5.0 Responsibilities

5.1 Project Lead

The Project Lead shall:

- Ensure that all remediation projects for which they have responsibility have a waste management plan as outlined in Section 4.0. Review and ensure updates are completed as necessary. Plans must also be submitted to the Records Manager for upload to the Document Management System (DMS).
- Consult with Corporate EESH Legal as needed to verify the listing determination.
- Ensure that the Contractor has outlined the applicable training requirements and provided a training plan or statement of completion within the waste management plan.
- Verify that the site has a Hazardous Waste Generator Identification Number prior to hazardous waste shipments, where applicable.
- Ensure that all hazardous waste manifests are signed and certified by a Lockheed Martin employee or authorized designee. For non-hazardous waste, there are no signatory requirements for waste manifests.
- Ensure that non-hazardous or hazardous waste is shipped to an approved facility per ESH-06 and that the Corporate Approved Waste Management Vendors are being used for hazardous waste transportation, storage, and/or disposal services.
- Ensure receipt of the waste characterization, chain of custody, transportation, and destruction records, where applicable, and submit them to the Records Manager for upload to the DMS.
- Ensure that the required regulatory and state hazardous waste reports are submitted (e.g. biennial waste reports).

5.2 Remediation Global Supply Chain Management Representative

The Global Supply Chain Representative shall:

- Ensure that the KNA includes the requirements defined in Section 3.0.
- Send the Remediation Contractors an updated version of the approved non-hazardous facility list quarterly.
- Send the Corporate Approved Waste Management Vendors an updated version of the Lockheed Martin Corporate Hazardous Waste Approved Vendors List quarterly.

5.3 Corporate EESH Legal

The Corporate EESH Legal Counsel shall:

- Provide the Project Lead with support when making listed waste determinations.
- Notify the Project Leads of regulation changes that would affect prior listing determinations.

6.0 Training Requirements

The EESH remediation staff training requirements are summarized in Table 1.

6.1 RCRA Hazardous Waste Handling and Emergency Procedures

RCRA Generator Status Facilities

Generators who generate more than 1,000 kg/month of hazardous waste (or more than 1 kg/month of acutely hazardous waste) must comply with the emergency preparedness and personnel training requirements outlined in 40 CFR §265.16 (see 40 CFR §262.34(a)(4)). This training is intended for all facility personnel including the generator's contractors and includes training by a qualified person on hazardous waste management and emergency response procedures. Personnel shall receive an annual refresher. Project Leads are responsible for ensuring this training is provided to contractor staff on remediation projects that meet this generator criterion. Contractor personnel training records must also be maintained by the Project Lead.

"Small quantity generators" who generate greater than 100 kg but less than 1000 kg/month of hazardous waste, must comply with the emergency preparedness and personnel training requirements at 40 CFR §262.34(d)(5). These generators "must ensure that all employees are thoroughly familiar with proper waste handling and emergency procedures, relevant to their responsibilities during normal facility operations and emergencies" (40 CFR §262.34 (d)(5)(iii)). Project Leads shall ensure that all contractor staff has had the appropriate hazardous waste handling and emergency procedure training on remediation projects that meet this generator criterion.

Federal training requirements do not apply to remediation projects that generate less than 100 kg/month of hazardous waste. However, Project Leads shall ensure that the contractor staff is familiar with hazardous waste handling and emergency procedure training appropriate for waste management.

RCRA Permitted or Interim Status Facilities

Permitted or interim status facilities must follow training requirements in accordance with 40 CFR §264.16 and 40 CFR §265.16, respectively (the same requirements apply as outlined in the first paragraph under Section 6.1).

Additional training may be required by state and/or host country hazardous waste regulations. Any such additional training shall be verified and implemented by the Project Lead.

6.2 Department of Transportation Training

Department of Transportation (DOT) Hazmat Employee training is required for a person involved in shipment preparation, offering for transport and transportation of hazardous waste, including signing of hazardous waste manifests (see 49 CFR 172, Subpart H). All Lockheed Martin Remediation representatives, designees, and/or waste management contractors shall complete the hazmat employee training and renew the training as necessary to meet DOT requirements for hazardous waste transportation.

6.3 OSHA HAZWOPER Training

All contractors working on Lockheed Martin remediation sites shall complete the appropriate OSHA hazardous waste operations (HAZWOPER) training and annual refresher training specified in 29 CFR §1910.120. Lockheed Martin employees managing projects where hazardous waste is generated shall complete the 24 hour OSHA HAZWOPER training and annual refresher training.

7.0 Deviations

All deviations from this procedure must have prior approval by the Director of Environmental Remediation. The approval shall be documented and uploaded to the DMS.

Table 1

EESH Remediation Staff Waste Management Training Matrix

Function	Task	Training Required	Requirements
EESH Remediation Employees (including IWTA and managing contractor staff (where the task description matches responsibilities))	Completing / Approving Waste Determinations	RCRA Generator Training	Refresher every 5 years
	Managing Remediation Sites where Hazardous Waste is Generated	OSHA HAZWOPER 24 HR	8 hr refresher annually
	Managing Hazardous Waste Shipments	DOT HazMat Certification (see Table 2)	Refresher every 3 years

The Lockheed Martin Project Lead shall update the Remediation Waste Management Training Matrix located on the Remediation Process Asset Library once training has occurred. All training and certification documentation will reside on the Remediation DMS under Training Records.

Table 2

EESH Remediation Staff DOT Requirements for Hazmat Employees	
Requirement	Completion Method
General Awareness [49 CFR 172.704(a)(1)]	• Vendor (e.g. Lions) provided Hazardous Materials Transportation Workshop • DOT OJT (taught by EESH DOT SME)
Function-Specific [49 CFR 172.704(a)(2)]	• Vendor (e.g. Lions) provided Hazardous Materials Transportation Workshop • DOT OJT (taught by EESH DOT SME)
Safety [49 CFR 172.704(a)(3)]	• Vendor (e.g. Lions) provided Hazardous Materials Transportation Workshop • DOT OJT (taught by EESH DOT SME) • Hazwoper 24 Hour Training • Site specific safety training [NOTE: This element of safety training may be fulfilled through completing any one (1) of the following three (3) options which provides the required site specific safety information: 1) Site Safety Plan Review, 2) Site HazCom/ General Employee Training or 3) Site Visitor Safety Briefing/Training. The source of the training must be entered as part of the information on the test which is administered for site specific safety training.]
Security Awareness [49 CFR 172.704(a)(4)]	• Vendor (e.g. Lions) provided Hazardous Materials Transportation Workshop • DOT OJT (taught by EESH DOT SME) • Site specific security awareness training [NOTE: This element of security awareness training may be fulfilled through completing any one (1) of the following three (3) options which provides the required site specific security information: 1) Site Security Plan Review, 2) Site HazCom/General Employee Training or 3) Site Visitor Security Briefing/Training. The source of the training must be entered as part of the information on the test which is administered for site specific security training.]
In-Depth Security (Hazmat Security Plan) Only applicable when haz material/waste meets certain class and volume thresholds (reference Section 4.1, Element C, iv, 4) [49 CFR 172.704(a)(5)]	• Site Hazmat Transportation Security Plan Training

The EESH DOT SME will certify EESH Remediation staff members as DOT Hazmat Employees on behalf of Lockheed Martin once training and safety and security tests have been completed.

Attachment #1

Waste Listing Assessment Form



Waste Listing
Assessment Form

Attachment #2

Hazardous Waste Manifest Signature Authorization Form



Designee
Authorization Form

Attachment #3

Hazardous Material/Waste Shipment Checklist



Hazardous Material/
Waste Shipment Check

Attachment #4

Non-Specification Bulk Container Packing and Closing Instructions



Non-Specification
Bulk Container Packing

Waste Listing Assessmet Form - Example			
LMC Remediation Project		State Generated	
Description of Waste			
Generic Name		Solid, Liquid, Gas	
		Additional Info.	
Date of Waste Generation		Ongoing (Y/N)?	
Description of Process Generating Waste			
Listed Waste ? (Y/N)		F,K, P or U Codes, if applicable	
Justification for Waste Classification (attach support documentation)			
Justification:			
Completed by			
Company			
Date			

Lockheed Martin Hazardous Material/Waste Shipment Checklist

Date:

Project Site Name:

Shipping Document No.:

A. DESCRIPTION

- A1. _____ UN/NA Identification Number, Proper Shipping Name, Hazard Class/Division Number, Packing Group
A2. _____ Subsidiary hazard class(es) or division number(s), if any, in parenthesis
A3. _____ Total Quantity of Material
A4. _____ 24-Hour Emergency Phone Number and Response Information ERG No.: _____
A5. _____ Page of Pages, for multiple shipping papers/EPA Manifest/Air Decs.
A6. _____ Shipper's Certification, as applicable
A7. _____ Small Quantity Exception/Dangerous Goods In Excepted Quantities/Diagnostic Specimen/Sample

B. ADDITIONAL DESCRIPTIONS - GENERAL

- B1. _____ Exemptions "DOT-E-ex.#"
B2. _____ "Limited Quantity" (not to exceed 66 lb gross weight)
B3. _____ "X" or "RQ" (if RQ, Hazardous Substance Contact @ 1-800-424-8802)
B4. _____ "Waste" for RCRA regulated material
B5. _____ "Mixture" or "Solution" - as appropriate.
B6. _____ (technical names), for poisons/mixtures/n.o.s./generic proper shipping names
B7. _____ "Marine Pollutant" and constituent in (), for bulk shipments only
B8. _____ (hazardous substance names) per 172.101 appendix if not contained in proper shipping name
B9. _____ (EPA waste identification numbers)- used to identify the hazardous substance
B10. _____ "Poison" - if not identified in proper shipping name or hazard class
B11. _____ "Poison-Inhalation Hazard" & Zone A, Zone B, Zone C, or Zone D, as appropriate*
(*Note Special Provisions 1-6 and 13 in Column 7 of 172.101)

C. MARKING FOR NON-BULK PACKAGINGS

- C1. _____ Proper Shipping Name, UN/NA Identification Number
C2. _____ (technical name)
C3. _____ (EPA waste identification number)
C4. _____ "RQ"
C5. _____ Exemption Packagings "DOT-E-ex.#"
C6. _____ Consignee's Name & Address
C7. _____ Net or Gross quantity for non-rad Dangerous Goods (adjacent to PSN & UN#)
C8. _____ Ltd. Qty - PSN only per 172.301(a)(1) or UN ID# placed in square-on-point border per 172.315
C9. _____ Package Orientation Arrows, for liquids in inner packagings
C10. _____ "Inhalation Hazard", unless these words appear on the label prescribed in 172.416 or 172.429
C11. _____ "Overpack" adjacent to proper shipping name marking [see 173.25(a)(4)]
C12. _____ TSCA PCB Marking (for actual or source concentration greater than or equal to 50 ppm *)
(* Note Potential Vehicle Marking Requirements in 40 CFR 761.40)

D. MARKING FOR BULK PACKAGINGS (DUMP TRUCKS OR ROLL-OFFS)

- D1. _____ UN/NA Identification Number on orange panel or placard or white square-on-point display configuration as prescribed by 172.302 and 172.332

E. LABELING

- E1. _____ Primary Hazard Label(s): _____
E2. _____ Subsidiary Hazard Label(s) with class/division: _____
E3. _____ Hazardous Wastes Label(s)

F. PLACARDING

F1. 172.504 Table 1 Materials - Any Amount

F1.1. _____ Dangerous When Wet (4.3)

F1.2. _____ Poison (6.1, Inhalation Hazard, Zone A or B)* (Primary or Subsidiary _____)

(*Materials subject to the "Poison-Inhalation Hazard" notation must be placarded with a POISON INHALATION HAZARD or POISON GAS placard, as appropriate, and also placarded for any other hazard class required for that material in 172.504)

F1.3. _____ Radioactive (7, LSA/SCO Exclusive Use Shipments)

F2. 172.504 Table 2 Materials - 1,001 lb:

G. PACKAGING

- G1. _____ Container Type: (Inner Pkg) _____
G2. _____ Container Type: (Outer Pkg) _____

Lockheed Martin Hazardous Material/Waste Shipment Checklist

G3. _____ Container Type: (Bulk Pkg) _____
G4. _____ Loaded and Closed As Required _____

Lockheed Martin Hazardous Material/Waste Shipment Checklist

H. PAPERWORK AND MISCELLANEOUS ITEMS

- H1. _____ Shipping Paper/Hazardous Waste Manifest/Bill of Lading/Airway Bill/Shipper's Declaration
- H2. _____ Instructions for Maintenance of Exclusive Use Shipments
- H3. _____ Small Quantity/Excepted Quantity Statement on Package, *for 173.4 shipments / DGEQ statement per 2.7.7.2*
noted on Airway Bill
- H4. _____ Photograph, *if applicable*
- H5. _____ Vehicle Inspection
- H6. _____ Check Driver's Qualifications
- H7. _____ Emergency Telephone Number Notification, if required, see 172.604(b)
- H8. _____ LMC Notification Instructions

I. ADDITIONAL REQUIREMENTS FOR RADIOACTIVE MATERIAL SHIPMENTS

I1. SHIPPING PAPER DESCRIPTIONS

- I1.1. _____ Radionuclide Symbol(s), *per 173.435*
- I1.2. _____ Physical & Chemical Form, *if not special form*
- I1.3. _____ Activity per Package
- I1.4. _____ Radioactive Labels
- I1.5. _____ Fissile Excepted, *if applicable*
- I1.6. _____ "Exclusive Use Shipment"

I2. MARKING FOR NON-BULK PACKAGINGS

- I2.1. _____ Gross Weight, *for radioactive material packages in excess of 110 lb*
- I2.2. _____ "Radioactive"; "Radioactive – LSA"; "Radioactive – SCO"
- I2.3. _____ Package Certification Number, *for radioactive material packages, as appropriate*
- I2.4. _____ IP-1, IP-2, IP-3 markings
- I2.5. _____ "USA" on all IP and Type A packagings
- I2.6. _____ Packaging manufacturer marking on Type A

I3. LABELING

- I3.1. _____ Radioactive Labels
- I3.2. _____ "EMPTY" Label
- I3.3. _____ "Radioactive Material, Excepted Package" handling label

I4. PLACARDING (172.504 TABLE 1 MATERIALS - ANY AMOUNT)

- I4.1. _____ Radioactive (7, LSA/SCO Exclusive Use Shipments)

I5. PAPERWORK AND MISCELLANEOUS ITEMS

- H1. _____ Instructions for Maintenance of Exclusive Use Shipments
- H2. _____ Radioactive Excepted Package statement per 10.8.8.3.3 on Airway Bill
- H3. _____ Limited Quantity Radioactive Material *for multiple hazard limited quantity Class 7.*
- H4. _____ Health Physics Information
- H5. _____ NRC Manifest #540 for radioactive waste shipment for land disposal.

Completed By:

Company:

Date:

Lockheed Martin Hazardous Waste Manifest Signatory Authorization

This Authorization Agreement, effective for the remediation site and period of performance written below, is entered into by and between:

LOCKHEED MARTIN CORPORATION (hereinafter "Lockheed Martin"),
having a business office at 6801 Rockledge Drive, Bethesda, Maryland 20817
USA, and incorporated in the State of Maryland, and

(hereinafter "_____")

having a business office at _____
_____.

WHEREAS, _____ (company representative) of
_____ (company) will sign Hazardous Waste Manifests on behalf of
Lockheed Martin for the project and hazardous waste, as defined at 40 CFR Pt.
261 *et seq.* indicated below.

Remediation Site: _____

Site Address: _____

Period of Performance: _____

Hazardous Waste Description:

Hazardous Waste Disposal Facility and Location: _____

This Authorization Agreement certifies that the representative signing on behalf of Lockheed Martin has taken the appropriate Department of Transportation training, as delineated at 49 CFR Part 172 *t seq.* to sign Hazardous Waste Manifests and is in compliance with all state and federal requirements for hazardous waste manifesting.

Lockheed Martin shall remain responsible and liable for the hazardous waste being disposed regardless of the Signatory Authorization provided herein.

LOCKHEED MARTIN CORPORATION

By:_____

By:_____

Name:_____

Name:_____

Title:_____

Title:_____

Date:_____

Date:_____

**PACKING AND CLOSING INSTRUCTIONS FOR
NON-SPECIFICATION BULK CONTAINERS
(DUMP TRUCKS AND ROLL-OFFS)**

04/10/2009

PRELIMINARY TASKS

- Select the transport container based on the Department of Transportation hazard classification and the packaging requirements specified in the Hazardous Materials Table.
- Perform moisture evaluation of waste material to be loaded into transport containers to determine the potential for releasing liquid.

PREPARATION OF BULK CONTAINERS FOR LOADING

- Transport containers must be inspected for any condition that may affect their safety or performance prior to each use.
- Dump trucks and roll-offs with doors must have gaskets installed at the tailgate or doors that when the tailgate or doors are closed the gasket is compressed sealing the tailgate or doors to assure package integrity and containment of materials. The gasket must be inspected prior to each use for overall integrity including positioning, damage such as holes or tears or debris which could prevent tight closure. Any deficiencies shall require replacement prior to use.
- An absorption pad shall be placed in the truck or roll-off bed. The pad specification shall be determined utilizing the data determined in the waste material moisture evaluation and must be capable of absorbing the liquid which could be released.
- An absorption log at the rear of the transport container along the bottom of the tailgate or rear doors.
- A minimum 6 mil poly liner shall be placed over the absorption pad and absorption log prior to loading.
- Determine the amount of waste that can be loaded into the transport container. (Subtract the unladen weight of the transport vehicle from the maximum licensed weight of the transport vehicle. NOTE: Do not load the maximum permissible load determined in the mathematical calculation to allow for variance in scales that may be utilized to weigh the loaded vehicle.)

LOADING AND CLOSING BULK CONTAINERS

- Waste material shall be loaded into the transport container in such a manner that does not compromise either the liner or container integrity.
- Do not load material above the height of the sides of the transport container.
- Close the poly liner over of the waste material prior to tarping the load.
- Close the transport container by putting a heavy roll tarp over the top of the transport container and secure the tarp by utilizing tie downs on all four sides.