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SHEPLEY HILL LANDFILL SUPPLEMENTAL INVESTIGATION WORKPLAN ADDENDUM

REVISION 1 TO THE FINAL WORKPLAN DATED JANUARY 2010

Prepared for:

US Army Corp of Engineers
New England District
Concord, Massachusetts

Prepared by:

Sovereign Consulting Inc.
905B South Main Street, Suite 202
Mansfield, Massachusetts 02048

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NOTICE

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Shepley's Hill Landfill
Supplemental Investigation Workplan Addendum

Devens, Massachusetts

May 2010

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SHL-SOV01

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CERTIFICATION:

I hereby certify that the enclosed Report, shown and marked in this submittal, is that proposed to be incorporated with Contract Number GS-10F-0230J. This Document has been prepared in accordance with USACE Scope of Work and is hereby submitted for Government Approval.

Reviewed By:

Sovereign Project Manager Date

Sovereign Senior Reviewer Date

Received By:

USACE Project Manager Date

Shepley's Hill Landfill
Supplemental Investigation
Workplan Addendum

Volume 1 – Technical Approval and Rational

Devens, Massachusetts

May 2010

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Sovereign Consulting Inc
905B South Main Street, Suite 202
Mansfield, Massachusetts
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TABLE OF CONTENTS

List of Tables

List of Figures

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AMEC	AMEC Earth and Environmental, Inc.
AOC	Area of Concern
AR	Annual Report
ATP	Arsenic Treatment Plant
AW	Additional Work
BCT	BRAC Cleanup Team
bgs	below ground surface
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	Conceptual Site Model
cy	cubic yards
DO	Dissolved Oxygen
DQO	Data Quality Objective
ECC	Environmental Chemical Corporation
FFS	Focused Feasibility Study
FS	Feasibility Study
FSSR	Feasibility Study Screening Report
HERA	Human and Ecological Risk Assessment
IC	Institutional Control
LTM	Long Term Monitoring
MA	Massachusetts
MassDEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
MNR	Monitored Natural Recovery
ORP	Oxidation-Reduction Potential
pH	Standard potential of Hydrogen ion concentration
ppb	parts per billion
ppm	parts per million
RI	Remedial Investigation
ROD	Record of Decision
RSE	Remediation System Evaluation
RTC	Response to Comments
SAP	Sampling and Analysis Plan
SAR	Supplemental Assessment Report (AMEC 2009)
SC	Specific Conductance
SHL	Shepley's Hill Landfill
Sovereign	Sovereign Consulting Inc.
USACE-NAE	U.S. Army Corps of Engineers – New England District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

This Supplemental Investigation Workplan Addendum presents the rationale and technical approach for data collection to address Additional Work (**AW**) requirements and Draft Focused Feasibility Study (**FFS**) data gaps for Shepley's Hill Landfill (**SHL**) in Ayer, Massachusetts. This workplan provides a summary of relevant site conditions including the current remedy in place and remedial alternatives under consideration in the FFS (Alternatives 1 through 5). This workplan was developed in two parts to allow for Base Realignment and Closure (**BRAC**) Cleanup Team (**BCT**) agreement on the scope and rationale for investigations before the detailed procedures associated with those studies are finalized. This Supplemental Investigation Workplan Addendum summarizes the overall Technical Approach and Rationale, and the accompanying Volume 2 of the workplan provides a Sampling and Analysis Plan (SAP) for investigations that are expected to be implemented earliest in the project schedule. Detailed development of procedures for the later investigations described in Volume 1 is expected to continue for several months, and will be documented in a subsequent SAP addendum.

Technical objectives identified in the AW requirements or in the Draft FFS list of data needs are summarized in Table 1. Each objective has an associated "hypothesis" that represents the current state of knowledge regarding the objective. The data needed to fill any gaps in that hypothesis are listed, and a technical approach to collecting those data is summarized. These objectives and technical approaches are discussed in detail in Section 2 of this submittal. Proposed investigations in the Impacted Area north of the current capture zone are shown in Figure 1, and investigations in the area south of the capture zone are shown in Figure 2.

Table 1 and the detailed technical approaches in Section 2 describe a series of supplemental investigations that include:

A. Geophysical survey, borings and monitoring well installations as needed to delineate the arsenic plume and establish temporary groundwater monitoring locations in the Impacted Area north of SHL (see Section 2.1).
B. Borings and monitoring well installations as needed to confirm the arsenic capture zone on the east side of the landfill (see Section 2.2).
C. Sampling and testing of aquifer materials within the Impacted Area to evaluate mechanisms associated with Monitored Natural Attenuation (**MNA**) in this area (see Section 2.3).
D. Modeling the potential for methane intrusion into basement air from dissolved methane in groundwater (see Section 2.4).
E. Borings and monitoring well installations as needed to provide hydraulic and chemistry information in the area upgradient of Area of Concern (**AOC**) 72, i.e., Plow Shop Pond (see Section 2.5).
F. Sampling and testing of landfill source materials to evaluate arsenic mobilization mechanisms and the potential source concentrations within the landfill (see Section 2.6).
G. Perform an evaluation of the applicability for an air sparging system to treat the arsenic plume discharging into Red Cove as described in FFS Alternative 4 (see Section 2.7). This evaluation may include bench scale and/or pilot testing if deemed appropriate.

H. Evaluate relocating wastes above the water table and eliminate leaching to groundwater as described in FFS Alternative 5 (see Section 2.9).

Also, as explained in Section 2.8, the Feasibility Study Screening Report for AOC 72 will have information developed regarding a floc removal process for Red Cove that can be used to satisfy the data gap for FFS Alternative 2.

The above investigations will be conducted in 2010 as described in Section 3, and results will be incorporated in either the Final FFS or in a report on the AW activities, as appropriate. The attached Volume 2 contains procedures addressing items A, B, and E above, which are expected to be the first field investigations for this workplan. Items D and H do not require sampling and analysis at this time, and so may proceed independent from the initial field work. An addendum to Volume 2 will be developed to provide procedures for addressing items C and F above, and the evaluation of the air sparging alternative conducted under item G. A proposed schedule for these plans and subsequent work is provided in Section 3.

Though the submission of this Workplan Addendum, the following changed were made in the January 2010 Shepley's Hill Landfill Supplemental Investigation Workplan (Final Version):

1. As part of the East Plume evaluation, one boring / well will be installed to evaluate conditions. This information will be incorporated into the FFS, and used to determine the location of other points in the landfill during the remedial design phase, if necessary. Representative soil samples obtained from this location will be analyzed for concentrations of TAL Metals and Total Organic Carbon. Analysis will be targeted at lithology changes.
2. Air sparging is not considered a viable alternative based upon a review of the site conditions, analysis of site data, based upon experience with other locations of this nature.
3. The limits of the wetlands was evaluated and determined, and a report with plan submitted to the Ayer Conservation Commission.
4. Drilling operations conducted within the East Plume will be conducted using a Rotosonic drill-rig. All other locations will be conducted using a direct push method.
5. Groundwater samples obtained at 10-foot sampling intervals will be screened using an Arsenic Test Kit, and analyzed for arsenic by the laboratory under a 24-hour turn-around time frame.
6. Copies of the Standard Operations Procedures and Laboratory Qualification are included as an attachment to the Field Sampling Plan, and the Quality Assurance Project Plan is being revised to comply with current UFP-QAPP Manual requirements.

1.0 INTRODUCTION

Information contained within this document was prepared by AMEC and outlined in a Supplemental Investigation Workplan dated January 2010. As part of contract requirements, Sovereign has updated sections or attachments to this document to conduct the proposed investigation.

1.1 Purpose and Organization

The purpose of this Supplemental Investigation Workplan is to present the technical approach to collecting data needed for AW items and the Draft FFS for Shepley's Hill Landfill in Ayer, Massachusetts. This draft workplan provides a summary of relevant site conditions including the current remedy in place and remedial alternatives under consideration in the FFS. This workplan was originally prepared under contract Number GS-10F-0230J, Delivery Order Number W912WJ-05-F-0037, for the US Army Corps of Engineers, New England District.

This workplan was developed in two parts to allow for BCT agreement on the scope and rationale for investigations before the detailed procedures associated with those studies are finalized. This phased approach will maximize the efficiency of workplan development. The current submittal represents the Supplemental Investigation Workplan Addendum Volume 2 Technical Approach and Rationale. Volume 2 of the workplan provides a Sampling and Analysis Plan for investigations that are expected to be implemented earliest in the project schedule.

Section 1 of this workplan provides a brief history of the site and current conditions. Portions of Section 1 are summarized from recent reports including the *Supplemental Groundwater and Landfill Cap Assessment for Long-Term Monitoring and Maintenance* (AMEC 2009) or Supplemental Assessment Report (**SAR**) and the *2008 Annual Report* (ECC 2009). Section 2 describes objectives and data gaps related to AW items and the Draft FFS, and presents a technical approach to collecting the required information. Section 3 provides an activity-based project schedule including dependencies.

1.2 Site History

SHL encompasses approximately 84 acres in the northeast corner of the main post of the former Fort Devens. The landfill is bordered to the northeast by Plow Shop Pond, to the north by residences and Nonacoicus Brook, to the west by Shepley's Hill, to the south by recent commercial development, and to the southeast by land formerly containing a railroad roundhouse. The landfill includes three AOCs investigated under the Comprehensive Environmental Response, Compensation, and Liability Act (**CERCLA**) in accordance with US Environmental Protection Agency (**USEPA**) requirements: AOC 4, the sanitary landfill incinerator; AOC 5, sanitary landfill No. 1; and AOC 18, the asbestos cell. Plow Shop Pond is identified as AOC 72 (Operable Unit for surface water and sediments) and is being investigated under CERCLA for groundwater impacts emanating from SHL.

The landfill was reportedly operating by the early 1940s, and evidence from test pits within the landfill suggests earlier usage, possibly as early as the mid-nineteenth century. The landfill contains a variety of waste materials, including incinerator ash, demolition debris, asbestos, sanitary wastes, spent shell casings, glass, and other wastes. As described previously (Harding ESE 2002), the maximum depth of the refuse occurs in the central portion of the landfill and is estimated to be about 40 feet below ground surface (**bgs**). The volume of waste in the landfill SHL-0127 Page 1has been estimated at over 1,300,000 cubic yards (**cy**), of which approximately 320,000 cy (25%) is below the water table. The saturated wastes may be emplaced in a wetland reducing environment; at least two areas previously mapped as swamps appear to have been filled (Harding ESE 2002).

The landfill was closed in five phases between 1987 and 1992-93 in accordance with Massachusetts regulations at 310 CMR 19.000. The Massachusetts Department of Environmental Protection (**MassDEP**) approved the closure plan in 1985. Closure consisted of installing a 30-mil polyvinyl chloride membrane cap, covered with soil and vegetation and incorporating gas vents. Closure also included installation of wells to monitor groundwater quality around the landfill, and construction of drainage swales to control surface water runoff. MassDEP issued a Landfill Capping Compliance Letter approving the closure in February 1996.

1.3 ROD and Contingency Remedy

Subsequent to closure of the landfill (1987-1993), remedial investigation (**RI**) under CERCLA evaluated soil, sediment, surface water, and groundwater conditions at and in the immediate vicinity of the landfill. The results confirmed the presence of various contaminants, particularly certain inorganics and volatile organic compounds, in groundwater, sediments, and surface water at or adjacent to Shepley's Hill Landfill. A Feasibility Study (**FS**) and Record of Decision (**ROD**) resulted in a remedy that required long term monitoring and maintenance of the existing landfill cap and groundwater monitoring.

The ROD (USEPA 1995) included a contingency provision, which required that a groundwater extraction and treatment system be installed if groundwater contaminant concentrations, primarily arsenic, did not meet risk-based performance standards over time. The Army installed and started full time operation of a groundwater extraction and treatment system in March 2006 to address groundwater contamination emanating from the northern portion of the landfill. In 2007 the BCT decided to increase the Arsenic Treatment Plant (**ATP**) flow rate from 25 gpm to 50 gpm, and this was completed in July 2007. The ATP system treated and discharged approximately 18 million gallons of groundwater during 2008, bringing the cumulative treatment total to approximately 38 million gallons as of 2008.

1.4 Conceptual Site Model

The Conceptual Site Model (**CSM**) for northern groundwater flow is summarized from the recent Supplemental Assessment report (AMEC 2009). Potential sources of arsenic in groundwater include bedrock, bedrock-derived soils, buried wetland sediments, and landfill wastes. The relative magnitudes of the various types of sources are unknown. Landfill wastes are located above and below the water table. Arsenic is dissolved from the source materials by landfill induced reducing conditions in groundwater. A portion of the landfill overlies a swamp where naturally-occurring reducing conditions may also have existed and where iron and arsenic might have accumulated because of focused groundwater discharge to the wetland prior to filling. The landfill cap completed in 1993 reduces infiltration and the formation of landfill leachate from wastes above the water table, but would not reduce the formation of landfill leachate from wastes below the water table. While reducing the flow of water through unsaturated wastes, the cap may exacerbate the severity or duration of reducing conditions below the water table by limiting the infiltration of relatively oxygenated rainwater or meltwater.

In the absence of landfill leachate, such as might be achieved with FFS Alternative 5 (landfill consolidation), the natural flushing of the aquifer with oxygenated groundwater may be expected to gradually reestablish aerobic conditions - except perhaps in the original swampy area that was filled - such that arsenic is immobilized as a solid precipitate. The duration over which reducing conditions would persist is not well known, though studies at a similar landfill suggest that flushing of hundreds of aquifer pore volumes is needed to oxidize the aquifer material. The additional oxygen demand posed by wastes below the water table would lengthen the time needed for recovery.

Arsenic in groundwater is mainly in the form of arsenite (As3+) under the reducing conditions associated with the highest arsenic concentrations. Groundwater carrying elevated arsenic concentrations flows north to the vicinity of Nonacoicus Brook. Arsenic is immobilized as a solid phase within the aquifer matrix in the area beneath the stream where reduced groundwater transitions to the oxygenated conditions present in the stream. Deeper groundwater near the stream travels north along the eastern flank of the buried bedrock surface, before turning west along the valley axis and discharging to the stream.

The CSM for eastern groundwater flow is summarized from the recent RI Workplan for AOC 72 (AMEC 2009). Groundwater from SHL carrying dissolved arsenic, iron, and other metals discharges to AOC 72 in the vicinity of Red Cove. Iron oxides precipitate as an orange-red floc or sediment in Red Cove as reduced groundwater discharges to oxygenated surface water. Arsenic is adsorbed by or co-precipitated with the iron floc. Precipitation of metals occurs near and above the sediment surface where oxidizing conditions prevail. Mixing of the sediment and surface water may lead to "recycling" of iron and arsenic where the dissolved contaminants from deeper zones are oxidized and precipitate again as sediment. Recycling between sediment and surface water may result in arsenic transport beyond the area of groundwater discharge, depending on the amount of turbulence and surface water flow. However, elevated sediment arsenic concentrations are observed primarily where the highest rates of groundwater from SHL are likely to discharge, closest to shore and south of the "hinge" between groundwater discharge to and recharge from the pond. Plow Shop Pond is a shallow, low-energy environment unfavorable to large-scale sedimentary mixing.

1.5 Recent Data on Remedy Performance

The Army prepares an Annual Report (**AR**) that documents the long-term monitoring, inspection, and operations and maintenance activities conducted at SHL. The AR includes a performance assessment for the ATP that is focused on extraction system hydraulics and demonstration of containment of contaminated groundwater in excess of Maximum Contaminant Levels (**MCLs**) established for drinking water. The 2008 AR concludes that the ATP contains the majority of arsenic mass being mobilized by landfill-induced reducing conditions (ECC 2009). Based on estimated groundwater velocities, it will take many years to 'flush' currently impacted groundwater from areas outside the capture zone. Further, it will likely require additional time for new equilibrium redox conditions (presumably oxidizing) to be established, which in turn are expected to result in declines in arsenic concentration. Studies indicate that the Contingency Remedy does not preclude or significantly reduce groundwater discharge to AOC 72.

USEPA conducted a Remediation System Evaluation (**RSE**) for the ATP in 2009 and provided recommendations to improve effectiveness, reduce costs, and other technical improvements (USEPA 2009). Recommendations regarding effectiveness include updating the groundwater flow model and evaluating options to increase plume capture such as treated water injection, hydraulic controls for clean groundwater, and increasing the extraction and treatment rate. Recommendations regarding cost reduction include evaluating options for treated water discharge, alternative chemical usage, and modified solids handling. Other technical recommendations included measurement of specific capacity of wells, and discontinuing addition of hypochlorite to a microfiltration clear well. Several recommendations of the RSE have already been adopted or are included for evaluation in the Draft FFS.

1.6 Risk Summary

The Army prepared a Supplemental Groundwater and Landfill Cap Assessment for Long-Term Monitoring and Maintenance which evaluated whether a significant risk to human health or the environment exists at or to the north of SHL with the current remedy in place (AMEC 2009). This report concluded that no significant current risk to human health is present, but such a risk could exist if groundwater is used as a source of drinking water. Exposure pathways considered for the human health risk assessment included drinking water use, recreational use of Nonacoicus Brook, and landfill gas exposures from: 1) direct venting of gases from the landfill; 2) lateral migration from the landfill through shallow soils, and; 3) migration of gases from groundwater containing dissolved gas. Risks to aquatic, benthic, and terrestrial organisms in Nonacoicus Brook appear to either be related to sources in or upstream of Sawmill Brook, and/or related to chromium which appears to have a source(s) not related to Army activities.

The Army will prepare a Human and Ecological Risk Assessment (**HERA**) for AOC 72 based on the recent RI Workplan (AMEC 2009) and data collected from 1991 to 2009. Earlier risk assessments for AOC 72 and the adjacent Grove Pond have concluded that human and ecological risk drivers include arsenic, other metals, and other compounds such as polycyclic aromatic hydrocarbons, some of which may have anthropogenic sources (Gannett Fleming

2006). The RI and HERA for AOC 72 are expected to be submitted in draft form during January 2010.

1.7 Draft Focused Feasibility Study

The Draft FFS was completed to evaluate alternatives to the current remedy in place. The report described five remedial alternatives (including the current remedy, and optimizations of it) and evaluated each one in terms of CERCLA criteria. The Draft FFS conducted a preliminary comparison among the alternatives and identified several data gaps based on these evaluations and comparisons. The Army recommended that these data gaps be filled before a final, detailed comparison between alternatives. These data gaps are considered in the workplan that follows.

2.0 TECHICAL OBJECTIVE AND DATA COLLECTION

Technical objectives identified in the Additional Work requirements or in the Draft FFS data needs are summarized in Table 1. Each objective has an associated "hypothesis" that represents the current state of knowledge regarding the objective. The data needed to fill any gaps in that hypothesis are listed, and a technical approach to collecting those data is summarized. These objectives and technical approaches are discussed in the following subsections.

A schedule for implementing these investigations is provided in Section 3. The initial investigations of Landfill Gas Impacts (Section 2.4), Floc Removal Feasibility (Section 2.8), and Landfill Consolidation (Section 2.9) do not require field data collection and may proceed upon contract approval. The first proposed field investigations are for North Plume Delineation (Section 2.1), North Plume Capture Evaluation (Section 2.2), and East Plume Delineation and Capture (Section 2.5); procedures for data collection are provided in the attached Volume 3. Data collection procedures will be developed for MNA and Source Strength Evaluations (Sections 2.3 and 2.6) and provided in an addendum to Volume 3. A separate pilot test workplan will be submitted for the proposed Air Sparging Implementability evaluation (Section 2.7).

2.1 North Plume Delineation and Monitoring for Impacted Area

An AW objective is to further delineate the arsenic plume north of the ATP capture zone in all directions (including depth), and install monitoring and sentry wells around the delineated boundaries. Figure 1 is adapted from the SAR (Figure 4-5) and AR (Figure 4-4) to show dissolved arsenic detections above and below the drinking water criterion of 10 micrograms per liter or parts per billion (**ppb**), based on the most recent well sampling results. Figure 1 includes groundwater results along West Main Street from 2001 sampling; some of the results are for unfiltered samples, but these are the only data available for this area. The SAR also includes Figures 4-3 and 4-4 showing detections in cross-sectional view.

Figure 1 also contains model-generated tracks of particles ("particle tracks") introduced at the mid-point of well screens in which arsenic was detected at concentrations greater than the MCL (10 ppb) and allowed to migrate with the groundwater flow. The tracks represent the paths that particles would take through the aquifer under ambient conditions with the ATP extraction wells operating at 42 gallons per minute. While the particle tracks provide valuable information for understanding groundwater flow directions and selecting locations for new wells, they do not provide information on concentrations of arsenic along the expected flow paths.

In the area immediately north of the landfill, the western and eastern plume limits (defined as clearly impacted groundwater with negative ORP and arsenic >100 ppb) along Molumco Road appear to be near SHM-07-03 (ND in 2007) and SHM-99-32X (204 ppb in 2008), respectively. The eastern limit in this area is also supported by earlier results from SHX-99-05 (1999) and SHP-99-34 (2001) as illustrated in SAR Figure 4-3. A Supplemental Groundwater Investigation (Harding ESE, 2002) indicates arsenic detections along the eastern extent are neither contiguous with the main plume lobe nor strongly correlated with ORP. Because prevailing hydraulic gradients are westward in the Nonacoicus Brook valley fill aquifer, further investigation east of SHX-01-06X and Nonacoicus Brook has not been a key issue. However, since Institutional Controls (ICs) on residential use of groundwater are under consideration in the FFS, further investigation is proposed to better define the area where ICs would be needed.

Farther north the following initial data gaps are apparent:

- The western plume limit just north and downgradient of West Main Street is west of DEP-08-03, which had 1700 ppb dissolved arsenic (6/08). While this plume edge is constrained by earlier (2001) profile results from SHX-01-10X, -13X, and -11X located slightly upgradient, the screens at SHP-07-01C and -01D sampled in 2007 are shallower than DEP-08-03 and may be above the plume. Consequently, the western plume in the area of West Main Street is unconstrained in the area east of DEP-08-05 (which extended to bedrock) and northwest of SHX-01-11X.
- The northern plume limit is interpreted to be under Nonacoicus Brook immediately north of DEP-08-03 and -08, which had 1700 and 240 ppb dissolved arsenic respectively (both 6/08). There is no monitoring well situated directly north of these locations where drilling access is limited by the wetland.
- To the northwest the plume appears to be constrained by DEP-08-07, but a data gap may exist to the west between DEP-08-05 and DEP-08-07.

Borings are proposed in each of the above areas at the approximate locations indicated in Figure 1. Bedrock has a strong influence on groundwater flow patterns, therefore a geophysical survey to map the bedrock surface in this area is proposed to precede the selection of final boring locations. Each boring would extend to bedrock with groundwater sampling every 10 feet during drilling, and analysis for arsenic and field parameters (pH, SC, ORP, DO). If drilling results suggest the 100 ppb plume limit has not been adequately identified, a new boring may be advanced to collect this data. When drilling results suggest the plume limit has been identified, temporary well screens would be constructed at appropriate intervals and sampled for metals and water quality characteristics. The plume will be mapped in plan and section views based on these results. Sentry monitoring wells will be identified following plume delineation, and may include new and existing wells. If any existing wells identified for sentry monitoring are not constructed or sited appropriately, they will be replaced with new wells.

2.2 North Plume Capture at Boundary

Objectives for the current remedy in place include operating the treatment system to contain the arsenic plume in the vicinity of the base boundary near the north end of the landfill and demonstrating that the arsenic plume is captured. The latest revised groundwater model and other lines of evidence as presented in the 2008 Annual Report suggest that impacted groundwater at the toe of the landfill is fully contained, subject to some uncertainty on the eastern plume extent at the toe (ECC 2009). This uncertainty relates to the extent of impact east of SHM-96-5B. A boring is proposed in the area of SHL-21 as indicated in Figure 1, extending to bedrock with groundwater sampling every 10 feet during drilling, and analysis for arsenic and field parameters. If drilling results suggest the plume limit has not been identified, a new boring would be advanced (offset east away from the plume) to collect this data. When drilling results suggest the plume limit has been identified, temporary well screens would be constructed at appropriate intervals and sampled for metals and water quality characteristics.

2.3 North Plume MNA for the Impacted Area

An AW objective is to establish that MNA will be effective for remediation for the arsenic plume north of the ATP capture zone within a timeframe that is reasonable given the circumstances of the site. The expected attenuation mechanism is immobilization of dissolved arsenic as it reaches the oxygenated groundwater discharge zone around Nonacoicus Brook. Unimpacted and oxygenated groundwater entering the area downgradient from the capture zone is not expected to mobilize arsenic sorbed to aquifer solids. An evaluation of MNA effectiveness will be based on criteria established by USEPA for inorganic contaminants, as identified in EPA/600/R-07/140. The determination of whether an MNA timeframe is reasonable is part of a comparison between MNA and aggressive remedies, such as Alternative 3B in the Draft FFS which consists of implementing a separate ATP for the Impacted Area.

USEPA recommends a four-tier approach for site characterization to evaluate the viability of MNA for site remediation (USEPA 2007):

1. demonstrate a static or shrinking plume that has not reached compliance boundaries or impacted existing water supplies;
2. determine rates and mechanisms of attenuation;
3. determine stability of immobilized arsenic and capacity of the aquifer to sustain uptake; and
4. establish a monitoring plan and contingency plans in the event of MNA failure.

The results of the SAR indicate that arsenic is sequestered in the aquifer below and south of Nonacoicus Brook, and is not expected to migrate to the nearest downgradient water supply well. As described in the CSM (Section 1.4), arsenic is immobilized as a solid phase in the aquifer where reduced groundwater transitions to the oxygenated conditions present in the stream. Further investigations will be completed to demonstrate a static or shrinking plume and monitor plume boundaries within the Impacted Area as described in Section 2.1 above.

The general mechanism for attenuation is immobilization of dissolved arsenic through precipitation, co-precipitation, and sorption on aquifer solids associated with a change in redox conditions in groundwater. Dissolved arsenite and arsenate species have been observed in groundwater, with the former dominating under reducing conditions and the latter under oxidizing conditions. Data characterizing aquifer solids - immobilized forms of arsenic and minerals that control or react with arsenic - remain to be collected. These data can be used to identify specific mechanisms for immobilization, which can further the understanding of reaction rates and stability of the immobilized material. Collection of co-located solid and liquid samples from representative portions of the aquifer is recommended, with analysis of arsenic species, other metals, mineral phases, and organic carbon in each media.

The stability of immobilized arsenic and the time to achieve cleanup goals in the Impacted Area will be evaluated theoretically based on the determination of specific reactions from the solid / liquid phase analyses discussed above, and empirically by a core flushing study similar to an evaluation conducted by US Geological Survey for the Saco Landfill (USGS 2004). This study will use cores of aquifer material collected from the same locations used for the solid-liquid phase analyses. The cores will be flushed with arsenic-free groundwater from areas near the site that are upgradient of the sampling locations. The eluting water will be tested for metals and organic carbon. Results will be used with a reaction-transport model to simulate long-term geochemical changes and the time required to achieve cleanup goals. Mineralogy of selected cores will be tested again following flushing to confirm the immobilization mechanisms. Relevant data from the LTM monitoring network, before and after full scale operation of the ATP, will also be considered in the assessment of attenuation mechanisms and timeframes.

The capacity of the aquifer to sustain arsenic uptake will be evaluated considering the specific immobilization mechanisms to be determined as describe above, and the mass distribution of metals, minerals, or other reactants in the aquifer. The data to be used for this evaluation are expected to be provided from the studies described above. Likewise, monitoring and contingency planning will be tailored to the site based on the specific reactions that are found to be integral to MNA and the expected capacity for further uptake.

Specific sampling locations and test methods for the above investigations will be developed after further evaluation of current and historic groundwater flow paths and discussion of field screening methods. A schedule for this additional investigation planning is provided in Section 3, including documentation in a subsequent Sampling and Analysis Plan.

2.4 Landfill Gas Impact

Objectives for the current remedy in place include completing an evaluation of landfill gas impacts in the Impacted Area to ensure that methane emanating from the landfill will not cause unacceptable risks in nearby structures. This evaluation will be conducted in accordance with USEPA Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities (USEPA 2005a). The referenced guidance document describes the evaluations of potential gas migration pathways, which include lateral migration of gas through soil or utility pipe bedding and indoor vapor intrusion in structures. Results of monitoring perimeter soil gas probes at the north end of the landfill indicate that landfill gas is not migrating offsite laterally through soil

(ECC 2009). Recent improvements have been made to the soil gas monitoring system to ensure that the appropriate soil depths are sampled. USEPA recommends vapor intrusion modeling as a screening step to evaluate the hazard for structures overlying a plume of contaminated groundwater.

Vapor intrusion modeling is proposed in accordance with the referenced guidance and using USEPA's GW-SCREEN or GW-ADV models to estimate the potential for methane intrusion into basement air from dissolved methane in groundwater. Methane poses an explosion hazard at air concentrations of 50,000 parts per million (**ppm**) which is 5% of air (the lower explosive limit) and is an asphyxiant at air concentrations above 140,000 ppm. There is no identified adverse health effect from potential human exposure to non-explosive levels of methane in air. The proposed model inputs are as follows:

- Depth to groundwater = 10 feet
- SCS Soil type above the water table = Sand
- Dissolved methane concentration in groundwater = 10 mg/l

The depth to groundwater in the Impacted Area appears to be shallowest on the north side of West Main Street, where it is approximately 20 feet bgs; if a 10-foot deep basement is assumed then the model depth would be 10 feet. Soil types in the Impacted Area are sandy and the SCS type of "Sand" provides the highest modeled vapor intrusion. The dissolved methane concentration of 10 mg/l is near the upper end of the range of concentrations in groundwater entering the ATP, and is higher than any measured concentration in a monitoring well near the Impacted Area, therefore it is a "worst case" estimate for this screening. The model output will be an estimated methane vapor concentration in a hypothetical building, for comparison with the methane lower explosive limit (50,000 ppm). Results will be discussed with BCT to evaluate the need for further modeling or field measurements. Previous air sampling in residential basements in the Scully Road area did not find detectable levels of methane.

2.5 East Plume Delineation and Capture

Objectives for the current remedy in place include controlling the continuing discharge of high arsenic groundwater from SHL to Plow Shop Pond (AOC 72) sediments. New groundwater monitoring wells were recommended by USEPA for the area between SHL and AOC 72 to collect data in this area (USEPA 2008). This information will be used, in combination with groundwater modeling, to evaluate remedies such as hydraulic controls (extraction or injection) or in situ treatment in the discharge area.

The proposed well locations identified by USEPA included the following:

- three locations within and near the center of the landfill, southwest of Red Cove; and
- two locations along the eastern edge of the landfill west of Red Cove.

These well installations were proposed to evaluate horizontal and vertical plume dimensions in the area upgradient of the discharge to AOC 72. However, it was decided by the Army that one location would be completed at the location identified as SHP-10-07 on Figure 2. Information obtained from this location would be used and incorporated into the Focus Feasibility Study. Additional borings and wells, at or near the EPA locations may be completed as part of the remedial design phase of the east plume discharge remedy.

The groundwater flow model for SHL was recently revised as part of the comment/response process for the 2008 AR. The model is currently being revised further as described in the AOC 72 RI Workplan, through adjustment of parameters controlling pond-aquifer communication. That revised model will be used in the AOC 72 RI/FS and in the SHL Final FFS. Since the current model revision will incorporate the latest relevant data and represent the best understanding of groundwater flow patterns near the pond, this model is proposed to be used for siting the wells required for the upgradient area. Results obtained from SHP-10-07 will be used to determine locations for additional wells in this area, if they are required.

This boring (SHP-10-07) would be extended to bedrock with groundwater sampling every 10 feet during drilling, and analysis for arsenic and field parameters. Temporary well screens would be constructed at appropriate intervals and sampled for metals and water quality characteristics. Based on the new hydraulic and chemistry data and using the updated groundwater model, an evaluation of hydraulic controls or extent of in-situ remedy will be conducted in the Final FFS.

2.6 Arsenic Source Strength Evaluation

Objectives for the SHL FFS include evaluation of remedial timeframes that require estimates of the arsenic source strength within the landfill wastes and surrounding aquifer materials. Potential sources of arsenic in groundwater include bedrock, bedrock-derived soils, former wetland sediments, and landfill wastes which are located above and below the water table. Arsenic is dissolved from the source materials by landfill-induced reducing conditions in groundwater. A portion of the landfill overlies a swamp where naturally-occurring organic material and reducing conditions may also have existed and where iron and arsenic might have accumulated because of focused groundwater discharge to the wetland prior to filling. Arsenic mobilized from source materials to groundwater may deposit in aquifer solids downgradient from the source through precipitation, co-precipitation, and sorption. This solid phase arsenic in the downgradient aquifer is a potential source material if groundwater conditions change to upset the equilibrium between solid and liquid phases.

Arsenic source strength can be estimated theoretically from an understanding of mobilization and immobilization mechanisms and masses of the reactants, and empirically through testing of source materials to evaluate reaction rates. The data gaps are similar to those identified for the evaluation of MNA in the Impacted Area in Section 2.3, but apply in this case to the source materials (including bedrock) in and around the landfill rather than the aquifer in the downgradient Impacted Area. The proposed investigations are therefore similar in terms of characterizing solid and liquid phases for the source materials. The core flushing study in this case will be conducted using site groundwater from the area of the source material to simulate arsenic mobilization. The eluting water will be tested for metals and organic carbon. Results will be used with a reaction-transport model to simulate long-term geochemical changes.

Chemistry of selected cores will be tested again following flushing to confirm the mobilization rate.

Specific sampling locations and test methods for the above investigations will be developed after further evaluation of historic data (including aerial photos and maps) and discussion of field screening methods and the potential use of geophysical techniques. Borings proposed for East Plume Delineation in Section 2.5 of the Workplan might also be utilized in this effort. A schedule for this additional investigation planning is provided in Section 3, including documentation in a subsequent SAP.

2.7 Air Sparging Implementability

Objectives for the SHL Draft FFS included evaluation of implementability for an air sparging remedy that would be constructed along and above the bedrock surface several hundred feet north of the landfill. The original northern proposed location of air sparging was suggested in the comments on the Draft FFS. Based on our review and analyses of the site data and conditions we do not believe that air sparging is a viable alternative for the treatment of impacted groundwater water at this time. Attempts to implement air sparging for similar sites has shown that the shift in groundwater geochemistry from anaerobic to aerobic typically causes major performance problems that include:

- Uniform injection of oxygen may be difficult to achieve,
- Injection and sparging wells will require frequent maintenance due to blinding with precipitates,
- Formation of precipitates may also affect groundwater flow patterns and reduction in effective hydraulic conductivity. These occur from growth of excessive biomass and build up of unwanted mineral precipitation side reactions that include calcite solids and iron slimes that can effectively foul the air sparging system and reduce effective pore size in the aquifer, altering flow and permeability.
- Reduced performance or inability of system to maintain treatment objectives due to the aforementioned issues.

Based on these concerns/issues as well as our experience with air sparging, typical systems are implemented and operated for less than five to ten years, which is much less than what would be required for this site. Therefore, air sparging is not deemed to be a viable long term alternative for this site and will be no longer retained as an in-situ alternative in the Focused Feasibility Study.

2.8 Floc Removal Feasibility Study

The SHL Draft FFS proposes a floc removal remedy for Red Cove that can reduce risks to ecological receptors in the presence of a continuing source of contamination as part of Alternative 2, an MNA approach. Such a removal process could also be combined with other alternatives under consideration in the FFS. Ecological risks in AOC 72 are currently under evaluation as part of an RI as described in Section 1.6. RI results will be used to establish remedial action objectives for sediment or surface water and identify/screen remedial technologies in an AOC 72 FS Screening Report (**FSSR**). The Draft FSSR is scheduled to be completed approximately two months before the SHL Draft Final FFS (see Section 3). Since the FSSR would be the usual vehicle for developing information needed to evaluate a remedy in an FS, and the FSSR timing is adequate for this purpose, the AOC 72 FSSR will be used to select an appropriate floc removal remedy to include in the SHL Final FFS.

The FSSR evaluation is expected to include typical sediment remediation techniques such as Monitored Natural Recovery (**MNR**), in situ capping, and dredging/excavation (USEPA 2005b). MNR may not be feasible in the case where a continuing source is present, since the contaminant would not be degraded or isolated through thin-layer placement of solids or burial by natural sediments. In situ capping might be feasible if a reactive or oxygen-release material was used to sequester arsenic beneath the benthic habitat cap. Dredging or excavations to periodically remove impacted sediment for offsite disposal also appear to be feasible, and such a dredging remedy is currently in use for a similar arsenic discharge at the HBHA Pond portion of the Industri-plex Superfund site in Woburn, MA.

2.9 Landfill Consolidation Feasibility Study

The SHL Draft FFS proposes a landfill consolidation remedy Alternative remedy that would include relocating wastes above the water table and lining the landfill to eliminate leaching to groundwater. In order to evaluate the landfill consolidation, the Army will utilize existing data to map the extent of landfill waste. Using the data collection, a memorandum will present a description of two consolidation alternatives that include:

1. Consolidation of north part of the landfill to the southern part that is designed to contain the waste material; and,
2. Removal and consolidation of the waste material that is located within the saturated zone.

This memorandum shall provide a description of each alternative including a discussion of the LTO&M environmental controls (run-on and runoff, drainage, gas, leachate) required, a list of various assumptions, a conceptual drawing, and drawing(s) that present a conceptual depiction of the proposed remedy for each of the two alternatives. In accordance with the work plan, and consistent with EPA guidance for feasibility Studies, the cost estimate prepared for each of the two landfill consolidation alternatives will be within a 30 to 50 percent accuracy range. In addition this memo will evaluate the implementability and constructability of the alternatives as well as the long term effectiveness and permanence of the remedies. Finally the memo shall also identify any significant data gaps that would limit accuracy of the conceptual design outside of the 30 to 50 percent accuracy range.

2.10 Wetlands Evaluation / Delineation

Prior to commencing field activities, personnel will locate and mark out the exploration points, geophysical lines within the North Plume Delineation area, and access points. Personnel will inspect each of the locations, flag wetlands, and map activities which will occur within the wetlands or buffer zone. The locations of these points / lines will be GPS located on a plan. A wetlands report will be prepared that will describe wetlands and buffer zone areas impacts and the scope of the work within the wetlands or buffer zone. Measure to minimize impacts to wetlands will be discussed. The Army will submit the report to the Ayer Conservation Commission. Further information on the geophysical investigation, transect lines, and grubbing are outlined in the Field Sampling Plan Report.

3.0 PROPOSED SCHEDULE

The project schedule is illustrated in Figure 3 and consists of the following milestones:

1. Submitting the Supplemental Investigation Workplan Addendum, Sampling and Analysis Plan (SAP), Data Assessment Plan (DAP), and Quality Assurance Project Plan (QAPP) in May 2010;
2. Commence Rotosonic Drilling and the DPT Drilling in May 2010 to June 2010;
3. Submission the draft MNA / Source Strength Work Plan Addendum in July 2010;

The status of these investigation and plans will be detailed within the Monthly Monitoring Letter Report.

4.0 REFERENCE

AMEC 2009. Draft Final Supplemental Groundwater and Landfill Cap Assessment for Long-Term Monitoring and Maintenance, Shepley's Hill Landfill, Devens MA. Prepared for USACENAE, June 2009

ECC 2009. Final 2008 Annual Report, Shepley's Hill Landfill, Devens MA. Prepared for Army BRAC Environmental, September 2009

Gannett Fleming 2006. Expanded Site Investigation, Remedial Oversight of Activities at Fort Devens Plow Shop and Grove Ponds. Prepared for USEPA Region 1, May 2006

Harding ESE 2002. Revised Draft Shepley's Hill Landfill Supplemental Groundwater Investigation, Devens Reserve Forces Training Area. Devens, MA.

USEPA 1995. Superfund Record of Decision: Fort Devens, EPA ID: MA7210025154.

USEPA 2005a. Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities, EPA-600-R-05-123a, September 2005.

USEPA 2005b. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, EPA-540-R-05-012, OSWER 9355.0-85, December 2005.

USEPA 2007. Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volume 2, EPA-600-R-07-140, October 2007.

USEPA 2008. Final Report; Arsenic Fate, Transport, and Stability Study; Groundwater, Surface Water, Soil and Sediment Investigation; Fort Devens Superfund Site, Devens MA, September 2008.

USEPA 2009. Final Report for the Remediation System Evaluation & Green Remediation Evaluation of Shepley's Hill Landfill, August 2009

USGS 2004. Natural Remediation of Arsenic Contaminated Ground Water Associated with Landfill Leachate, Fact Sheet 2004-3057, May 2004.

ATTACHMENT A - RESPONSE TO COMMENTS ON THE 10/30/09 SUPPLEMENTAL INVESTIGATION WORKPLAN

INTRODUCTION

This Response to Comments (RTC) is for the 10/30/09 Draft Supplemental Investigation Workplan Volume 1 for Shepley's Hill Landfill. The draft workplan presents the rationale and technical approach for data collection to address Additional Work requirements and Focused Feasibility Study (FFS) data gaps for Shepley's Hill Landfill in Ayer MA. The Army proposes to provide a detailed sampling and analysis plan for the data collection as Volume 2 of the workplan.

The Draft Workplan Volume 1 describes site characterization activities including conventional drilling and sampling and specialized testing of aquifer cores and landfill source materials for geochemical properties. The comments on the general approach contained in draft Volume 1 were generally supportive of the overall concepts, but included many suggestions on refining the approach or details regarding testing. Some of these suggestions are adopted as described in the RTC that follows. The Army expects to develop other details of the workplan through discussions with the BCT.

The Army proposes a two-prong approach for completing Volume 2 as needed to allow the field investigations to proceed. First, initial discussions should focus on completing an expedited sampling and analysis plan for the more conventional types of field investigations such as plume delineation and monitoring. Second, discussions and communications should continue as needed to develop details for the more specialized testing related to MNA and source strength evaluations. Because this latter component of the investigations involves some techniques that have not been employed at the site to date, the Army expects that relatively more development time will be needed to ensure consensus on data quality objectives and collection methods. Selection of final test locations for this work may also involve field screening measurements. We propose to advance these discussions as needed to allow the associated sample collection or field screening to occur during the same field mobilization as the conventional investigations. A schedule for this process will be provided in the Final Workplan Volume 1.

USEPA COMMENTS

Comments on the 10/30/09 Draft Workplan were received from USEPA on 12/1/09. The comments are provided below with responses in italics following each comment. Several comments have been divided into separate paragraphs to clarify the responses to multiple issues.

EPA has reviewed the document titled "Shepley's Hill Landfill, Draft Supplemental Investigation Workplan - Volume 1," dated October 2009 and prepared by AMEC Earth & Environmental, Inc., on behalf of the Army. EPA comments on the Draft Workplan are attached. The majority of the comments relate to details of the investigation sampling locations and implementation and are provided to support the ongoing preparation of the Sampling and Analysis Plan (Volume 2). It is our understanding that the BCT meeting planned for December 17, 2009 will be a technical meeting on the supplemental investigation and serve as an opportunity for discussion and resolution of the enclosed comments.

In addition, the Draft Workplan refers numerous times to the FFS. Note that the FFS is to be revised to address stakeholder comments, as discussed at the November 19, 2009 BCT meeting. Where appropriate, the Draft Workplan should be revised to be consistent with revisions proposed for the FFS.

Response: Revisions to the remedial alternatives listed in the Draft FFS are indicated in the 12/3/09 RTC for that document. Any corresponding revisions to the Draft Workplan will be as indicated in the following RTC for the workplan and subsequent meetings or communications.

USEPA General Comments:

1. General Subsurface Investigation Approach: Given the importance of the data to be collected during this supplemental investigation, as well as recent experiences from the last round of field work, a robust approach to the subsurface investigation is needed. EPA recommends a combination of surface geophysical methods and 'traditional' geotechnical drilling approaches. This more comprehensive and traditional approach is advantageous in that residual uncertainties will be minimized. Detailed recommendations follow, below.

Response: Data collection techniques will be designed to achieve Data Quality Objectives (DQOs), which will be discussed with BCT and detailed in the Workplan Volume 2.

2. Seismic Surveys: As a first phase, surface geophysical (i.e., seismic) methods are recommended to better target drilling locations as well as to corroborate results from subsequent and previous drilling phases. In particular, a combination of traditional seismic refraction methods as well as the multi-channel analysis of surface waves (MASW) method are recommended. The MASW approach is likely to be advantageous in areas containing low-velocity subsurface materials such as trench fill and buried waste, which typically inhibit standard refraction approaches. Specific approaches are discussed below for various site sub-areas. EPA would be willing to consider assisting with seismic survey conceptualization, design, and/or implementation via our IAG with USGS.

Response: We note that specific recommendations for seismic surveys are contained in EPA specific comments 3, 4, 5, 7, and 11. The Army's responses to those recommendations are provided below.

3. Drilling Methodology: Light-duty drilling approaches (Geoprobe, MicroWells®, hand-held vibratory hammers, etc.) have been used with varying levels of success by the Army, EPA and DEP for various facets of the SHL characterization. While these methods have many advantages, they share a common deficiency, i.e., a general inability to penetrate harder subsurface layers, particularly at depth. At this stage, as the investigation becomes more focused towards evaluation of particular remedial alternatives and specific remedial components, there is a greater need for reliable subsurface data. For this reason, a return to traditional drilling approaches, using standard geotechnical methodologies (e.g., standard penetration test, drive and wash and/or hollow-stem auger drilling), is recommended. EPA looks forward to discussing the specific drilling approach in more detail with the Army, but it is our general expectation that the methods employed will

adhere to the guidelines discussed in US Army Corps of Engineers Engineering and Design Manual EM-1110-1-4000, 1 Nov 98, *Monitoring Well Design, Installation and Documentation at Hazardous, Toxic and Radioactive Waste Sites.*

Response: The investigation technologies will be selected to provide results that meet data quality objectives.

4. Soil and Groundwater Profiling: In order to further evaluate the geochemical complexities at this site and answer questions regarding the specific processes responsible for arsenic fate and transport, EPA requests that soil and groundwater be profiled in tandem at all new locations. At all new boring locations, split-spoon soil samples should be collected at a minimum of 5-foot intervals and at each change in stratigraphy. In some locations and depth intervals, it may be advisable to collect a continuous profile of soil samples using these methods. At depths beyond which split-spoon "refusal" is encountered, bedrock should be confirmed through collection of at least 5-feet of bedrock core. While the Draft Workplan proposes groundwater profiling at 10-foot intervals, it may be advisable to collect samples at a tighter discretization (e.g., 5-foot intervals) at some locations and depth intervals (e.g., at locations above and below buried swamp horizons) or perform continuous vertical groundwater profiling at selected locations. Given the proposed coupling of soil and groundwater data, it may be advantageous to employ a temporary sampling screen for groundwater in concert with the split-spoon sampler for soil within the same casing string in order to collect both data sets with a single vertical advancement to depth. However, it may be advantageous for other reasons to collect groundwater profiles using a separate method/advancement.

Response: Sampling procedures will be selected to fill identified data gaps and meet data quality objectives. If collocated soil and groundwater samples are needed to meet an objective, as the Army has identified for some locations in the Draft Workplan, these samples will be collected. We do not propose to collect such samples if the results would not fill a data gap.

USEPA Specific Comments:

1. Page 1-2, Section 1.2, Site History: A summary of land use within the historical operating boundary of Shepley's Hill Landfill is provided in this section, making reference to three facility locations/operations – "AOC 4, the sanitary landfill incinerator; AOC 5, sanitary landfill No. 1; and AOC 18, the asbestos cell". Within the text of the 1995 Record of Decision (page 3), the following additional descriptive text is provided: "AOC 4, the sanitary landfill incinerator was located in former Building 38 near the end of Cook Street within the area included in Phase I of the sanitary landfill closure. The incinerator was constructed in 1941, burned household refuse, and operated until the late 1940s. Ash from the incinerator was buried in the landfill." Within the 1995 Record of Decision (page 4), reference is made to additional information provided in the "…RI Addendum report, December 1993, Section 3, and the Feasibility Study (FS) report, February 1995, Subsection 1.2". Based on the apparent time of operation of the incinerator and ash disposal, it appears reasonable that Municipal Solid Waste Incinerator (MSWI) ash was disposed in

the portion of Shepley's Hill Landfill that was capped during Phase I of the landfill closure effort. [See also EPA's September 15, 2005 letter, General Comment 3, and EPA's February 21, 2006 letter, Response 1 follow-up.] As reported in the technical literature, MSWI ash is a potential source of elevated arsenic concentrations in leachate, with example references provided below. In addition to these potential sources, the potential presence of waste water treatment plant residuals (e.g., sludges), septic waste, arsenic trioxide (e.g., "white arsenic", rat poison) and copper chromated arsenic (CCA) cannot be overlooked. As proposed in Section 2.6, soil cores will be collected by drilling into buried waste and underlying soil down to bedrock at three locations illustrated in Figure 2. As illustrated, two of these proposed locations are located within the area of the landfill suspected to have received MSWI ash (i.e., during Phase I capping). It is anticipated that information derived from these analyses will help in pinpointing whether elevated arsenic in groundwater below buried waste is derived from waste materials, natural soils or bedrock, or some combination thereof. In support of the final selection for these soil boring locations, it is recommended that a review of the following document be conducted to determine if historical aerial photography may help in confirming the historical location of the "sanitary landfill incinerator" and refining the location(s) where MSWI ash may have been disposed: EPIC (Environmental Photographic Interpretation Center), September 1991, EPA Installation Assessment, Fort Devens, Volumes I and II, Final.

Landsberger, S., Buchholz, B. A., Kaminski, M., and Plewa, M. Trace elements in municipal solid waste incinerator fly ash. Journal of Radioanalytical and Nuclear Chemistry 167:331-340 (1993).

Rahman, Farhana Alamgir; A; R; S, Arsenic Availability from Chromated Copper Arsenate (CCA)-Treated Wood. Journal of Environmental Quality 33 (1): 173–180. http://jeq.scijournals.org/cgi/reprint/33/1/173. (2004).

Sabbas, T., Polettini, A., Pomi, R., Astrup, T., Hjelmar, O., Mostbauer, P., Cappai, G., Magel, G., Salhofer, S., Speiser, C., Heuss-Assbichler, S., Klein, R., and Lechner, P. Management of municipal solid waste incineration residues. Waste Management 23:61-88 (2003).

Shimaoka, T., Zhang, R., and Watanabe, K. Alterations of municipal solid waste incineration residues in a landfill. Waste Management 27:1444-1451 (2007).

Response: The available historic aerial photography will be reviewed and discussed with BCT prior to finalizing boring locations. Please see related EPA comments 7 and 8, and MassDEP comment 3 and the responses regarding identification of source areas and appropriate sampling locations.

2. Page 3, Section 1.5, Recent Data on Remedy Performance: The language in this Section is consistent with language in Section 1.5 of the Draft FFS. Please see EPA's October 30, 2009 comment letter on the Draft FFS, Specific Comment 3, and the Army's response on this comment. Please revise this Section to be consistent with the proposed revisions to the FFS.

Response: The statement "Given that a number..." near the end of the first paragraph will be deleted.

3. Page 5, Section 2.1, North Plume Delineation and Monitoring for Impacted Area: A seismic refraction survey should be performed from DEP-08-05 northeastward to DEP-08-08. Subsurface data from this alignment will serve to define the configuration of the bedrock/overburden contact, as well as provide depth information for till or other subsurface layers. This information should guide the location of proposed new wells. In addition, the seismic data will serve to verify the adequacy of the depth-of-penetration achieved from the "SHP-07" and "DEP-08" series which were all advanced with direct-push equipment.

Response: We agree that additional bedrock delineation in this area would assist with plume delineation, since bedrock is a strong influence on groundwater flow patterns.

In addition, one of the purposes of the Additional Work objective cited in this section was to ensure that there are permanent monitoring locations for all significant areas of the plume and to serve as sentry wells to ensure that the plume does not migrate beyond final delineated plume boundaries (i.e., that it remains stable or shrinking). The focus of this section is to delineate the plume limits and this is a critical first step for determining locations for sentry wells. The proposed MNA sampling locations may offer important information for determining locations for additional monitoring wells within the plume. However, it is not clear that the proposed sampling program will result in a sufficient long-term monitoring well network. Once the data from the proposed investigation is evaluated, EPA requests that the BCT discuss the LTM network and work together to select locations for additional permanent monitoring wells.

Response: The Army agrees with this concept and the text can be revised accordingly.

4. Page 6, Section 2.2, North Plume Capture at Boundary: An MASW or traditional seismic refraction survey is recommended in an alignment roughly from the extraction wells on the west to just beyond SHL-21 on the east. This data will serve to define the configuration of the bedrock/overburden contact as well as providing depth information for till or other subsurface layers along the eastern edge of the capture zone, where subsurface information is presently limited.

Response: Seismic refraction data delineating bedrock in this area were collected during the SHL RI and reported by ABB in the 1993 Final RI Addendum. The additional boring(s) proposed in this area for the plume capture objective (Section 2.2) will provide further information. No specific data objectives relating to Additional Work or the FFS have been identified for this area.

5. Page 6, Section 2.3, North Plume MNA for the Impacted Area: Relative to selection of proposed locations for "MNA Sampling", it is recommended that Figure 1 be revised to provide an overlay of existing and proposed well/boring locations with measured potentiometric surface for groundwater representative of the anticipated period for installation and sampling. This groundwater flow analysis should be used to develop a consensus regarding appropriate locations for the proposed soil and/or groundwater

profiling. An important aspect to this characterization effort is delineation of the vertical distribution of arsenic concentrations in groundwater along the presumed flow path(s) delineated by the "proposed MNA sampling locations". The Workplan proposes collection of co-located solids and groundwater at 3 depth intervals for the 3 proposed well/boring locations. However, as noted in General Comment 4, it may be advisable to profile soils and groundwater at a tighter discretization (e.g., 5- or 10-foot intervals) or perform continuous vertical profiling. The results of profiling groundwater chemistry would provide valuable information for targeting the locations and depth of the aquifer solids sampling and testing effort for the purpose of confirming the hypothesized mechanism for attenuation and the stability of sequestered arsenic. This information would also support decision-making for the installation of permanent LTM wells in the future.

Response: A revised Figure 1 will be developed to show the modeled potentiometric surface and groundwater flow paths before and after implementation of the extraction system. We agree that conditions affecting MNA may vary significantly within the Impacted Area, and that further evaluation of existing data and field screening methods is appropriate to ensure that the tested materials are representative of the majority of the aquifer. As discussed in the Introduction to this RTC, we propose to conduct this investigation planning on a separate track from other Additional Work requirements so as not to delay those efforts; a schedule for this activity will be developed for discussion. Please see related EPA comment 9 part 2 and MassDEP comment 2 and the responses regarding identification of appropriate sampling locations.

Relative to the hypothesized mechanism that might lead to attenuation of arsenic migration in groundwater and relative time frame(s) or capacity for attenuation, it is recommended that recently compiled site characterization information from AOC50 studies be reviewed. One source of these data is available via the following public document: http://www.serdp.org/Research/upload/ER-1374-FR.pdf. While the characteristics of the groundwater flow system and contaminant plume are different at this location, the information derived from this site evaluation effort can provide useful perspective towards refining the characterization effort and data quality objectives for the proposed supplemental characterization effort for the North Plume.

Response: The referenced document has been reviewed, and we agree that it is relevant in particular for developing sampling and analysis procedures.

In addition, it is recommended that the design and implementation of the proposed coreflushing study be discussed with the BCT given the sensitivity of the chemical characteristics of sampled groundwater and aquifer solids that may depend on the techniques used for sample retrieval and processing. As an example, please see the case study analysis of potential problems particular to assessments of arsenic attenuation that is provided in EPA/600/R-08/114 (http://www.epa.gov/nrmrl/pubs/600r08114/600r08114.pdf). While the core-flushing work, as described, seems to be a logical approach, it may not be reasonable to expect that results will be similar to those obtained from the Saco Landfill experiment. Key similarities and differences between the Saco Landfill and SHL - for example, in the type(s) and amount(s) of organic carbon sorbed to the aquifer materials used in the columns - should be considered in designing and conducting the proposed experimental work. It is cautioned that the applicability of the results of the proposed flushing study depends upon the assumption that redox conditions in the North Plume Impacted Area are stable. Changes in redox conditions, driven by actions already taken (e.g., construction of the landfill cap, operation of the extraction system) or by future actions (e.g., installation of an air sparging system), may alter the mobility of arsenic at any particular location. Lastly, it should be noted that there are likely nontechnical differences between the Saco Landfill and SHL which will need to be carefully assessed. For example, the land ownership situation is quite different at the two sites. At Saco Landfill, the town of Saco owns the land underlain by the down-gradient plume, and there are no known residences which are affected offsite.

Response: The referenced document has been reviewed. We do not necessarily believe that the results of the SHL study will be similar to the Saco study results. Rather, the Saco study was offered as an approach to examine the conditions at SHL. Other relevant studies (such as the AOC 50 study cited in the preceding comment) will also be considered in developing the details of the testing program. Similar to the planning for sample collection (see response to first part of this comment), we propose to conduct this test program planning on a separate track from other Additional Work requirements so as not to delay those efforts; a schedule for this activity will be developed for discussion.

Note, also, that the data from the LTM monitoring network should also be considered in the evaluation of arsenic attenuation and remedial timeframes. Although only a couple of data points are available for post-full-scale ATP operation, this data set should provide important information into the assessment.

Response: The available data will be considered, and this will be made explicit in the workplan.

Finally, while numerous MicroWells® have been installed along West Main Street (~ 2001) and Molumco Road (~ 1999 to 2007), there is still some ambiguity, given the inherent limitations of MicroWells®, regarding the true depth to bedrock, the presence of till layers, etc., in these areas. While the proposed new borings co-located with SHM-07-05 (Molumco Rd.) and SHX-01-09X (W. Main St.) respectively will provide some insight into the depth to bedrock and presence of till at those locations, the affected areas along these existing 'transects' are 800+ ft and 1000+ ft respectively. In this context, it is worth considering additional seismic refraction surveys in these areas, primarily to insure the adequacy of the current monitoring network in these areas.

Response: We note that this comment relates more to the adequacy of monitoring (Section 2.1; see EPA Specific Comment 3 and the response) than to the MNA evaluation (Section 2.3). We agree that bedrock delineation in this area would assist with plume delineation, since bedrock is a strong influence on groundwater flow patterns.

6. Page 8, Section 2.4, Landfill Gas Impacts: The text notes the significant result that air monitoring in residential basements along Scully Road did not detect methane. Given that the potential for vapor intrusion is now being considered for homes along West Main

Street, further direct measurements (e.g., basement indoor air or soil gas) should be considered in this area, rather than relying entirely on model calculations. The proposed modeling may be insightful, but the "ground truth" provided by direct measurements may be more compelling.

Response: Vapor intrusion modeling is recommended in EPA guidance as a screening approach to estimate the potential for methane exposure within buildings. Results will be discussed with the BCT to evaluate the need for further modeling or measurement of soil gas concentrations.

7. Page 8, Section 2.5. East Plume Delineation and Capture: The Workplan notes that the groundwater flow model for SHL is currently being revised to better incorporate parameters controlling pond-aquifer interaction. The need for this revision is illustrated by the relative lack of correspondence between the observed and model-predicted potentiometric surface contours in the eastern portion of the modeled domain presented in Figure 5-5 of the 2008 Annual Report. Proper revision of the model using hydraulic head data from wells in the RSK network adjacent to Red Cove should result in a better match between predicted and observed gradients in this area.

Response: The revisions to the model will include recalibration to long-term average water levels including those from wells in ORD's RSK network for which there are multiple synoptic observations.

Consistent with EPA's recommendations in the "Final Report, Arsenic Fate, Transport and Stability Study," dated September 30, 2008, which was prepared by EPA's Office of Research and Development ("EPA/ORD Final Report" - page 130 and Figure 74), five new proposed wells/borings are shown on Figure 2. The Workplan indicates that borings at the well locations will extend to bedrock and groundwater will be sampled every 10 feet during drilling. As discussed above in General Comment 4, EPA recommends collection of soil samples collocated with the groundwater samples, for characterization of aquifer solids and landfill waste along the same (or adjacent) vertical profiles. The deep overburden, in particular, represents a significant data gap with respect to characterization of arsenic in association with aquifer solids. Given that the highest groundwater arsenic concentrations are typically found at depth, characterization of the deep soils, in conjunction with collection of vertically-discretized groundwater samples, is critical to further testing and development of the conceptual model.

Response: We agree that characterization of aquifer solids and wastes on the eastern side of the landfill would be beneficial for further development of the CSM and possible evaluation of remedies. This issue is closely associated with the landfill source strength characterization described in Section 2.6. Please see related EPA comments 1 and 8, and MassDEP comment 3 and the responses regarding identification of source areas and appropriate sampling locations. To the extent possible considering the schedule and that some or all of the five proposed wells/borings described in Section 2.5 for the East Plume Delineation may be completed while details of the source characterization effort are still being developed, the data needs for source characterization will be considered during the plume delineation.

EPA requests that the Army consider one additional well immediately adjacent to the boring location shown next to the N-5 piezometer pair, with vertical-profile sampling of groundwater and soil during installation. This area is of particular interest, because it is known from the boring log for the N5 piezometer pair that there is saturated waste at this location, the deep piezometer (screened in bedrock) has shown historically very high arsenic concentrations, and the shallow piezometer (screened in waste) has shown relatively low concentrations. The relatively thick domain between these two piezometer screens remains uncharacterized chemically.

Response: Similar to the preceding comment, this issue appears to be associated with the landfill source strength characterization as described in Section 2.6, and we propose to address it as part of that investigation program.

In addition, a north-south oriented seismic refraction or MASW transect along the access road between Red Cove and the landfill cap could be beneficial to improving the CSM for the east plume as well as contributing to a better understanding of site subsurface in this area for purposes of landfill consolidation. Better control on the elevation of the top of bedrock surface in this area could also assist in fine-tuning the locations for the new wells, as well as helping to constrain the model in this area given the widely known sensitivity of models to the position of the top-of bedrock surface.

Response: Seismic refraction data delineating bedrock in this area were collected during the SHL RI and reported by ABB in the 1993 Final RI Addendum. The RSK borings around Red Cove provide supporting data for this delineation.

Finally, reference is made within this draft to "eliminating the continuing discharge of high arsenic groundwater (arsenic >100 ppb)" as an objective for the current remedy. However, this statement implies that discharge of groundwater with arsenic concentrations greater than 10 ppb, but less than 100 ppb would be acceptable. Please explain the basis of the 100 ppb criterion proposed here.

Response: The remedial objective is to eliminate discharge of groundwater to the pond at levels exceeding risk-based concentrations. Those concentrations have not yet been determined, nor have background groundwater concentrations been determined. The text "(arsenic >100 ppb)" will be deleted from the referenced statement.

8. Page 9, Section 2.6. Arsenic Source Strength: The objective concerning arsenic source strength is multi-faceted. In addition to naturally occurring sources, among the potential contributors to the dissolved arsenic plume in groundwater within the landfill footprint, incinerator ash deposition and buried swamp (i.e., wetlands/peat) deposits have been hypothesized and merit further investigation. As such, in order to distinguish between these various potential inputs, boring locations and intervals for core selection will need to be carefully considered. For example, a boring targeted to a buried swamp deposit, which also may have received anthropogenic waste, would be an ideal candidate for a continuous soil profile. In such an area, a core sample above the former swamp horizon (e.g., waste material) may have different characteristics than naturally-produced arsenic

containing substances (e.g., "bog-iron") within or beneath the former swamp horizon. Additional discussions are needed in order to ensure that a comprehensive set of unique 'end-members' (e.g., incinerator ash, swamp deposits unaffected by waste, sludge deposits, etc.) are identified and selected for core sample collection and subsequent analysis.

Response: We agree that there are many possible substances and geochemical conditions which may exist in and under the landfill. Considering the difficulty in characterizing heterogeneous areas under the landfill, it appears that the evaluation of remedial timeframes will necessarily be broad and results expressed as a range. Please see related EPA comments 1 and 7, and MassDEP comment 3 and the responses regarding identification of source areas and appropriate sampling locations. We agree that further evaluation of historic data (including aerial photos and maps) and discussion of field screening methods is appropriate to ensure that the tested materials include significant arsenic and carbon sources. Borings proposed for East Plume Delineation in Section 2.5 of the Workplan might also be utilized in this effort (see EPA comment 7 parts 2-3 and the response). As indicated in the Introduction to this RTC, we propose to conduct this investigation planning on a separate track from other Additional Work requirements so as not to delay those efforts; a schedule for the planning and related field screening activities will be developed for discussion.

As identified in the EPA/ORD Final Report, a current data gap for understanding the source of arsenic contamination in groundwater below buried waste is the lack of information on the vertical distribution of arsenic and other potential leachate indicators (e.g., see groundwater constituent data for piezometer pair N5-P1,P2 shown in Figure 43 of the referenced report). Prior to the collection of subsurface solids for the core flushing study, EPA recommends vertical profiling of soils and groundwater as a first phase, similar to the recommendation for Section 2.3. The data derived from this effort will help inform the selection of boring and well installation locations and provide critical information on the vertical dimension of the plume that is migrating towards the groundwater extraction system. This phased approach could be undertaken using staged field deployments or via concurrent operations to evaluate field groundwater chemistry measurements to guide the selection of subsurface solids for further testing and/or the placement of well screens. As an example, there are field methods for the analysis of dissolved arsenic concentrations that could be implemented during drilling and vertical profiling (see example reference below).

Response: The plume that is migrating towards the groundwater extraction system extends from the water table to bedrock, as indicated by the results at the N5 well pair and the profile results at the extraction well location. We agree that some field screening is likely appropriate to select samples for the MNA testing, as indicated in the preceding response. Please see also the Introduction to this RTC regarding the overall approach to the MNA and source strength evaluations.

In addition, it is requested that the boundaries of the historical land feature addressed in the statement, "A portion of the landfill overlies a swamp where naturally-occurring organic material and reducing conditions may also have existed and where iron and arsenic might have accumulated because of focused groundwater discharge to the wetland prior to filling", be graphically delineated in Figure 2. It is not clear to what area of the landfill this description applies.

Response: A revised Figure 2 will be developed as part of the investigation planning described above.

Finally, the discussion of empirical assessment of arsenic source strength by testing of source materials refers again to the proposed core-flushing study. It should be noted that the reactive transport model in the Saco Landfill study assumed that sorption of arsenic by hydrous ferric oxides (HFO) and the subsequent dissolution of HFO under reducing conditions due to landfill carbon were the primary processes controlling arsenic uptake and release. Other mechanisms that may determine arsenic behavior in the SHL system, including precipitation and dissolution of other arsenic-containing phases and other redox-controlled reactions besides reductive dissolution, should also be considered in conjunction with further testing and development of the conceptual model.

Steinmaus, C. M., George, C. M., Kalman, D. A., and Smith, A. H. Evaluation of two new arsenic field test kits capable of detecting arsenic water concentrations close to 10 µg/L. Environmental Science & Technology 40:3362-3366 (2006).

Response: The PHREEQC model used in the Saco study was calibrated to the column study results; therefore it is expected to reasonably simulate the mechanisms controlling arsenic behavior in the samples tested. Likewise for the SHL study, calibration of the model to experimental results will provide the most realistic simulation of future conditions. Experimental results will be evaluated along with theoretical estimates based on specific chemical reactions as determined from the solid/liquid phase analyses.

9. Page 9-10, Section 2.7. Horizontal Drilling Implementability: A seismic refraction line should be considered in the area identified on Figure 1 for the "horizontal drilling evaluation". The seismic survey line should extend westward from SHL-9 to the bedrock upland. A seismic survey is necessary to support this objective in order to determine whether bedrock pinnacles or other abrupt variations in subsurface topography are present in the area. Such features may be problematic for a horizontal drilling scheme, and may not be revealed with three widely-spaced vertical test borings.

Response: Considering potential advantages of moving an air sparging remedy closer to (or into) the landfill as were suggested in the comments on the Draft FFS, the SGI-proposed location of air sparging along an east-west line about 200 feet north of the landfill may no longer be optimal. The Army proposes to hold off on the original proposed series of borings until further data are collected on source materials and geochemical conditions within the landfill as described in the response to EPA comment 8, part 1.

It is noted that three borings to bedrock are proposed to better define the distribution of contaminants west of well SHL-9. Consistent with General Comment 4, it is recommended that the proposed vertical-profile sampling of groundwater in this area be expanded to include collection of co-located soil samples as well. It is also recommended that a piezometer be installed in at least one of the boreholes at the western plume boundary to provide hydraulic head data to aid in the evaluation of the capture zone for the ongoing extraction system.

Response: The three borings proposed in the draft workplan may no longer be needed; please see the preceding response, and the 12/3/09 RTC for the Draft FFS, regarding potential changes to the Air Sparging alternative. The Army will consider collecting one or more samples of aquifer solids in this area as part of the MNA evaluation for the Impacted Area described in Section 2.3; please see the response to EPA comment 5, part 1.

In addition, air-sparging systems are susceptible to fouling and plugging from the precipitation of iron oxyhydroxides for systems with high dissolved ferrous iron concentrations. This process results in rapidly diminishing efficiency and/or high maintenance costs. The problem encountered in these systems is, in part, due to the high concentrations of oxygen introduced during direct injection of air. It is suggested that injection of treated, oxygenated effluent water from the existing treatment system be considered as an alternative source of oxygen that would introduce less severe gradients in oxygen concentrations that would otherwise induce fouling of system components due to iron oxyhydroxide precipitation. It is also recommended that consideration be given to the potential added benefit of injecting water to exert greater hydraulic control on subsurface flow within this portion of the aquifer, relative to performance objectives for the groundwater extraction system.

Response: The use of oxygenated water as part of an in situ remedy will be considered in the FFS, as indicated in the 12/3/09 RTC (see MassDEP comment 4 and the response). Injection of water for hydraulic control is also under consideration as part of Alternative 3A. After additional consideration of the potential applications for air sparging, the Army proposes to develop a pilot test of this remedy on the east side of the landfill to evaluate groundwater treatment upgradient of Red Cove. Details for this test would be developed in a separate plan, which would consider data developed for the East Plume Delineation described in Section 2.5 of the workplan. Please see also EPA comment 7 and the response regarding plume delineation.

10. Page 10, Section 2.8. Floc Removal Feasibility Study: It is recommended that the objective of this component of the draft be more clearly defined. Based on the title of this section, it appears that an objective of this task could be to evaluate the efficacy of existing dredging technologies to remove the shallow sediment layer ("floc") in a manner that does not result in dispersal of these arsenic-bearing solids to other portions of Plow Shop Pond that currently possess lower arsenic concentrations. However, the current text does not provide a clear picture of the objective(s) to be targeted under this section.

Response: RI results will be used to establish remedial action objectives for sediment or surface water or both. These objectives will be addressed in a Draft FS Screening Report (FSSR) for AOC 72 as described in the text. The FSSR will be used to select an appropriate floc removal remedy to include in the SHL Final FFS.

In addition, the following statement is made within the text from this section: "Dredging or excavations to periodically remove impacted sediment for offsite disposal also appear to be feasible, and such a dredging remedy is currently in use for a similar arsenic discharge at the HBHA Pond portion of the Industri-Plex Superfund site in Woburn, MA." It should be noted that there are two objectives for sediment dredging under the proposed OU02 remedy for the Industri-Plex Superfund Site: 1) potential periodic removal of accumulated sediments in the northern treatment cell in order to sustain performance for arsenic removal from the discharging arsenic plume, and 2) removal of existing contaminated sediments from the southern cell of the HBHA Pond that does not serve as a component of the treatment system. Contaminated sediments within the portion of the HBHA Pond used as a component of the OU02 groundwater remedy will be left in place, except for situations where degradation in treatment performance is observed due to excess sediment accumulation. The loss of this portion of the pond/wetland system is being offset through purchase, by the Responsible Parties, of additional un-impacted wetland areas with equivalent acreage within the same watershed.

Response: Comment noted.

11. Page 10, Section 2.9, Landfill Consolidation Feasibility Study: Careful consideration should be given to a comprehensive MASW survey in order to supplement the proposed interpretation of photos, maps, and borings in determining the extent of buried waste. An MASW survey would help to determine not only the locations of buried waste materials, but the thickness of such deposits, relationship to the water table, and the configuration, thickness, and depth of undisturbed geologic materials beneath the waste. A MASW survey promises to provide a much more accurate engineering estimate of the volume of buried waste, which will be invaluable to a decision to consolidate. Further, a more refined knowledge of waste locations, depths and the configuration of geologic deposits beneath the waste will be invaluable toward locating proposed boreholes within the landfill footprint. A series of northsouth MASW survey lines are likely needed given the presumed east-west linear character of trench-fill deposits located in the landfill. However, potential benefits, logistics and other considerations of MASW at the landfill merit additional BCT discussions.

Response: The Army would like to discuss whether there is relevant experience using the MASW method for evaluation of landfill composition. The landfill wastes are expected to be significantly less compacted than the typical geological materials that are evaluated with seismic techniques. The costs and track record for this survey method can be compared with the available alternatives such as drilling, if a significant data gap is identified following the initial evaluation of existing data that is described in the workplan.

12. Table 1, Item 5: Under Hypothesis, bedrock is listed as a potential source of arsenic in groundwater. Also, aquifer mineralogy and association of arsenic with solid phases are listed as data gaps. However, the Technical Approach for this item indicates that only soil and groundwater samples will be collected and characterized. Explain how bedrock as a potential arsenic source will be evaluated and discuss how mechanisms potentially responsible for mobilizing arsenic from bedrock will be assessed. Given the identification of bedrock as a potential arsenic source, please expand this section to explain how bedrock will be included in the estimate of arsenic source strength and duration.

Response: The details of the arsenic source strength evaluation remain to be developed as described in EPA comment 8 and the response, but may include bedrock sampling to evaluated mineralogy and conduct column flushing tests. Table 1 and the text in Section 2.6 will be clarified to indicate the potential for inclusion of bedrock samples, to be determined based on additional investigation planning.

MASSDEP COMMENTS

Comments on the 10/30/09 Draft Workplan were received from MassDEP on 11/23/09. The comments are provided below with responses in italics following each comment.

1. Section 2.1: Available data indicate that the plume axis is located north of the two exploratory borings proposed to delineate the extent of the north plume. In particular, the West Main Street samples with the highest arsenic concentrations were collected from wells SHX-01-09X (≤3,070 µg/L) and SHX-01-10X (≤4,640 µg/L), and water level measurements and groundwater modeling indicate that groundwater flow downgradient of these wells is west-north-westward. Consequently, if sample results indicate that one or both of the exploratory borings is located outside of the plume, subsequent borings should be offset northward, rather than westward, until the plume axis is located, and thereafter extended downgradient along the plume axis until the downgradient extent of the plume is determined and sentry well locations can be identified.

Response: Suitable drilling locations in this area may be restricted due to wetland protections and allowable access from property owners. We agree with the general concept that if sample results indicate the initial boring(s) did not encounter the plume, additional borings will be advanced until the limit is encountered, and any restrictions on drilling will be discussed with the BCT, the Conservation Commission and other town officials, and property owners as appropriate. The text will be revised to clarify this.

2. Section 2.3: The workplan should briefly explain how the "representative portions of the aquifer" will be identified.

Response: The Army proposes to further evaluate existing data and field screening methods to ensure that the tested materials are representative of the majority of the aquifer, as described in the response to EPA comment 5, part 1. We propose to conduct this investigation planning on a separate track from other Additional Work requirements so as not to delay those efforts; a schedule for this activity will be developed for discussion.

3. Section 2.6: The workplan should briefly explain how the depth intervals that would be sampled at each source material sampling location will be determined. The proposed source material locations should be selected so that the underlying wetland may be sampled to further understand the role of the wetland deposits and provide necessary data for the design of landfill consolidation. More than three samples at each location should be considered, including locating the bottom of the waste, determining how much waste is saturated, identifying different wastes as arsenic sources, and a sample of the wetland deposits.

Response: We agree that testing of source area materials may require more than three samples at some locations, and propose to develop a detailed approach as described in the response to EPA comment 8; please also see related EPA comments 1 and 7.

PACE COMMENTS

Comments on the 10/30/09 BCT Draft Workplan were received from ECR on behalf of PACE on 12/11/09. The comments are provided below with responses in italics following each comment.

According to Figure 1 of the Work Plan, only two borings are proposed in the down-gradient portion of the Impacted Area, one of which is located in the immediate vicinity of an existing boring. This effort seems insufficient to meet the stated goal of "delineating the north plume in all directions." To meet this goal, additional wells should be installed in several areas, including the following:

- North and northeast of SHM-99-31 and SHM-99-32X, where arsenic concentrations exceeded the MCL by a factor of more than 20. While the data indicate that the heart of the plume trends to the northwest, the data also show that the eastern portion of the plume appears to be significantly more diffuse than the western portion. This portion should be better defined to ensure that residential properties to the north/northeast are not impacted.
- North, northwest and northeast of DEP-08-08, including locations across Nonacoicus Brook, to define the extent of the arsenic plume and in these areas. Existing information suggests that the arsenic plume makes an approximately 90-degree turn to the west in this area; however, sufficient groundwater data has yet to be obtained to demonstrate that the plume actually does make this turn, and to demonstrate that a portion of the plume does not migrate to the north.
- To provide an adequate delineation of the plume, the area northwest of DEP-08-05 should be investigated using a well transect rather than the single well proposed in the Work Plan.
- The Work Plan should include a contingency to install additional wells based on the data obtained from the initial round of wells. Additional wells may be needed to meet the goal of delineating the plume in all directions.

Response: The eastern limit of the north plume in the area of SHM-99-32X is supported by earlier results from profiling at SHX-99-05 (1999) and monitoring at SHP-99-34 (2001). These results are not shown in the workplan Figure 1 because they are older, but they are included in the SAR (AMEC 2009) cross section Figure 4-3. In addition, the SGI included a detailed investigation of conditions along the West Main St. transect (see SGI Figure 3-26) which indicates arsenic detections along the eastern extent (the area due north of SHM-99-31 and SHM-99-32X) are neither contiguous with the main plume lobe nor strongly correlated with ORP. Because prevailing hydraulic gradients are westward in the Nonacoicus Brook valley fill aquifer, further investigation east of

SHX-01-06X was considered unnecessary. However, since Institutional Controls (ICs) on residential use of groundwater are under consideration in the FFS, further investigation is proposed to better define the area where ICs would be needed.

Beyond West Main St, the north plume limit would be difficult to confirm near DEP-08-08 since this area is a broad wetland with limited drilling access. However, we agree that data on the north side of the wetland (east of DEP-08-07) would be useful to provide an additional constraint. Additional data on the bedrock surface, which has a significant affect on groundwater flow, will be collected in the stream valley area as described in the response to EPA Specific Comment 3. Water levels on either side of the wetland (from existing and proposed wells) can be used to confirm the expected flow gradients and groundwater discharge to the stream. As indicated in the last paragraph of Section 2.1, additional or contingent boring(s) will be advanced in this area as needed to delineate the north plume. Please also see EPA General Comment 3 and the response regarding additional wells in this area.

The Conceptual Site Model discussion in Section 1.4 should mention that the placement of the cap limited the infiltration of rainwater/meltwater into the landfill wastes, and that this likely resulted in the creation of a more reducing environment within the landfill.

Response: The requested change will be made.

In Section 1.4, it is stated that "Arsenic is immobilized as a solid phase within the aquifer matrix in the area beneath the stream (*i.e., the Nonacoicus Brook*) where reduced groundwater transitions to the oxygenated conditions present in the stream" (italics added). Although this is a plausible scenario, ECR is not aware of any field data from the Brook that verifies that dissolved arsenic precipitates within the aquifer matrix. In the following paragraph of Section 1.4, it is stated that arsenic migrating into Red Cove is adsorbed or co-precipitated with iron floc within the surface water (as opposed to within the aquifer matrix). What data are used by the Army to conclude that arsenic is immobilized within the aquifer beneath the Nonacoicus Brook? And what is the basis for concluding that the primary location of arsenic precipitation differs between Red Cove and Nonacoicus Brook? The eventual immobilization of arsenic is a crucial component of the CSM, and should be verified with field data from the site.

Response: The CSM regarding transport near Nonacoicus Brook is based on the following observations described in the Supplemental Assessment Report (AMEC 2009): oxygenated conditions directly beneath the stream, reducing conditions in the deeper aquifer, absence of iron floc in the stream, and that the stream and surrounding wetland are a groundwater discharge area. The Army acknowledges that direct measurement of solid arsenic types and amounts in the aquifer in this area are yet to be made, and these are proposed in Section 2.3 of the draft workplan. The CSM for Red Cove is based largely on USEPA's studies of arsenic fate and transport in this area since 2005 (USEPA 2008).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 1
5 POST OFFICE SQUARE, SUITE 100
BOSTON, MASSACHUSETTS 02109-3912

February 25, 2010

Mr. Robert Simeone
BRAC Environmental Coordinator
BRAC Environmental Office
30 Quebec Street, Box 100
Devens, MA 01434

Re: Shepley's Hill Landfill
Supplemental Investigation Workplan
January 2010

Dear Mr. Simeone:

EPA has reviewed the document titled "Shepley's Hill Landfill, Supplemental Investigation Workplan," dated January 2010, as prepared by AMEC Earth & Environmental, Inc., on behalf of the Army. The Workplan was discussed in detail at the February 18, 2010 BCT meeting. EPA comments on the Workplan are attached.

If you have any questions, please contact me at (617) 918-1754 or at lombardo.ginny@epa.gov.

Sincerely,

Ginny Lombardo
Remedial Project Manager

Attachment

cc: Bill Brawner, Army BRAC Program Manager
David Chaffin, MassDEP
Hui Liang, MassDEP
Bill Brandon, EPA
Ron Ostrowski, MassDevelopment
Dave McTigue, Gannett Fleming
Carol Stein, Gannett Fleming
Marilyn McMillan, Ayer Board of Health
Brian Poitras, National Industrial Portfolio, LLC
John Root, Hackman Capital Partners, LLC
Richard Doherty, ECR Consulting, Inc.
Laurie Nehring, PACE
Julie Corenzwit, PACE
Ron McGuigan, Southern Container

EPA Comments on
Shepley's Hill Landfill
Supplemental Investigation Workplan
January 2010

Volume 1 – Technical Approach and Rationale:

1. Page 5, Section 2.0: EPA believes that the evaluation of landfill consolidation would benefit from "field data collection". Specifically, a better understanding of the geometry and volume of the buried waste deposits could serve to refine cost estimates for landfill consolidation. Surface geophysical surveys should be considered in this respect.

2. Page 9, Section 2.5: Text needs to be added here regarding the collection of soil and waste samples. Refer to page 12 of Volume 2 – Field Sampling Plan, Section 4.3.1.1, which indicates that soil and waste samples from the boring installed in the landfill will be collected every 10 feet, logged for visual characteristics, and sampled for reference purposes. See Comment 9 on the Field Sampling Plan, below, regarding EPA's request that the aquifer solids and wastes be further characterized.

3. Pages 9-10, Sections 2.5 and 2.6: As indicated in past communications with the BCT, EPA is in favor of using surface geophysical methods in an attempt to better delineate the geometry of buried waste deposits (e.g., source materials) and the depth and shapes of buried layers such as former swamp deposits, the position of the top-of-bedrock surface, etc. In this respect, we would like to discuss potentially running a limited scale pilot study in a subset area of the larger landfill in order to verify which techniques are most amenable to the SHL environment. As a follow-up to the USGS presentation to the BCT on February 18, 2010, EPA plans on working with USGS and the BCT to identify a suitable sub-area within the landfill where a pilot test could be conducted. Such a test would seek to test a variety of geophysical methods over identical survey lines. Ideally, a pilot study of this type could help to streamline follow-on geophysical work by identifying the most effective geophysical methodologies for this site. Ultimately, surface geophysical surveys may prove to be extremely useful in locating additional wells/borings within the landfill footprint.

4. Page 11, Section 2.9: EPA believes evaluation of a landfill consolidation remedy would benefit from a more accurate understanding of the waste geometry, potentially afforded through application of surface geophysical surveys.

Volume 2 – Field Sampling Plan

1. Page 6, Section 3.1.2.1: In addition to the geophysical survey lines presented on Figure 1, an additional line is needed south of Nonacoicus Brook, roughly parallel to the proposed line B-B'. The new line should extend from the DEP-08-05 area northeasterly to the vicinity of DEP-08-03, projecting along this orientation several hundred feet further to the northeast so as to intersect the green NW-trending forward particle tracks shown on the figure. Similarly, additional NNW-SSE trending alignments should be considered to better constrain the expected low, generally thought to underlie the brook area. In this respect, C-C' should be

extended across Nonacoicus brook southward to the DEP-08-05 area. For extending across the brook, specialized equipment such as geophones designed for use in swamps and water areas will be required.

2. Page 6-7, Section 3.1.2.2: It is likely that the plume, or at least a significant portion of it, turns to the west/southwest in the area south of the stream channel. As such, while it is appropriate to develop better control to the north (i.e., proposed SHM-10-02, -03, -04), a commensurate or greater level of effort is needed to the south. It is likely, given the past detections at SHX-01-11X, -13X, and -12X that at least some portion of the plume takes a more abrupt bend to the WSW than the forward particle tracks on Figure 1 would suggest. Modifications to the proposed well locations shown on Figure 1and addition of new locations will allow for a reasonable degree of N-S characterization if an irregular quasi N-S transect is constructed. As such, EPA proposes the following modifications and additions to the proposed North Plume delineation effort:

   - Move SHM-10-03 ~ 50 to 100' south of the proposed location;
   - SHM-10-02 as proposed;
   - Move SHM-10-04 to the southern end of A-A' or C-C';
   - SHM-10-01 as proposed;
   - New MW location equidistant between DEP-08-05 and SHM-10-01;
   - Additional groundwater profiling to TOR in SHP-07-01CS/CD area; and
   - New MW location co-located with DEP-08-03 and/or SHP-07-01CS/CD.

3. Page 7, Section 3.1.2.2: EPA requests that Army collect soil samples co-located with the proposed groundwater samples where permanent monitoring wells will be installed. The purpose of co-located soil samples is to characterize the aquifer matrix, as little solid phase information exists in the North Plume area. For some locations, chemical analysis of the soil profile samples should be considered, with particular emphasis on obtaining information about mineral phases that may play a role in controlling arsenic behavior (e.g., sequestration, attenuation, etc.). This information will be useful towards improving the CSM with respect to arsenic fate and transport in the downgradient portion of the plume, and may provide insight into MNA strategies. For example, such data could provide insight in the key area adjacent to Nonacoicus Brook, where previous work by AMEC and the MADEP has shown that redox conditions and associated arsenic concentrations can be highly variable on small vertical length scales. Comment 8, below, provides further information.

4. Page 7, Section 3.1.2.2: The second paragraph of this section indicates that field screening for arsenic (described further in Appendix C) will be conducted and, in addition, groundwater samples will be submitted for laboratory analysis of arsenic, iron, and manganese. It is not clear how the field and/or lab data will be used to locate the appropriate intervals for the proposed well screens, nor is it clear how these data will be used to determine whether the 100 ppb plume limit has been found and, if not, if a new boring is required. Will these decisions be made on the basis of the field As results, or does the reference to laboratory analysis imply an expedited turn-around for the results? What degree of confidence can be placed on the accuracy of the field screening results? A comparison of field results obtained using the Arsenic Quick Test Kit and laboratory data would help to

support decision-making based on the field results alone. If such data are available, please include these in this document, along with clarification regarding the use of field As results for defining plume limits and locating monitoring well screens.

5. Page 7, Section 3.2.2: For the proposed boring(s) in the vicinity of SHL-21, please see Comment 4 regarding accuracy of As field screening results and decisions regarding well screen placement or additional borings based on these results. See also Comment 8, below.

6. Page 8, Section 3.3.1: The text here indicates: "*Information derived from installation and sampling of this well will be used initially to evaluate the need for additional wells in this area, and ultimately, in combination with groundwater modeling, to evaluate remedies such as hydraulic controls or in situ treatment*." Note that Volume 1, page 9, Section 2.5, states: "*...results from this monitoring well will be used to determine locations for additional wells in this area*." The language in Volume 1, Section 2.5, implies that additional wells will be installed, whereas the language in this section is not as decisive on future wells to evaluate the discharge to Red Cove. EPA's position is that additional wells will be required in this area in order to adequately characterize groundwater discharging to Red Cove and evaluate remedies for this area. The choice of a single monitoring well within the landfill footprint, and its proposed location, raises several questions:

   - What is the rationale for placing this single well on a groundwater 'divide'? How accurately will this well be sited with respect to the groundwater divide? What information will be used to locate this well, given the probability that the exact position of the groundwater divide moves with time? If locating the divide is important, at least three (or more?) wells will be needed to constrain the hydraulic gradients in that area.

   - The last sentence in this section states that data from this well will be used to evaluate the need for additional wells. What information is anticipated from this well? What decision process is envisioned for using information from this well to support a decision to install more wells?

   EPA recognizes that the Arsenic Source Strength evaluation, which is to be addressed in the next phase of the work plan, may propose boring/monitoring wells that could serve both the Arsenic Source Strength objective and the East Plume objective. We look forward to discussing this situation in greater detail with the benefit of the new information to be provided by the initial new well, SHM-10-07, and/or geophysical survey data.

7. Page 8, Section 3.3.2: Text needs to be added here regarding the collection of soil and waste samples. Refer to page 12 of Volume 2 – Field Sampling Plan, Section 4.3.1.1, which indicates that soil and waste samples from the boring installed in the landfill will be collected every 10 feet, logged for visual characteristics, and sampled for reference purposes. Also, please see Comment 4, above, regarding use of As field screening results as a basis for decision-making and Comment 9, below.

8. Page 11, Section 4.3: The text in this section indicates that air-rotary methods will be used to advance the borings from which groundwater profile samples are to be collected. As

discussed at the February 18, 2010 BCT meeting, the air-rotary method will not permit collection of co-located solid and groundwater samples, and will not allow for the collection of rock core samples to confirm bedrock. Instead, EPA recommends standard hollow-stem auger/drive-and-wash or roto-sonic methods. While it may be possible to conduct groundwater profiling in conjunction with these methods (through the same casing string), it may or may not be more cost-effective to instead consider using a succession of two drilling methods, at least in some areas, to collect co-located soil and ground water characterization data. For example, one effective strategy may be to advance drive-and-wash or roto-sonic borings (e.g., for soil and rock characterization) in tandem with a second hole which could be advanced for groundwater profiling using direct-push sampling methods (e.g., Microwell technology has been effective in the past in ground water profiling at SHL). The ground water profiles could be advanced to "refusal depth". Depending on the results of groundwater samples submitted to the laboratory, a second co-located borehole could be drilled at locations selected for permanent monitoring well installation. This would enable collecting split-spoon soil samples and rock core (e.g., using standard hollow-stem auger/drive-and-wash/rock coring or roto-sonic methods), and subsequently installing the permanent monitoring well at these locations. Soil and rock samples are needed at all locations where monitoring wells are planned so that the CSM can be informed by the geologic units present at that location.

EPA requests that 5-10 feet of bedrock core be collected at all locations where monitoring wells are installed. Due to the significant role that bedrock plays in the system, it will be critical to obtain core samples from the planning monitoring well locations for visual characterization and possible future analysis. It should be noted that the presence of large glacial erratics on Shepley's Hill suggests that at least 10 feet of rock core should be collected in order to insure that an accurate measurement of the top-of-rock surface is collected and to identify rock type(s) at these locations, as well as providing some information on the density and orientation of fractures.

The initial well proposed within the landfill footprint represents a special case. A combination of roto-sonic drilling and direct-push groundwater profiling may be most effective here. A groundwater profile using a separate advancement with direct-push methods would contribute initial groundwater quality results. A second co-located hole could be collected with roto-sonic drilling methods. The roto-sonic method affords the ability to collect continuous solid cores through a variety of materials including soils, waste, peat, till, and bedrock. This may prove invaluable for borings located in waste. Waste material may thus be inspected and described over a nearly continuous profile, and a sub-set of representative specific intervals can then be selected for chemical analysis at a desired vertical spacing.

9. Page 12, Section 4.3.1.1: The text at the end of this section states that soil and waste samples will be collected every 10 feet during the installation of the single monitoring well currently proposed within the landfill footprint. These samples "...will be logged for visual characteristics, and a representative sample collected in an 8-ounce jar for reference purposes." EPA recommends the use of appropriate EPA protocols for collection, preservation, and analysis of these samples. The issue of As as a component of the landfill

waste has been a 'data gap' for the BCT for years, so the proposed boring presents an opportunity to address this issue. Decisions regarding analytical methods will have to be made in consultation with laboratory personnel once the nature of the waste and matrix are better known. At a minimum, EPA suggests analysis of solid samples for TAL metals and TOC. Please refer to the attached table for further details on EPA's recommendations.

10. <u>Page 12, Section 4.3.2:</u> According to the text, vertical-profile groundwater samples from the boring through the landfill cover will be analyzed in the laboratory for iron, manganese, and arsenic. As discussed at the February 18, 2010 BCT meeting, EPA requests that groundwater profile samples also be analyzed for additional parameters. Please refer to the attached table for further details on EPA's recommendations. These data will be critical to refining the CSM and may provide key information on the geochemical nature of landfill impacts to groundwater. As shown in the attached table and as also discussed at the BCT meeting, EPA requests that analysis of groundwater from the monitoring wells also include the major cations. Sampling rounds from the monitoring wells installed downgradient of the landfill may then be compared to the "source term" groundwater geochemistry (i.e., from new and existing wells screened within the landfill/waste) in an effort to establish whether or not the limits of landfill-impacted groundwater may or may not coincide with the arsenic "plume."

11. <u>Table 1-1, Red Cove Area:</u> Under "Technical and Data Quality Objectives", bullet 2 indicates that one objective is to get "*data on bedrock elevation, waste thickness, presence of peat deposits and till layers.*" Bullet 3 indicates another objective is "*evaluate waste and bedrock as a potential source of arsenic and/or reducing conditions.*" In order for these objectives to be met, the additional characterization of soil and wastes and bedrock coring requirements outlined in comments 8 and 9 above must be completed. In addition, under "Technical Approach," bullet 2 indicates that objectives will be met via "*core sampling and detailed analysis of stratigraphy.*" Further, a bullet should be added under "Data Evaluation" related to the soil and waste characterization.

12. <u>Table 1-1, Red Cove Area:</u> Volume 1, page 9, Section 2.5, states: "*…results from this monitoring well will be used to determine locations for additional wells in this area.*" Volume 2, page 8, Section 3.3.1, states: "*Information derived from installation and sampling of this well will be used initially to evaluate the need for additional wells in this area, and ultimately, in combination with groundwater modeling, to evaluate remedies such as hydraulic controls or in situ treatment.*" These objectives are not represented in the table.

Data Analysis Plan:

1. <u>Page 2, Section 2.0:</u> Change "Grove Shop Pond" to "Plow Shop Pond."

2. <u>Page 4, Section 2.2.3:</u> See Comment 8 on the Field Sampling Plan, above.

Quality Assurance Project Plan:

1. The QAPP should be updated to reflect decisions regarding collection and analysis of solid (soil and waste) samples.

TABLE OF EPA RECOMMENDATIONS
FOR GROUNDWATER AND SOIL SAMPLING

WELL/ BORING*	VERTICAL PROFILE GW SAMPLES		WELL SCREEN GW SAMPLES		VERTICAL PROFILE SOIL SAMPLES	
	No. samples**	analytes	No. samples	analytes	No. samples***	analytes
SHM-10-01	5	[1]—[4]	2	[1]—[3],[5]	8	[6], [7]*
SHM-10-02	6	[1]—[4]	2	[1]—[3],[5]	6	Visual Characterization
SHM-10-03	10	[1]—[4]	2	[1]—[3],[5]	11	Visual Characterization
SHM-10-04	10	[1]—[4]	2	[1]—[3],[5]	11	[6], [7]*
SHM-10-05	5	[1]—[4]	2	[1]—[3],[5]	10	[6], [7]*
SHM-10-06	8	[1]—[4]	2	[1]—[3],[5]	11	Visual Characterization
SHM-10-07	4	[1]—[4]	2	[1]—[3],[5]	8***	[6], [7]

Recommended analytes for vertical profile and well screen samples (in addition to field water-quality parameters):

[1] Metals of interest: As, Fe, Mn
[2] Major cations: Ca, Mg, K, Na
[3] Major anions: Cl, SO4, nitrate/nitrite, alkalinity
[4] Possible landfill indicators: ammonia (Method 350.2 or 350.3), COD (Method 410.4)
[5] ROD metals not otherwise specified: Al, Cr, Pb, Ni

Recommended analytes for vertical profile soil samples:

[6] TAL metals
[7] TOC
If Army is unable to perform the analysis of the soil profile samples, EPA would be willing to use our laboratory services to conduct the recommended soil profile sample analysis.

* Note for SHM-10-01, -02, -03, -04 and -05: We recognize these well locations may be adjusted based on other comments. EPA's recommendations for soil profile sampling and analysis can be adjusted based on the modified well locations. Our recommendation for soil profiling and analysis is based on trying to obtain soil data from a few widely spaced well locations.

** Anticipated saturated thickness (from Table 4-1)/profile sampling interval of 10 feet.

*** Anticipated depth (from Table 4-1)/soil sampling interval of 10 feet. Profiling should be completed at a minimum every 10 feet and at each change in stratigraphy. For well location SHM-10-07, soil profiling it is recommended completed every 5 feet and at each change in stratigraphy. If this is done, the number of samples would increase to 16.

TABLES

Table 1 Technical Objective and Approach for Data Collection

Objective	Hypothesis	Data Gaps	Technical Approach
From EPA Additional Work Letter			
North Plume Delineation & Monitoring for Impacted Area Delineate the north plume in all directions to depth in order to establish final delineated plume boundaries. Install additional monitoring wells to be incorporated into the long-term monitoring program that will ensure that there are permanent monitoring locations for all significant areas of the plume (e.g., West Main Street) and to serve as sentry wells to ensure that the plume does not migrate further beyond the final delineated plume boundaries. Incorporate these wells into a revised long-term monitoring plan.	The plume north of the capture zone has stable limits bounded by bedrock and advective flow of unimpacted or oxygenated groundwater (GW). The plume limits in the area of Molumco Rd are near SHM-07-03 on the west and SHM-99-32X on the east; in the area of West Main St are west of DEP-08-03 and near DEP-08-08 on the east; and in the area of Nonacoicus Brook are southwest of DEP-08-07 (See Figure 1).	GW chemistry data above, below, and lateral to the plume in the following general areas: • West Main St west of DEP-08-03 • Nonacoicus Brook north west of DEP-08-05 and southwest of DEP-08-07 • North of the brook, NE of DEP-08-07 • East of SHX-01-06X	Install borings extending to bedrock in each area and collect GW samples at 10-ft intervals for arsenic and field parameters. Complete permanent wells based on profile results and sample twice for metals. Map plume in 3D based on the results
2a. North Plume Capture at Boundary Operate and/or modify the treatment system to contain the arsenic plume in the vicinity of the base boundary near the north end of the landfill and demonstrate that the arsenic plume is captured.	The latest revised GW model and other lines of evidence as presented in the 2008 Annual Report (ECC 2009) suggest that impacted GW at the toe of the landfill is fully contained, subject to some uncertainty on the eastern plume extent at the toe.	GW chemistry data east of the toe of the landfill, in the area east of SHM-96-5B.	Install boring(s) extending to bedrock and collect GW samples at 10-ft intervals for metals and field parameters. Complete permanent well(s) based on profile results and sample twice for metals. **[See Note 1]**
2b. North Plume Monitored Natural Attenuation (MNA) for the Impacted Area Once capture is demonstrated, establish that monitored natural attenuation will be effective at remediating the north plume (i.e., the Impacted Area) within a timeframe that is reasonable given the circumstances of the site	MNA in the Impacted Area will be effective based on immobilization of dissolved arsenic. Effectiveness depends on: (1) demonstration of a static or shrinking plume (see objective #1); (2) determining rates and mechanisms of attenuation; (3) determining stability of immobilized arsenic; and (4) establishing a monitoring plan and contingency plans (USEPA 2007). The time required for arsenic to be immobilized in the Impacted Area by MNA or by an aggressive remedy are both decades or longer.	Aquifer mineralogy and association of arsenic with the various solid phase components. Time to achieve MCLs due to flushing with unimpacted GW, both for MNA and aggressive (FFS Alternative 3B) scenarios.	Collect co-located soil and GW samples from the Impacted Area for chemical and microscopic-spectroscopic analysis of solids. Conduct flushing timeframe study similar to USGS Saco Landfill study; test cores of aquifer material from the Impacted Area and use reaction model to simulate immobilization.

Objective	Hypothesis	Data Gaps	Technical Approach
From EPA Additional Work Letter			
3. Landfill Gas Impacts Complete an evaluation of landfill gas impacts in the area of the north plume (i.e., the Impacted Area) in accordance with the EPA Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities to ensure that methane emanating from the landfill will not cause unacceptable risks (i.e., explosive conditions) in nearby structures.	Results of monitoring perimeter soil gas probes at the north end of the landfill indicate that methane is not migrating offsite laterally through soil. Offsite structures in the Impacted Area north of the capture zone may have methane intrusion from groundwater if sufficient levels of methane volatilize from the top of the water table and migrate through the vadose zone.	None at this time.	Conduct vapor intrusion modeling based on conservative estimates of site conditions. Discuss results and need for site-specific measurements with BCT.
4. East Plume Delineation and Capture Eliminate the continuing discharge of high-arsenic groundwater to Plow Shop Pond sediments. It is expected that new groundwater monitoring wells, as recommended in EPA's October 2, 2008 letter and in Section 5.3 of ORD's Final Report, will be completed and data from these wells will be considered in this effort.	Discharge of shallow arsenicimpacted groundwater from the eastern portion of the landfill to Red Cove may be controlled using GW injection, extraction, or in-situ treatment.	Arsenic GW concentrations and flow rates between SHL and Red Cove.	Update GW model based on pond flux measurements and use model for siting wells upgradient of Red Cove. Install borings extending to bedrock and collect GW samples at 10-ft intervals for metals and field parameters. Complete permanent well(s) based on profile results and sample twice for metals.
From 9/30/09 Draft FFS:			
5. Arsenic Source Strength Estimate the arsenic source strength and duration, including the quantity of arsenic that may be mobilized and the strength and duration of sources of reducing conditions.	Potential sources of arsenic in groundwater include bedrock, bedrock-derived soils, and landfill wastes, which are located above and below the water table. Arsenic is dissolved from the source materials by landfill-induced reducing conditions in groundwater. A portion of the landfill overlies a swamp where naturally-occurring reducing conditions may also have existed.	Aquifer mineralogy and association of arsenic with the various solid phase components. Time to deplete source materials due to mobilization.	Collect co-located solid and GW samples from source materials for chemical and microscopic-spectroscopic analysis of solids. Conduct flushing timeframe study; test cores of source material using reduced groundwater to simulate mobilization of metals. **[See Note 1]**
6. Air Sparging Feasibility Evaluate no longer retained as a results of assessment. See Section 2.7.	Not Applicable	Not Applicable	Not Applicable

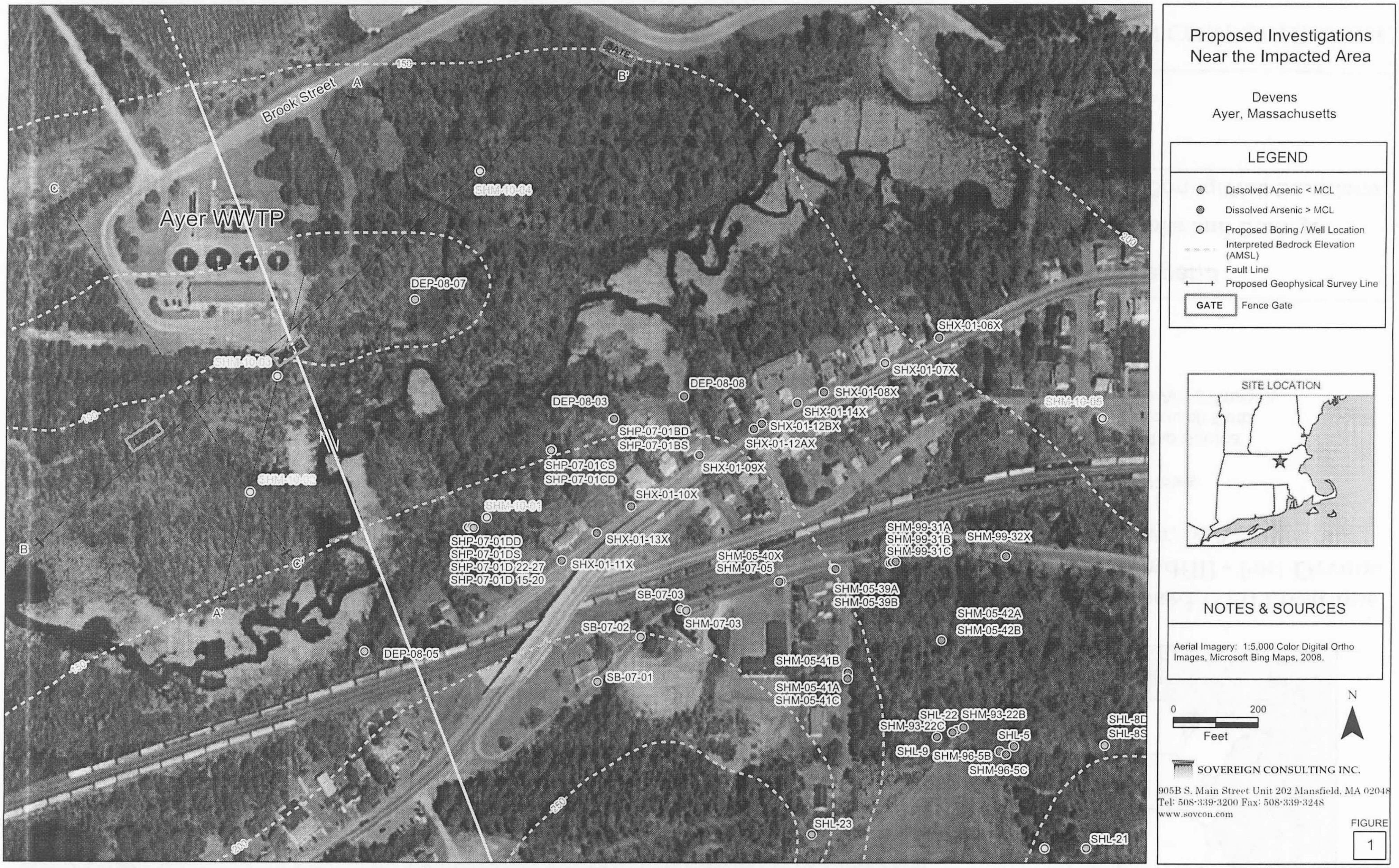
Objective	Hypothesis	Data Gaps	Technical Approach
7. Floc Removal Feasibility Evaluate implementability, conceptual design, and costs of floc removal in Red Cove (FFS Alternative 2).	Arsenic-bearing floc accumulating in Red Cove sediments may be removed or sequestered to reduce risks to ecological receptors. The FFS alternative incorporating this remedy assumes that the source of floc is continuing.	None at this time.	Evaluate floc removal remedies in the AOC 72 FSSR.
8. Landfill Consolidation Feasibility Evaluate implementability of onsite waste management for landfill consolidation (FFS Alternative 5) based on waste volumes and footprint.	Landfill wastes may be removed from below the water table and the landfill reconstructed and lined to eliminate leaching to groundwater. This FFS alternative assumes that wastes would be relocated within the existing landfill footprint.	None at this time.	Map current waste extent based on photos, maps, and boring logs. Complete a conceptual design for the reconstructed landfill, including construction and waste management methods, sufficient for estimating costs to -30/+50% accuracy.

Note 1: The objective and approach to be finalized during the 5/20/10 BCT meeting

FIGURES

Proposed Investigations Near the Impacted Area

Devens
Ayer, Massachusetts



LEGEND

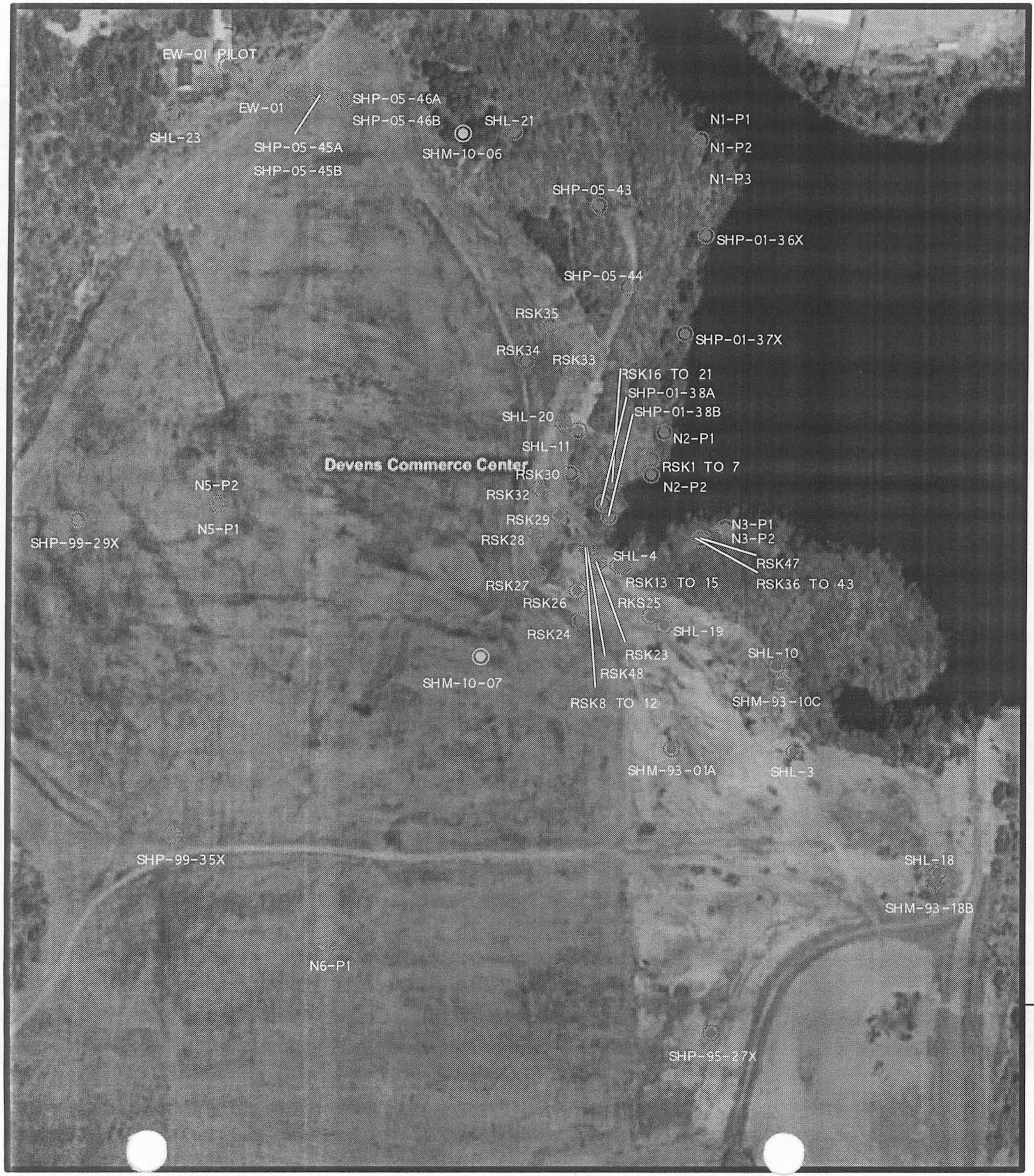
- ○ Dissolved Arsenic < MCL
- ● Dissolved Arsenic > MCL
- ○ Proposed Boring / Well Location
- Interpreted Bedrock Elevation (AMSL)
- Fault Line
- Proposed Geophysical Survey Line
- GATE Fence Gate

NOTES & SOURCES

Aerial Imagery: 1:5,000 Color Digital Ortho Images, Microsoft Bing Maps, 2008.

SOVEREIGN CONSULTING INC.
905B S. Main Street Unit 202 Mansfield, MA 02048
Tel: 508-339-3200 Fax: 508-339-3248
www.sovcon.com

FIGURE
1



SITE LOCATION

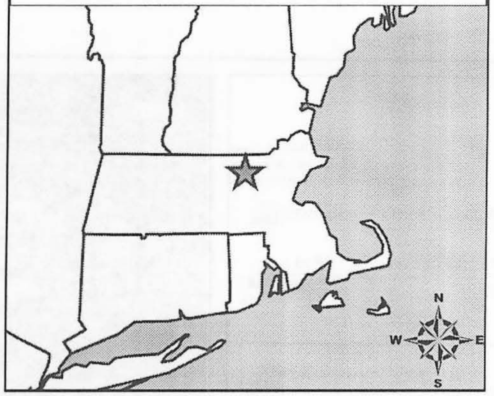


Figure 2 - Proposed Well Locations
Shepley Hill Landfill - Fort Devens
Ayer, MA

Notes:

Base Map Source:
2009 Microsoft Corp.
Bing Maps Aerial Imagery

Legend

◉ Existing Wells and Borings

○ Proposed Boring/Well Locations

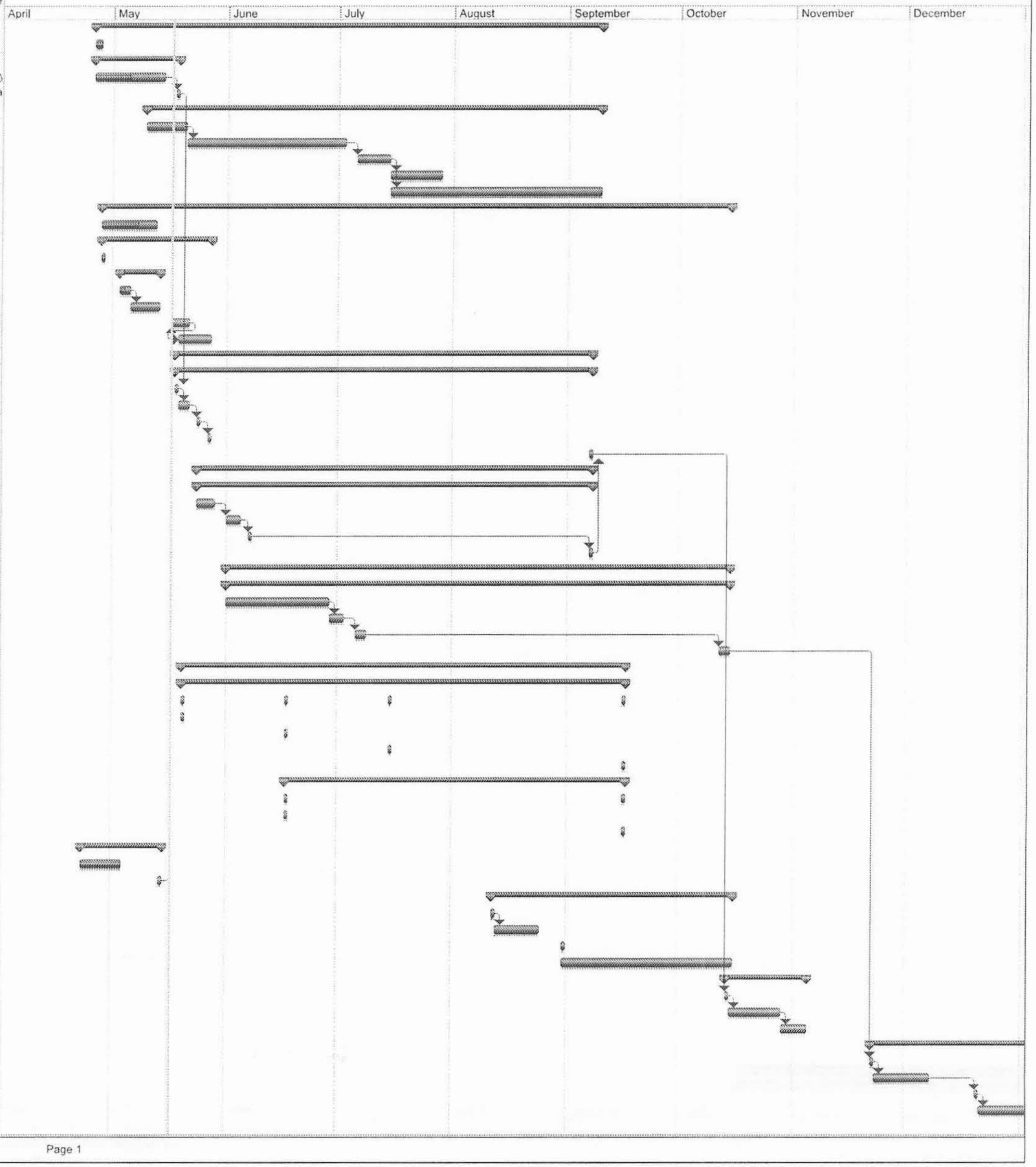
SOVEREIGN CONSULTING INC.

905B S. Main Street Unit 202 Mansfield, MA 02048
Tel: 508-339-3200 Fax: 508-339-3248
www.sovcon.com

SHL Working Project Schedule

Mon 5/17/10

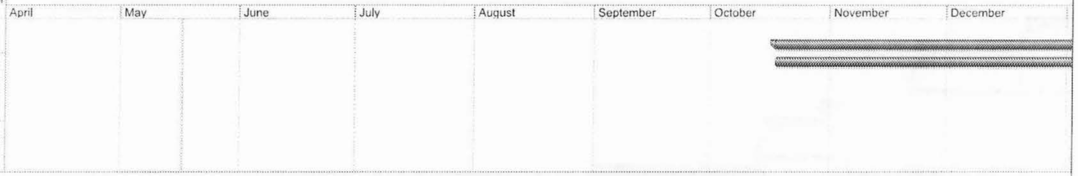
ID	% Complete	Task Name	Duration	Start	Finish	Predecesso	Successor
1	**8%**	**Task 1: SHP Supplemental Work Plan Addendum**	**96 days**	**Mon 4/26/10**	**Thu 9/9/10**		
2	100%	Prepare Site HASP	2 days	Mon 4/26/10	Tue 4/27/10		
3	**47%**	**Prepare Final Workplan - Revision No 1**	**17 days**	**Mon 4/26/10**	**Tue 5/18/10**		
4	50%	Prepare Final Workplan - Revision No 1	15 days	Mon 4/26/10	Fri 5/14/10		5FS+1 day
5	0%	Submit Final Workplan - Revision No 1 to BCT (See Note 1)	1 day	Tue 5/18/10	Tue 5/18/10	4FS+1 day	23FS-1 da
6	**0%**	**Prepare Workplan Addendum (MNA/SS)**	**86 days**	**Mon 5/10/10**	**Thu 9/9/10**		
7	0%	MNA/SS Scoping Meetings	9 days	Mon 5/10/10	Thu 5/20/10		8
8	0%	Prepare Army Draft MNA/SS Work Plan	30 days	Fri 5/21/10	Fri 7/2/10	7	9
9	0%	BCT Review of Draft MNA/SS Work Plan	7 days	Tue 7/6/10	Wed 7/14/10	8	10,11
10	0%	Additional Data Collection (See Note 2)	10 days	Thu 7/15/10	Wed 7/28/10	9	
11	0%	Prepare and Submit Draft Final MNA/SS Evaluation (See Note 3)	40 days	Thu 7/15/10	Thu 9/9/10	9	
12	**13%**	**Task 2: Field Investigations**	**118 days**	**Wed 4/28/10**	**Thu 10/14/10**		
13	73%	**Arsenic Field Kit Correlation Study (USACE)**	11 days	Wed 4/28/10	Wed 5/12/10		
14	**11%**	**Geophysical Investigation**	**22 days**	**Wed 4/28/10**	**Thu 5/27/10**		
15	100%	Initial Layout	1 day	Wed 4/28/10	Wed 4/28/10		
16	**17%**	**Delineate Wetland Boundaries**	**9 days**	**Mon 5/3/10**	**Thu 5/13/10**		
17	50%	Wetland Delineation	3 days	Mon 5/3/10	Wed 5/5/10		18
18	0%	Wetland Delineation Report	6 days	Thu 5/6/10	Thu 5/13/10	17	
19	0%	Clearing, Surveying and Gate Installation	5 days	Mon 5/17/10	Fri 5/21/10	53	20FS-3 da
20	0%	Geophysical Survey	7 days	Wed 5/19/10	Thu 5/27/10	19FS-3 day	
21	**0%**	**East Plume Delineation and Capture**	**78 days**	**Tue 5/18/10**	**Tue 9/7/10**		
22	**0%**	**Rotosonic Investigation**	**78 days**	**Tue 5/18/10**	**Tue 9/7/10**		
23	0%	Site Preparation	1 day	Tue 5/18/10	Tue 5/18/10	5FS-1 day	24FS-1 da
24	0%	Drilling	3 days	Wed 5/19/10	Fri 5/21/10	23FS-1 day	25
25	0%	Develop and Survey Well	1 day	Mon 5/24/10	Mon 5/24/10	24	26
26	0%	Sampling Event No. 1	1 day	Thu 5/27/10	Thu 5/27/10	25	
27	0%	Sampling Event No. 2 (See Note 4)	1 day	Tue 9/7/10	Tue 9/7/10	33FS-1 day	60FS+25
28	**0%**	**North plume capture wells**	**74 days**	**Mon 5/24/10**	**Tue 9/7/10**		
29	**0%**	**DPT Investigation and Sampling**	**74 days**	**Mon 5/24/10**	**Tue 9/7/10**		
30	0%	Drilling	5 days	Mon 5/24/10	Fri 5/28/10		31
31	0%	Develop and Survey Well	4 days	Tue 6/1/10	Fri 6/4/10	30	32
32	0%	Groundwater Sampling Event No. 1	1 day	Mon 6/7/10	Mon 6/7/10	31	33
33	0%	Groundwater Sampling Event No. 2 (See Note 4)	1 day	Tue 9/7/10	Tue 9/7/10	32	27FS-1 da
34	**0%**	**North Plume Delineation**	**95 days**	**Tue 6/1/10**	**Thu 10/14/10**		
35	**0%**	**DPT Investigation and Sampling**	**95 days**	**Tue 6/1/10**	**Thu 10/14/10**		
36	0%	Drilling	20 days	Tue 6/1/10	Mon 6/28/10		37
37	0%	Develop and Survey Wells	4 days	Tue 6/29/10	Fri 7/2/10	36	38
38	0%	Groundwater Sampling Event No. 1	3 days	Tue 7/6/10	Thu 7/8/10	37	39
39	0%	Groundwater Sampling Event No. 2	3 days	Tue 10/12/10	Thu 10/14/10	38	64FS+25
40	**0%**	**Task 3: Meetings**	**83 days**	**Thu 5/20/10**	**Thu 9/16/10**		
41	**0%**	**BRAC Closure Team (BCT) Meetings**	**83 days**	**Thu 5/20/10**	**Thu 9/16/10**		
42	**0%**	**BCT Meetings**	**83 days**	**Thu 5/20/10**	**Thu 9/16/10**		
43	0%	BCT Meetings 1	1 day	Thu 5/20/10	Thu 5/20/10		
44	0%	BCT Meetings 2	1 day	Thu 6/17/10	Thu 6/17/10		
45	0%	BCT Meetings 3	1 day	Thu 7/15/10	Thu 7/15/10		
46	0%	BCT Meetings 4	1 day	Thu 9/16/10	Thu 9/16/10		
47	**0%**	**Restoration Advisory Board (RAB) Meetings**	**64 days**	**Thu 6/17/10**	**Thu 9/16/10**		
48	**0%**	**RAB Meetings**	**64 days**	**Thu 6/17/10**	**Thu 9/16/10**		
49	0%	RAB Meeting 1	1 day	Thu 6/17/10	Thu 6/17/10		
50	0%	RAB Meetings 2	1 day	Thu 9/16/10	Thu 9/16/10		
51	**88%**	**Task 4: Real Estate and Conservation Commission Documentation**	**16 days**	**Fri 4/23/10**	**Fri 5/14/10**		
52	100%	Property Owner Notification	7 days	Fri 4/23/10	Mon 5/3/10		
53	0%	Town of Ayer/ConCom Notification - Right of Entry	1 day	Fri 5/14/10	Fri 5/14/10		19
54	**0%**	**Task 5: FFS Report (See Note 5)**	**45 days**	**Thu 8/12/10**	**Fri 10/15/10**		
55	0%	Submit Draft FFS Report Update (See Note 6)	1 day	Thu 8/12/10	Thu 8/12/10		56
56	0%	Army Review and Comment	8 days	Fri 8/13/10	Tue 8/24/10	55	
57	0%	Submit Draft Final FSS Report to BCT	1 day	Tue 8/31/10	Tue 8/31/10		
58	0%	Draft Final FSS Report becomes Final	32 days	Tue 8/31/10	Fri 10/15/10		
59	**0%**	**Task 6: FFS Data Report Update**	**16 days**	**Thu 10/14/10**	**Thu 11/4/10**		
60	0%	Submit Draft FFS Data Report Update (See Note 7)	1 day	Thu 10/14/10	Thu 10/14/10	27FS+25 da	61
61	0%	Army Review and Comment	10 days	Fri 10/15/10	Thu 10/28/10	60	62
62	0%	Submit FSS Report Update to BCT	5 days	Fri 10/29/10	Thu 11/4/10	61	
63	**0%**	**Task 7: Supplemental Investigation Report (SAR Addendum)**	**60 days**	**Mon 11/22/10**	**Tue 2/15/11**		
64	0%	Submit Draft Supplemental Investigation Report	1 day	Mon 11/22/10	Mon 11/22/10	39FS+25 da	65
65	0%	Army Review and Comment	10 days	Tue 11/23/10	Tue 12/7/10	64	66FS+8 da
66	0%	Submit Draft Supplemental Investigation Report to BCT	1 day	Mon 12/20/10	Mon 12/20/10	65FS+8 day	67
67	0%	BCT Review of Response to Comments	15 days	Tue 12/21/10	Tue 1/11/11	66	68
68	0%	Submit Draft Final Supplemental Investigation Report	10 days	Wed 1/12/11	Tue 1/25/11	67	69



SHL Working Project Schedule

Mon 5/17/10

ID	% Complete	Task Name	Duration	Start	Finish	Predecesso	Successor
69	0%	Draft Final Supplemental Investigation Report becomes Final	15 days	Wed 1/26/11	Tue 2/15/11	68	
70	**0%**	**Task 8: SHL ROD or ESD Amendment**	**88 days**	**Mon 10/18/10**	**Mon 2/21/11**		
71	0%	Draft ROD or ESD Amendment	62 days	Mon 10/18/10	Fri 1/14/11		72
72	0%	Final ROD or ESD Amendment	26 days	Mon 1/17/11	Mon 2/21/11	71	74
73	**0%**	**Task 9: SHL RD/RA**	**180 days**	**Tue 2/22/11**	**Mon 10/31/11**		
74	0%	60% Remedial Design Report	120 days	Tue 2/22/11	Mon 8/8/11	72	75
75	0%	Final 100% Remedial Design Report	60 days	Tue 8/9/11	Mon 10/31/11	74	
76	**0%**	**Task 10: SHL Remedial Action**	**1 day**	**Mon 4/30/12**	**Mon 4/30/12**		
77	0%	Commence Remedial Action	1 day	Mon 4/30/12	Mon 4/30/12		



SHL Working Project Schedule

Mon 5/17/10

ID	NOTES
5	**Submit Final Workplan - Revision No 1 to BCT (See Note 1)** Note 1: Field work will commence on May 17th and will be on-going from that date.
10	**Additional Data Collection (See Note 2)** Note 2: Additional Data Collection Requires Government approval of contract modification. Data will be made available to AMEC as soon as possible.
11	**Prepare and Submit Draft Final MNA/SS Evaluation (See Note 3)** Note 3: MNA/SS Evaluation will be submitted as an FFS Data Report which will be included as an appendix to the FFS Report.
27	**Sampling Event No. 2 (See Note 4)** Note 4: Event not included in August FFS submission
33	**Groundwater Sampling Event No. 2 (See Note 4)** Note 4: Event not included in August FFS submission
54	**Task 5: FFS Report (See Note 5)** Note 5: The FFS Report includes the following tasks: Landfill gas modeling, landfill consolidation memo; and FFS data report
55	**Submit Draft FFS Report Update (See Note 6)** Note 6: Includes results of capture analysis and MNA/SS work plan that will be submitted as an FFS Data Report which will be included as an appendix to the FFS Report.
60	**Submit Draft FFS Data Report Update (See Note 7)** Note 7: Includes results of second groundwater capture analysis sampling event. This will be an update to the FFS Data Report that was included as an appendix to the FFS Report.

SOVEREIGN CONSULTING INC

Environmental services executed safely and consistently...

SHEPLEY HILL LANDFILL SUPPLEMENTAL INVESTIGATION WORKPLAN ADDENDUM

REVISON 1 TO THE FINAL WORKPLAN DATED JANUARY 2010

FIELD SAMPLING PLAN

Prepared for:

US Army Corp of Engineers
New England District
Concord, Massachusetts

Prepared by:

Sovereign Consulting Inc.
905B South Main Street, Suite
202
Mansfield, Massachusetts 02048

May 2010

A Workplan Addendum has been prepared to the existing Shepley's Hill Landfill Supplemental Investigation Workplan prepared by AMEC dated January 2010. This Workplan Addendum details additional investigation work not covered by the AMEC Work Plans. The intent of this Workplan Addendum is to build upon the AMEC work plans and specifically detail the Army Contractor's Standard Operating Procedures (SOPs), Field Sampling Plan (FSP), Data Acquisition Plan, and Quality Assurance Project Plan.

This Sampling and Analysis Plan (SAP) includes a Field Sampling Plan (FSP) including an addendum to the Site Safety and Health Plan (SSHP), a Data Analysis Plan (DAP), and a Quality Assurance Project Plan (QAPP) each prepared as separate sections of the workplan. These plans are based on existing approved plans for the site (AMEC 2007). The field activities described in the FSP will be performed by the Army's contractor. The Army's contractor has completed the FSP and will provide its own QAPP and SSHP prior to conducting the fieldwork.

TABLE OF CONTENTS

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AMEC	AMEC Earth and Environmental, Inc.
As	Arsenic
bgs	below ground surface
BOD	biological oxygen demand
Ca	Calcium
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl	Chloride
COD	chemical oxygen demand
CSM	conceptual site model
DO	dissolved oxygen
DQO	data quality objective
EPA	Environmental Protection Agency
Fe	Iron
FS	Feasibility Study
ID	identification
MassDEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
Mg	Magnesium
mg/L	milligram per liter
µg/L	microgram per liter
umhos/cm	micro Mhos per centimeter
Mn	Manganese
mV	millivolt
Na	Sodium
NAS	National Academy of Science
NPL	National Priorities List
O&M	Operation and Maintenance
ORP	oxidation-reduction potential
pH	Standard potential of Hydrogen ion concentration
PVC	polyvinyl chloride
RI	remedial investigation
ROD	Record of Decision
SGI	Supplemental Groundwater Investigation
SHL	Shepley's Hill Landfill
TKN	Total Kjeldahl Nitrogen
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USACE-NAE	U.S. Army Corps of Engineers – New England District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

1.0 INTRODUCTION

The purpose of this Shepley's Hill Landfill Supplemental Investigation Workplan Addendum is to present the technical approach to collecting data needed for Additional Work items and the Draft FFS for Shepley's Hill Landfill in Ayer, Massachusetts. The Supplemental Investigation Workplan prepared by AMEC was submitted in January 2010 by AMEC, contained the objectives, hypotheses, and decision rules that provide a framework for data collection. This Field Sampling Plan (FSP) along with the Data Analysis Plan (DAP), the Quality Assurance Project Plan (QAPP) and the Site Safety and Health Plan (SSHP), are components of the Supplemental Investigation Workplan Addendum. This FSP describes the protocols for collecting additional information as described in the Supplemental Investigation Workplan (AMEC).

Information contained within this document was prepared by AMEC and outlined in a Supplemental Investigation Workplan dated January 2010. As part of contract requirements, the Army's contractor has updated sections or attachments to this document to conduct the proposed investigation.

1.1 Site History and Background

A summary of site history and project background is presented in Volume 1 of this workplan.

1.2 Scope and Objectives

The workplan technical objectives identified in the Supplemental Investigation Workplan (Table 1-1) are summarized here:

1. Extent of arsenic plume north and northwest of landfill;
2. North plume capture at landfill boundary;
3. North plume monitored natural attenuation within the Impacted Area;
4. Landfill gas impacts in the area of the North Plume;
5. East plume hydraulic characteristics in the vicinity of Plow Shop Pond;
6. Arsenic source strength and predicted duration;
7. Implementability of an air sparging system;
8. Implementability of floc removal in Red Cove of Plow Shop Pond;
9. Implementability of onsite waste management for landfill consolidation

The objective of the work presented in this FSP is to collect sufficient additional information to meet the data needs identified for Items 1, 2 and 5 above. These objectives are associated with distribution and extent of arsenic in groundwater north of the landfill, and at the eastern margin of the landfill in the vicinity of Red Cove. These specific data needs along with data quality objectives and proposed field activities to address the data need are presented in the attached Table 1-1 (Proposed Rationale for Selection of Sampling Locations).

For each data gap, the project team considered the data quality objective (DQO) process. The DQO process produces qualitative and quantitative statements that define the type, quality, and quantity of data necessary to support defensible technical decisions. The DQOs identify when and where to collect monitoring samples, the number of samples to be collected, how the samples should be analyzed, the analytical performance criteria to be met, how the results should be interpreted relative to the monitoring objectives, the practical constraints for collecting the samples, and the level of uncertainty that is acceptable to the decision makers using the data. The Supplemental Investigation Workplan contained the first steps in the DQO process. For each technical issue, it identified the objectives, hypotheses, and decision rules that provide a framework for data collection (USEPA, 2004). This FSP, in addition to other associated plans including the QAPP, contains the details regarding the precise data collection methods and quality control/ quality assurance measures. This FSP thus fulfills Step 4 of the framework for developing and implementing monitoring plans, including the development of DQOs.

1.3 Document Organization

This FSP represents one component of the Shepley's Hill Landfill Supplemental Investigation Workplan Addendum. The other components of the Supplemental Investigation Workplan Addendum (the DAP, QAPP, and SSHP) have been prepared as separate sections of the workplan. The DAP, QAPP, and HASP are stand-alone documents. A summary of the project organization and responsibilities during performance of the activities proposed in this FSP is presented in Section 2.0. Proposed field activities designed to meet the project objectives as well as the rationale for the sample design is presented in Section 3.0 while specific field procedures are presented in Section 4.0. In the terminology of USEPA's *Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation* (USEPA, 2004), Section 3 describes the monitoring boundaries, or the "what, where, and when" aspects of the Monitoring Plan. Section 4 describes the data collection methods in more detail. Section 5.0 summarizes the requirements for project documentation. Corrective action procedures are presented in Section 6.0.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

Specific roles related to this Supplemental Investigation Workplan Addendum are described below.

2.1 Laboratory Responsibilities

Quality assurance responsibilities of laboratory personnel are presented in the QAPP.

2.2 Field Technical Staff

2.2.1 Field Team Leader

The Field Team Leader will coordinate field mobilization activities and will oversee all phases of work at the Site that generates data, including items as follows:

- Coordinating field related activities with the Project Manager;
- Daily coordination with USACE personnel regarding field activities and logistical issues;
- Provide as appropriate daily or weekly updates to the Project Manager regarding progress and report on any technical or logistical issues that arise;
- Management and supervision of all field personnel, including subcontractors;
- Supervising the collection of the samples and providing and ensuring that field activities are conducted in accordance with approved procedures and methodologies, that QA/QC samples have been collected as required, and that sampling forms, labels, chain-of-custody forms and custody seals have been prepared correctly;
- Communicating with the laboratory for timely deliver of supplies;
- Advising the laboratory of any changes to scheduled sample submittals;
- Directing the packaging and delivering or shipping samples to the laboratory; and
- Adhering to work schedules as established by the Project Manager.

2.2.2 Site Health and Safety Officer

The Site Health and Safety Officer (SHSO) will be responsible for verifying that project personnel adhere to the site safety requirements. The Field Team Leader or his/her designee will serve as the SHSO. SHSO responsibilities include:

- Conducting the health and safety training for project personnel and subcontractors, as appropriate;
- Modifying health and safety equipment or procedure requirements based on data gathered during the site work;
- Determining and posting locations and routes to medical facilities, including poison control centers, and arranging for emergency transportation to medical facilities;
- Notifying local public emergency officers, i.e., police and fire departments, of the nature of the field operation and posting their telephone numbers;
- Assigning health and safety-related duties to qualified field team individuals;
- Ensuring that before personnel work on site, acceptable medical examinations are current;
- Ensuring the acceptability of health and safety training;
- Observing work party members for symptoms of exposure or stress;
- Providing first aid if necessary on site; and
- Performing site audits to verify adherence to the requirements of the project Health and Safety Plan.

The SHSO has the authority to stop any operation that threatens the health or safety of the team or surrounding populace. The daily health and safety activities may be overseen by the SHSO or his designee.

2.2.3 Additional Field Technical Staff

The Field Team will be composed of technical staff drawn from the Army's contractor pool of company resources. The technical team staff will be utilized to gather and analyze data, and to prepare various task reports and support materials. All of the designated technical team members are experienced professionals who possess the degree of specialization and technical competences required to effectively and efficiently perform the required work. Specific individual responsibilities will include:

- Provision of day-to-day assistance to the Field Team Leader on technical issues in specific areas of expertise;
- Maintaining field logs and transferring data for permanent storage;
- Coordination and oversight of technical efforts of subcontractors assisting the field team;
- Identifying problems at the field team level, resolving difficulties in consultation with the Field Team Leader, implementing and documenting corrective action procedures, and providing communication between team members and upper management; and
- Participating in preparation of the final report.

2.3 Special Training Requirements and Certification

All field personnel on-site have completed OSHA training in accordance with the Code of Federal Regulations (CFR) in 40CFR 1910.120 and are trained regarding the requirements stated in the QAPP and the SSHP. The drilling subcontractors selected for this project are Massachusetts Registered Well Driller. Each laboratory that analyzes samples for this project is Environmental Laboratory Accreditation Program (ELAP) certified, or have current (un-expired) USACE validation for applicable methods. In addition, the laboratory is Massachusetts State certified for any applicable analyses.

3.0 FIELD ACTIVITIES

As presented in the Supplemental Investigation Workplan (AMEC), various technical objectives have been identified in delineating the arsenic plume associated with SHL. This FSP addresses the following three objectives:

- North Plume Boundaries - downgradient extent in the vicinity of Nonacoicus Brook, and the east and west boundaries along West Main Street;
- Capture of eastern margin of North Plume east of capture wells; and
- East Plume boundary and behavior in the vicinity of Red Cove.

Field activities to address these data gaps will comprise the following tasks:

- Arsenic plume assessment, including installation of monitoring wells, gauging groundwater levels, and collecting and analyzing groundwater and soil samples;

- Geophysical survey, to provide information on the elevation and topography of the bedrock surface to assist with final placement of monitoring wells north of the landfill; and
- Determination of bedrock surface and location/orientation of buried bedrock valley in the vicinity of Nonacoicus Brook.

The following provides specific details about the data gaps and the steps proposed to close them.

3.1 North Plume Delineation and Monitoring for Impacted Area

3.1.1 Data Gap Summary – North Plume Boundary

A work objective is to further delineate the arsenic plume north of the ATP capture zone in all directions (including depth), and install monitoring and sentry wells around the delineated boundaries. Figure 1 shows dissolved arsenic detections above and below the drinking water criterion of 10 micrograms per liter or parts per billion (**ppb**), based on the most recent well sampling results. Figure 1 includes groundwater results along West Main Street from 2001 sampling; some of the results are for unfiltered samples, but these are the only data available for this area.

Figure 1 also contains model-generated tracks of particles ("particle tracks") introduced at the mid-point of well screens in which arsenic was detected at concentrations greater than the MCL (10 ug/l), and allowed to migrate with the groundwater flow. They represent the path a particle would take through the aquifer under ambient conditions with the ATP extraction wells operating at 42 gallons per minute (gpm). While the particle tracks provide valuable information for understanding groundwater flow directions and selecting locations for new wells, they do not provide information on concentrations of arsenic along the tracks.

In the area immediately north of the landfill, the western and eastern plume limits (defined as clearly impacted groundwater with negative ORP and arsenic >100 ppb) along Molumco Road appear to be near SHM-07-03 (ND in 2007) and SHM-99-32X (204 ppb in 2008), respectively. The eastern limit in this area is also supported by earlier results from SHX-99-05 (1999) and SHP-99-34 (2001) as illustrated in Figure 4-3 of the Supplemental Assessment Report (AMEC 2009). A Supplemental Groundwater Investigation (Harding ESE, 2002) indicates arsenic detections along the eastern extent are neither contiguous with the main plume lobe nor strongly correlated with ORP. Because prevailing hydraulic gradients are westward in the Nonacoicus Brook valley fill aquifer, further investigation east of SHX-01-06X and Nonacoicus Brook has not been a key issue. However, since Institutional Controls (ICs) on residential use of groundwater are under consideration in the FFS, further investigation is proposed to better define the area where ICs would be needed.

Farther north, the following data gaps were identified in of the Supplemental Investigation Workplan (AMEC):

- The western plume limit just north and downgradient of West Main Street is west of DEP-08-03, which had 1700 ppb dissolved arsenic (6/08). While this plume edge is constrained by earlier (2001) profile results from SHX-01-10X, -13X, and -11X located slightly upgradient, the screens at SHP-07-01C and -01D sampled in 2007 are shallower than DEP-08-03 and may be above the plume. Consequently, the western plume in the area of West Main Street is unconstrained in the area east of DEP-08-05 (which extended to bedrock) and northwest of SHX-01-11X.
- The northern plume limit is interpreted to be under Nonacoicus Brook immediately north of DEP-08-03 and -08, which had 1,700 and 240 ppb dissolved arsenic respectively (both 6/08). There is no monitoring well situated directly north of these locations where drilling access is limited by the wetland.
- To the northwest the plume appears to be constrained by DEP-08-07, but a data gap may exist to the west between DEP-08-05 and DEP-08-07.

3.1.2 Proposed Field Activities

The following describes field activities proposed to close the identified data gaps.

3.1.2.1 Wetlands Evaluation / Delineation

Prior to commencing field activities, the Army's contractor personnel will locate and mark out the exploration points and geophysical lines within the North Plume Delineation area. The Army's contractor personnel will inspection each of the locations, and determine whether the detailed items are located within the wetlands or buffer zone. The locations of these points / lines will be GPS located on a plan, with information and a letter detail the scope of the project being submitted to the Ayer Conservation Commission.

3.1.2.2 Geophysical Survey

Bedrock has a strong influence on groundwater flow patterns; therefore, a geophysical survey to map the bedrock surface in this area is proposed to precede the selection of final boring locations. The principal objective of the geophysical survey is to determine the depth to and the elevation of the bedrock surface in the vicinity of Nonacoicus Brook, downgradient of the landfill. Available information suggests the presence of a bedrock trough beneath the northern toe of the landfill and Nonacoicus Brook (Figure 1). The trough is oriented N-S beneath the landfill toe, and gradually turns west until generally aligned E-W beneath Nonacoicus Brook. Information generated from the geophysical survey will be reviewed prior to selection of final well locations. The geophysical survey includes the completion of seismic refraction imaging lines designated A-A', B-B' and C-C' as depicted on Figure 1. The refraction survey will be completed via the use of a Betsy-gun shock source and an evenly spaced geophone array placed along the imaging lines. Some minor grubbing and brush clearing will be performed to aid with access along the transect image lines.

3.1.2.3 Borings and Monitoring Wells

Borings are proposed in each of the above areas at the approximate locations indicated in Figure 1, subject to obtaining approvals and access agreements from private property owners. Proposed boring SHM-10-01 is located to evaluate the western limit of the plume in the area of West Main Street. Proposed borings SHM-10-02 and -03 are located to evaluate the western limit of the plume in the area of Nonacoicus Brook and the bedrock valley. Proposed location SHM-10-04 is located to evaluate the northern limit of the plume in the area of Nonacoicus Brook. Proposed location SHM-10-05 is located to evaluate the eastern limit of the plume in the area of West Main Street. Based on meetings between the Army's contractor and the USACE an additional 3 locations (SHM-10-08 through -10) were also included as depicted on Figure 1 to evaluate the limit of the plume in the area of Nonacoicus Brook.

Each boring would extend to bedrock (or maximum drilling refusal) with groundwater sampling (profiling) every 10 feet during drilling. During drilling, groundwater samples at 10 foot depth intervals through the water table will be field screened using an arsenic test kit (Appendix B) to expedite field decisions on "arsenic delineation" and boring locations. Split samples at each sampling interval will be prepared and submitted for laboratory analysis under a 24-hour turn-around. To confirm and document the accuracy of the testing kits a correlation study will be conducted prior to the implementation of the explorations program. The profile samples will also be screened in the field for water quality parameters (pH, SC, ORP, DO), and laboratory-analyzed for arsenic, iron, manganese, calcium, magnesium, potassium, sodium, chloride, sulfate, nitrate, nitrite, alkalinity, ammonia, and chemical oxygen demand (Table 4-3). If drilling results suggest the 100 ppb plume limit has not been adequately identified, a new boring may be advanced to collect this data. When drilling results suggest the plume limit has been identified, temporary well screens would be constructed at appropriate intervals and sampled for ROD metals and water quality characteristics. Two rounds of sampling will be conducted approximately three months apart following the installation of the wells. The plume will be mapped in plan and section views based on these results. A summary of groundwater sample collection is included on Table 4-3 of this FSP. Sentry monitoring wells will be identified following plume delineation, and may include new wells to be installed under a separate scope and mobilization at a future time. If any existing wells identified for sentry monitoring are not constructed or sited appropriately, they will be replaced with new wells.

All borings proposed for the North plume (and others specified in this workplan) will be advanced using direct-push drilling techniques capable of: 1) reaching the anticipated depth of 100 feet below ground surface (bgs); and 2) permitting collection of representative groundwater samples at discrete depths throughout the entire depth of the aquifer (i.e., profile samples). The direct push drilling technique will allow for the installation of temporary wells of diameters between 1 and 1.5 inches. While the direct push drilling technique may not be able to accurately confirm the presence and depth of bedrock, the final boring depth elevations will be compared to geophysical data and existing bedrock elevations (and interpreted surfaces) in defining the "type" of drilling refusal. Permanent sentry wells to be installed at a future time and mobilization, if necessary, will be installed using in locations determined following the two sampling events of the temporary wells. During the sentry well installation, depth to bedrock will be confirmed and permanent 2 inch diameter wells will be installed.

3.2 North Plume Capture at Boundary

3.2.1 Data Gap Summary

Objectives for the current remedy in place include operating the treatment system to contain the arsenic plume in the vicinity of the base boundary near the north end of the landfill and demonstrating that the arsenic plume is captured. The latest revised groundwater model and other lines of evidence as presented in the 2008 Annual Report suggest that impacted groundwater at the toe of the landfill is fully contained, subject to some uncertainty on the eastern plume extent at the toe (ECC 2009). This uncertainty relates to the extent of impact east of SHM-96-5B. The results from the proposed effort will be used to evaluate whether the current groundwater extraction system in capturing the eastern portion of the plume.

3.2.2 Proposed Field Activities

A boring is proposed in the area of SHL-21 as indicated in Figure 2, extending to bedrock with groundwater profile sampling every 10 feet during drilling and will be installed using direct push drilling techniques. During drilling, groundwater samples at 10 foot depth intervals through the water table will be field screened using an arsenic test kit (Appendix B) to determine relative arsenic concentration. The profile samples will also be screened in the field for water quality parameters (pH, SC, ORP, DO), and laboratory-analyzed for arsenic, iron and manganese. A summary groundwater sample collection is included on Table 4-3 of this FSP. If drilling results suggest the plume limit has not been identified, a new boring would be advanced (offset east away from the plume) to collect this data. Up to three drilling attempts are scoped for this activitiy. When drilling results suggest the plume limit has been identified (arsenic concentration less than 100-ppb), a temporary well screens would be constructed at appropriate intervals and sampled for ROD metals and water quality characteristics. Two rounds of groundwater sampling will be conducted in accordance with methods described in Section 4.4.

3.3 East Plume

3.3.1 Data Gap Summary

Objectives for the current remedy in place include controlling the continuing discharge of high-arsenic groundwater from SHL to Plow Shop Pond (AOC 72) sediments. Discussions among stakeholders have identified the need for additional information on the hydraulic characteristics of groundwater on the eastern margins of the landfill in the vicinity of Red Cove and near the center of the landfill, southwest of Red Cove. Five new groundwater monitoring wells were recommended by USEPA for the area between SHL and AOC 72 to collect data on arsenic concentrations in this area (USEPA 2008). Based on subsequent discussions among stakeholders, and review of results from an updated groundwater model, one new monitoring well is proposed at this time. Its location is shown on Figure 2 and is designated as SHM-10-07. It has been sited to provide initial information on the location of the divide between groundwater which discharges north and that which discharges east to Red Cove and Plow Shop Pond. Information derived from installation and sampling of this well will be used initially to evaluate the need for additional wells in this area, and ultimately, in combination with groundwater modeling, to evaluate remedies such as hydraulic controls (extraction or injection) or in situ treatment in the discharge area.

3.3.2 Proposed Field Activities

A boring is proposed in the area of RSK24 as indicated in Figure 2, designated as SHL-10-07, extending to bedrock with groundwater profile sampling every 10 feet during drilling and will be installed using rotosonic drilling techniques. During drilling, groundwater samples at 10 foot depth intervals through the water table will be field screened using an arsenic test kit (Appendix B) to determine relative arsenic concentration. The profile samples will be screened in the field for arsenic and water quality parameters (pH, SC, ORP, DO), and laboratory-analyzed for arsenic, iron and manganese. Additionally vertical profile soil samples will be collected from each lithology change and laboratory-analyzed for target analyte list (TAL) metals and total organic carbon (TOC). Based on the laboratory analytical groundwater results, a temporary well screen will be constructed at appropriate intervals and sampled for ROD metals and water quality characteristics. The well will be developed in accordance with well development SOPs outlined in Appendix C. and two rounds of groundwater sampling will be conducted in accordance with methods described in Section 4.4. Depth to groundwater will be measured during well installation, development and sampling. In addition, the well will be included during synoptic water level measurement rounds conducted in the area. A summary groundwater and soil sample collection is included as Table 4-3 of this FSP.

Because the boring will be advanced through the landfill cover, precautions will be taken to minimize disruption of the cover components and ensure that the completed well casing does not permit infiltration of surface water into the landfill. These procedures are described in Section 4.3.1.1.

4.0 FIELD PROCEDURES

4.1 Environmental Requirements and Protection of Property

Work on Shepley's Hill Landfill must comply with federal, state, and local requirements to protect the environment and the property on which the work is performed.

As part of project planning, applicable Federal, State and Local laws and regulations will be identified as well as installation-specific orders or agreements. Work will be performed in accordance with said authorities. This effort will include all permits, licenses, approvals, and/or certificates necessary to accomplish the work specified. All such regulatory requirements will apply to the Army's contactor and their subcontractors and suppliers. This list will be updated, as appropriate, as the project progresses.

In the unlikely event of noncompliance, the Army's contractor will immediately bring the incident to the attention of the USACE-NAE Contracting Officer (KO), Army's Contracting Officer's Representative (COR), and Devens Base Realignment and Closure (BRAC) Environmental

Coordinator (BEC) by telephone and then by written notice. The Army will independently review Contractor work to ensure compliance with all applicable requirements.

While completing this work, the Army's contractor will have the following responsibilities:

- When the work to be performed requires clearances, such as digging or drilling permits, the Army's contractor will obtain such clearances and/or permits, with the assistance of the facilities point of contact, prior to initiation of any drilling or excavating operations
- All excavating will be coordinated with the Mass Development Department of Public Works on Devens, and/or Town of Ayer Department of Public Works and Dig Safe (Rights of Entry and Easements) prior to performing work
- The Army's contractor will verify the available utility maps, contacting DigSafe for utility clearance
- The Army's contractor will comply with all on and off-site Installation or site-specific time and procedural requirements (federal, state, and local) described in the permits obtained
- The Army's contractor will exercise due diligence to protect all property on the premises from damage resulting from the work described herein, and will be responsible for any such damage. Any property of the United States damaged or destroyed by the Army's contractor incident to the exercise of the privileges herein granted shall be promptly repaired or replaced by the Army's contractor to a condition satisfactory to the COR or reimbursement is made therefore by the Army's contractor team in an amount necessary to restore or replace the property to a condition satisfactory to the COR in accordance with Federal Acquisition Regulation (FAR) Clause 52.245-2.

4.2 Geophysics

The geophysical technique of seismic refraction will be used to characterize bedrock elevations along multiple intersecting profiles. The method of seismic refraction uses a physical impact at the ground surface, such as a sledge hammer or Betsy Gun, to propagate seismic waves through the subsurface. The seismic energy travels through the geologic materials reflecting and refracting at geologic interfaces between layers that have differing acoustic impedances. The method of seismic refraction measures the travel times of waves that are refracted (rather than reflected) and is commonly used to ascertain the depth to "hard" layers, particularly bedrock, that underlay "softer" unconsolidated materials (such as sand and gravel layers). The pulse of seismic energy produced by the impact "source" travels down to bedrock, across the bedrock surface, and returns to the surface to be detected by an array of geophones installed along linear profiles at the ground surface. The depth to bedrock is calculated using the time it takes for the seismic pulse to travel from the source to each geophone in the array. Modern seismic processing allows the determination of bedrock depth directly beneath each geophone in the array. Seismic refraction profiles can be made to any length by stringing refraction arrays along a line. Seismic refraction may also provide information about the stratigraphy in overburden.

Seismic refraction will be conducted along three (3) intersecting profiles as shown on Figure 1. Each profile will be made up of strings of 250-foot long geophone arrays with inter-geophone spacings of ten (10) feet. Multiple seismic source locations ("shots") will be fired along the array and at off-set locations using a Betsy Gun. Should the Betsy Gun not produce a sufficient shock source at the onset of the project, the Army's contractor will contact USACE personnel and determine if the survey will continue. Explosive shock sources will not be utilized in this effort. The efficacy of the Betsy Gun will be readily apparent early in the survey and a field decision will be made as soon as possible to minimize the delay in completion of the survey.

The seismic profiles will be completed in the order A, B and C (Figure 1). The positioning of Profile A is intended to provide bedrock elevations cross-strike of the interpreted bedrock low and to intersect the approximate location of two proposed monitoring wells. Based on the nature of the field testing procedures for the North Plume Delineation as outlined in Section 3.1.2.2, the final location of direct push borings may offset from the seismic profile. Profile A will be approximately 1,250 feet long (i.e., five 250-foot refraction arrays) and strike roughly 14 degrees east of north. The northern end of Profile A will be just south of the Ayer Wastewater Treatment Plant (WWTP) access road. The southern end of Profile A will be just north of Nonacoicus Brook. Profile B is intended to provide depth-to-bedrock information that is roughly parallel to the strike of the interpreted bedrock low and to intersect the location of two proposed monitoring wells. Profile B will be approximately 1,750 feet long (i.e., seven 250-foot long refraction arrays) and strike approximately 55 degrees east of north. The northern end of the profile will be bound by Brook Street and the southern end will be bound by Nonacoicus Brook. Profile C is intended to provide bedrock topography information on a line perpendicular to the strike of the interpreted bedrock low and to intersect the location of one proposed monitoring well. Profile C will be approximately 1,250 feet long (i.e., five 250-foot long refraction arrays) and strike approximately 33 degrees west of north, paralleling the western boundary of the Ayer WWTP. The southeastern end of Profile C will be the Nonacoicus Brook. The northern end will extend approximately 100 feet north of the Ayer WWTP access road.

In the unlikely event that portions of the seismic lines are inundated (i.e., standing water in wetland areas), a field decision will be made as to whether: 1) the crossing is short enough to leave out of the survey, 2) the profile can be diverted slightly to avoid the wet area or, 3) marsh geophones should be used instead of the more conventional land geophones, if the section is considered critical. In no case will a section be removed if that section exceeds five percent of the full length of the profile.

4.3 Drilling and Monitoring Well Installation

As described in Sections 3.1, 3.2, and 3.3, up to eight proposed monitoring wells will be installed near the North Plume Delineation area, one well will be installed in the North Plume Capture area, and one well through the landfill cap near Red Cove. A vertical profile of arsenic concentrations and field parameters for groundwater will be generated at each well location using drilling and sampling techniques described below. Based on a review of these data, the well screen(s) will be installed at each location at the depth(s) determined after review of the profile data. Potential well locations are presented on Figures 1 and 2. Table 4-1 lists the proposed locations and anticipated maximum depth of each monitoring well.

4.3.1 Well Installation – Drilling Methods and Equipment

Because the soil borings for the temporary monitoring wells will be advanced below the water table into unconsolidated sediments, and because one primary objective is the collection of valid groundwater profile samples, soil borings will be advanced using roto-sonic and/or direct-push. These methods do not introduce supplemental air or water into the aquifer, and helps assure that the collected groundwater profile samples are representative of the local aquifer. Drilling will proceed until the elevation of the bedrock surface has been confirmed by drilling five to ten feet into bedrock only within the East Plume. All drilling operations will be performed in general accordance with the Monitoring Well Installation SOP included in and Appendix C of this FSP.

Collection of soil samples during advancement of soil borings in the North Plum Nonocoicus / Capture Areas is not required for this field effort. Vertical profile soil samples will be collected from each lithology change and laboratory-analyzed for TAL metals and TOC during the advancement of the soil boring in the East Plume Area. Observations regarding the density, competency, color, odor, and other overburden and bedrock characteristics that can be made during boring and well installation activities will be recorded on boring log forms during advancement of all soil borings.

Drill cuttings and drilling water generated during boring installation will be handled in accordance with the procedures for handling investigation derived waste (IDW) outlined in Section 4-9.

4.3.1.1 Boring and Well Installation – Through Landfill

One boring will be advanced within the margins of the landfill (Figure 2). This will involve penetrating the landfill cover components including topsoil, sand (drainage layer), PVC liner (cover), and gas collection system. Any impacts to the system components and their ability to function as designed must be minimized, and be temporary. The monitoring well must be constructed in such a manner that the cap retains its ability to direct surface water runoff, prevent infiltration through the cap and underlying wastes, and collect and direct landfill gases as designed. Boring advancement and well construction will be conducted in general accordance with guidance provided in the Supplemental Groundwater and Landfill Cap Assessment (SGLCA) Scope of Work (SOW) (AMEC 2007).

The following general procedures will be followed to minimize temporary and permanent impacts to the landfill cover:

- Construct drilling pads (gravel, wood, etc.) to minimize damage to cap from drill rigs and support vehicles during boring and well installation;
- Prepare a soil berm on the uphill side of the drilling location to divert surface water runoff away from the boring and minimize infiltration;
- Remove the topsoil and sand drainage layer by hand in the immediate vicinity of the boring location to expose the PVC liner/cover;
- Remove section of liner sufficiently large so that drill stem does not come in contact with the undisturbed liner material during boring advancement and well construction;
- Excavate by hand or small machine to sufficient depth to ensure that gas collection piping will not be impacted;
- Drill boring as described in previous section, being sure to prevent uncontrolled runoff of any drilling fluids.
- Construct well as described in Section 4.3.3; and

- Reconstruct liner and other cover components as described in Appendix A, ensuring the well penetration area is sealed to prevent infiltration of surface water through the cap.

During advancement of the boring(s) through the landfill, soil and waste samples will be collected every lithology change, in accordance with the Drilling Operations SOP in the SGLCA SOW. The samples will logged for visual characteristics, and a representative sample collected for laboratory analysis of TAL metals and TOC. The information will be used to help define the general composition and thickness of the waste, the elevation of the bottom of the waste, the saturated thickness of the waste, and characteristics of the native materials underlying the waste.

4.3.2 Vertical Groundwater Profiling

Vertical profiling will be conducted during boring advancement. Groundwater samples will be collected at 10-foot intervals, starting from approximately 10 feet below the water table to the bedrock interface using the procedures described below.

Groundwater profile samples will be collected using either a peristaltic or submersible nitrogen-purge bladder pump (depending on depth) equipped with dedicated polyethylene tubing. Field parameters (pH, temperature, conductivity, dissolved oxygen, redox potential and turbidity) will be measured using a flow-through cell. When parameters stabilize or following a 30 minute maximum purging time samples will be collected for: 1) field screening for arsenic using a colorimetric process, and 2) laboratory analysis for arsenic, iron and manganese. Samples will be analyzed as filtered by pumping water through a new 0.45 µm filter into the appropriate sample container. All sample containers will be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. Sample containers, preservatives, volumes, hold times, and shipping requirements are summarized in Table 4-2. Each sample will be labeled and placed into a cooler with ice for shipment to the laboratory in accordance with the procedures outlined in Section 4.8.

Field screening of the samples for arsenic will be conducted using Arsenic Quick™ Test Kits (Part No. 481396). The selected kit must be able to detect arsenic at concentrations in the 10-100 ug/l range. This particular kit is recommended because of its low detection level (5 ug/l) and number of sensitivity ranges (8) between 5 ug/l and 100 ug/l. The screening kits will be used in accordance with the screening kit manufacturer's instructions. Information on the Arsenic Quick™ Test Kits is included in Appendix B.

4.3.3 Well Installation – Materials and Construction

In general, all monitoring wells will be installed in accordance with and in accordance with the Monitoring Well Installation SOP included in the SGLCA SOW and Appendix C of this FSP and with the MassDEP Standard Reference for Monitoring Wells (MassDEP, 1991). Permanent monitoring wells will be constructed of 2-inch I.D. Schedule 40 PVC casing. Based on a review of existing site lithological information, it is anticipated the wells will be constructed using a well screens with a slot size of 0.010 inches and a screen length of 10 feet. The screen length and slot size may be modified based on field conditions with any modifications noted in the field logbook. Temporary wells will be constructed of 1 inch or 1.5 inch diameter Schedule 40 PVC and will also have 10 foot well screens with 0.010 inch slot sizes.

Screen intervals will be selected based on the results of the vertical profile sampling with the objective of monitoring zones of arsenic contamination. Although not anticipated based on previous sampling results from nearby wells, any wells to be installed at the water table will be installed such that the water table intersects the well screen taking into account temporal variations in groundwater elevation while ensuring that sufficient screened interval below the water is present to allow installation of bladder pumps for groundwater sampling. A locking waterproof cap will be installed on each well casing prior to placement of filter pack materials to prevent any of these materials from entering the well.

After placement of the well materials in the borehole, a sand filter pack will be placed in the boring to a depth of 2 feet above the top of the screen. After placement of the filter pack, a minimum 2-foot thick layer of bentonite chips will then be placed above the filter pack. If the bentonite layer is above the water table, bentonite powder may be used instead of bentonite chips and the bentonite will be hydrated with clean, potable water from the local municipal water source in order to ensure that a proper seal is created. The remaining annular space in the boring will be filled with bentonite grout to a depth of 1 foot bgs. As the annular space is being filled, the steel casing will be gradually withdrawn from the borehole being careful not to remove the casing to a depth where the bottom of the casing is above the top of the fill material.

The boring in the East Plume is expected to penetrate into bedrock five to ten feet. To protect against having the borehole act as a conduit between the overburden and bedrock aquifers, the portion of the borehole in the bedrock will be completely filled with a bentonite grout slurry, and the slurry will extend at least three feet above the bedrock-overburden interface (unless it interferes with a well screen).

At locations where surface completion is required to be flush with the ground surface, a road box capable of withstanding vehicular traffic will be installed over each well. At other locations, a protective steel casing with a locking cap will be cemented in place over each well. Protective bollards are not anticipated to be needed based on the location of the wells in this work scope.

4.3.4 Well Development

In order to ensure a proper connection with the aquifer after drilling, each monitoring well will be developed no sooner than 48 hours after installation. Monitoring well development will be conducted in accordance with the procedures outlined below and the Monitoring Well Development SOP included in Appendix C of this FSP.

Well development will be performed using surging and pumping. A surge block may be used to mechanically surge water back and forth between the well and the formation in order to remove fines from the filter pack and enhance the connection between the well and the aquifer. After surging, a submersible pump will be lowered into the well to pump out water and the associated fines. Surging and pumping cycles will continue as needed to reduce the amount of fines entering the well.

As development proceeds, water quality parameters (conductivity, pH, and temperature) shall be measured and turbidity shall be measured or described (e.g., low, moderate, high is acceptable) at approximately even fluid withdrawal increments during the course of development. Development will continue until at least three well volumes have been removed. If three successive parameters have stabilized (values within ten percent of each other) and turbidity is low, well development can cease. If stabilization has not been attained or if turbidity remains high, development shall continue until a maximum of ten well volumes has been removed. Purge water generated during development will be handled in accordance with the procedures for handling IDW outlined in Section 4.9.

4.4 Groundwater Sampling – Wells

Groundwater sampling at wells will be performed using low-flow sampling techniques using either a bladder pump or a peristaltic pump. At locations with inside diameters too small to accommodate a bladder pump, a peristaltic pump will be used. Procedures for vertical profile sampling are presented in Section 4.3.2.

The objective of performing low flow rate purging is to collect groundwater samples which best characterize actual groundwater conditions within the aquifer. Low flow rate sampling techniques minimize the amount of disturbance to the water contained within the well resulting in less agitation and minimal entrainment of particulates. The result is a more rapid stabilization of the parameters used to indicate that actual formation water (vs. stagnant casing water) is being collected.

Two rounds of groundwater samples will be collected from each of the newly installed wells: one after installation and the other approximately three months later in order to generate data from both high and low groundwater conditions. The second sampling event will be scheduled to coincide with groundwater sampling activities conducted by other parties in conjunction with the ongoing groundwater monitoring program under the SHL ROD. It is currently anticipated that the installation activities will be conducted in late Spring 2010 with the second sampling event to occur in Summer 2010 in order to provide additional data for the pending Focused Feasibility Study. Analytical parameters are summarized in Table 4-3.

4.4.1 Groundwater Sampling Methods

Groundwater sampling will be conducted in accordance with the procedures described below and in accordance with the USEPA Region 1 Low Flow Groundwater Sample Collection SOP in Appendix C of this FSP. Where different, procedures described below will supersede those of the SOP. Prior to sampling, the depth to the groundwater surface will be measured to the nearest 0.01 foot. The groundwater sampling pump will be equipped with dedicated polyethylene tubing and will be lowered slowly into the well to the approximate center of the saturated screen section. The pump intake will remain at least two feet above the bottom of the well to prevent the disturbance of any sediment which may be present. The water level will be measured and recorded before starting the pump. If available, sampling records from previously sampled nearby wells will be reviewed in order to determine initial flow rates. Otherwise, purging will be started at flow rates of approximately 0.2 to 0.5 liters per minute. The flow rate will be adjusted to ensure that little or no drawdown (less than 0.3 feet) occurs in the well. If this level of drawdown cannot be attained, the pumping rate will be reduced to the minimum capabilities of the pump to avoid pumping the well dry. The level of the water will not be allowed to drop below the intake on the pump to avoid the possible entrainment of air into the sample. If the recharge rate is very low, sampling shall commence as soon as the well has recharged to a sufficient level to purge one system volume (volume of pump and tubing) and then collect the appropriate volume of sample.

During the purging of the well, the field parameters (pH, temperature, conductivity, dissolved oxygen, redox potential and turbidity) will be monitored every 3 to 5 minutes, or as appropriate, using a flow-through cell, until the parameters stabilize. Field parameters will be considered stabilized when, for three consecutive readings, the temperature is within ± 3%, pH is within ± 0.1, dissolved oxygen is within ± 10% or changes less than 0.3 mg/L, redox potential is within ± 10 mV, conductivity is within ± 3%, and turbidity is within ± 10%. An attempt will be made to purge the well until turbidity of the purged water is less than 5 nephelometric turbidity units (NTUs). These measurements are consistent with the procedures in EPA/540/S-95/504, Ground Water Issue, Low-flow (Minimal Drawdown) Ground-Water Sampling Procedures. Purge water will be collected, characterized and disposed of in accordance with the procedures in Section 4.9.

After purging is completed, groundwater samples will be pumped directly into the proper sample containers. All sample containers will be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. Samples will be analyzed as both filtered and unfiltered samples. Samples requiring dissolved constituent analysis will be collected by pumping water through a new 0.45 µm filter into the appropriate sample container. Sample containers, preservatives, volumes, hold times, and shipping requirements are summarized in Table 4-2. Each sample will be labeled and placed into a cooler with ice for shipment to the laboratory in accordance with the procedures outlined in Section 4.8.

4.5 Field QC Sampling Procedures

Field QC samples that will be prepared and submitted to the laboratory for analyses during performance of this field effort will consist of equipment blanks (for all analyses), duplicate samples (for all analyses), and matrix spike/matrix spike duplicate samples (for all analyses). A summary of the QC samples can be found in Table 4-4. The frequency and method of collection of field QC samples are described in the QAPP.

4.6 Decontamination Procedures

All non-dedicated equipment will be decontaminated in accordance with the procedures outlined below and those presented in the Sampling Equipment Decontamination SOP presented in Appendix C of this FSP.

All down-hole drilling equipment shall be decontaminated prior to initial use and between each borehole. Non-dedicated groundwater sampling devices (i.e., pumps, etc.) shall be decontaminated prior to initial use and between collection of each sample to prevent the possible introduction of contaminants into successive samples. Equipment can be decontaminated at the sample location, or at a pre-designated, controlled location. All equipment must be decontaminated before leaving the site.

Decontamination of drilling equipment includes drill bits, drill-string tools, drill rods, tremie pipes, clamps, hand tools, steel cable, along with pump droplines and pumps. These items are typically cleaned, by the subcontractor, with a steam pressure washer.

Types of equipment requiring decontamination may also include, but are not limited to water level and water quality meters, bailers, and miscellaneous tools. All items will be cleaned using the method detailed within the attached SOPs.

Where possible, equipment shall be disassembled prior to cleaning. If equipment is heavily soiled, a second wash with an aqueous non-phosphate detergent solution will be added at the beginning of the process. In addition, heavily soiled items may require steam cleaning using a portable, high pressure steam cleaner equipped with a pressure hose and fittings.

4.7 Surveying

The horizontal and vertical position of all newly installed wells will be surveyed by a licensed and Massachusetts-registered surveyor to a horizontal accuracy of 0.1 ft and a vertical accuracy of 0.01 ft. These positions will be tied to a permanent benchmark located near the site (e.g., U.S. Coast and Geodetic Survey, USGS, or USACE benchmark), and the marker will be tied to the National Geodetic Vertical Datum (NGVD) Mean Sea Level. The water level measuring point (notch) on the riser pipe and the ground surface elevations will be surveyed at each monitoring well location.

4.8 Sample Packaging and Shipping Requirements

Packaging and shipment of all environmental samples collected during the field activities described above will be conducted in accordance with all appropriate U.S. Department of Transportation regulations (e.g., 49 CFR, Parts 100 199).

The sample containers will be placed in an insulated cooler with frozen gel packs (such as "blue ice") or ice in double, sealed zip-lock bags. The lids of the containers shall not be sealed with duct tape, but may be covered with custody seals or placed directly into self-sealing bags. Samples should occupy the lower portion of the cooler, while the ice should occupy the upper portion. Prior to shipping, glass sample containers will be wrapped on the sides, tops, and bottoms with bubble wrap or other appropriate padding to prevent breakage during transport. Samples shall be shipped as soon as possible to allow the laboratory to meet holding times for analyses. Prior to shipment, the ice or cold packs in the coolers will be replaced so that samples will be maintained as close to 4°C as possible from the time of collection through transport of the samples to the analytical laboratory.

When a cooler is ready for shipment to the laboratory, two copies of the chain of custody form shall be placed inside a zip-lock bag and taped to the inside of the cooler. Chain-of-custody seals will be placed on the coolers and the coolers will then be sealed with strapping tape and labeled "Fragile," "This-End-Up" or other appropriate notices. A letter stating the names and telephone numbers of the sampling and laboratory personnel at various locations who can be contacted in the event of problems with the sample shipment should also be taped to the outside of the cooler.

4.9 Investigation-Derived Waste (IDW) Management

As part of the field activities described above, investigation-derived waste (IDW) materials will be generated in association with soil boring, monitoring well installation, well development, sample collection and handling, and decontamination. IDW materials generated will be handled and disposed of in accordance with state and federal requirements. Decontamination fluids will be containerized and transported to a temporary storage area at Devens RFTA for characterization and disposal. Drilling cuttings and purge water associated with well development and sampling will be returned to the local setting, with the exception of the East plume. At this one location, drill cutting will be containerized for proper disposal.

4.10 Data Validation / Database

For all analytical services procured through Alpha Analytical in accordance with this Task Order, the laboratory will report data in a format compatible with the Army Environmental Information System (ERIS). The analytical datasets will comply with either ERIS or ERIS Range, as appropriate per the PWS. ERIS v3.0, which was released in January 2006, is the current version detailed at http://aec.army.mil/usaec/reporting/eris00.html. ERIS v3.0 combined the ERIS v2.0 and ERIS Range Databases into a single database. The data shall be entered into the ERIS v3.0 database through the ERIS website. Data will be entered either through data entry screens or through batch file uploads.

The Army's contractor shall provide the necessary data and documentation for closeout of this site in the Army Environmental Database – Restoration Module (AEDB-R) if SHLF achieves Response Complete during the performance period of this task order.

The Army's contractor will perform a QC review of project data in accordance with the review procedures and qualification requirements as described in *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (1999) and *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (2004). The validated analytical data will be included in the Annual RA(O)/LTMM Report.

Where there is conflict between the requirements of the USEPA guidance and the SW-846 analytical method, the method requirements will take precedence. For those methods where no USEPA guidance exists, the reviewer will apply the protocols from the guidelines that most closely correspond to the method in question. The validation effort will be guided by the installation and project-specific information presented in the site-specific QAPP. The data review will only be for the QC elements in described below and will not constitute a CLP-type validation normally associated with Level IV data collection activities. For each type of chemical analysis, the validator will complete a data validation report using the Army approved format.

Elements of The Army's contractor's data validation process include the following:

- Review of chain-of-custody documentation to verify sample identities.
- Review of sample log-in documents to determine if there are any problems with sample delivery and conditions.
- Review of rinse blank and trip blank data to determine whether problems with container contamination, preservative contamination, sampling equipment contamination, laboratory reagent water contamination, or cross-contamination between samples has occurred.
- Review of method blank data to determine whether there are any sources of contamination in the analytical process.
- Review of matrix spike/matrix spike duplicate (MS/MSD) recoveries to evaluate the potential for matrix effects and as a measure of analytical accuracy. MS/MSD recoveries will be compared against the laboratory's statistically derived acceptance criteria.
- Comparison of MS/MSD results to evaluate sample homogeneity and as a measure of analytical precision. MS/MSD precision data will be compared against the laboratory's statistically derived acceptance criteria.
- Review of laboratory control spike (LCS) data as a measure of analytical accuracy. LCS recoveries will be compared against the laboratory's statistically derived acceptance criteria.
- Review of LCS duplicate data (if available) as an additional measure of analytical accuracy and of analytical precision. LCS/LCSD data will be compared against the laboratory's statistically derived acceptance criteria.
- Review of sample duplicate data (if available) as a measure of sample homogeneity and as a measure of analytical precision. Sample duplicate data against the laboratory's statistically derived acceptance criteria.
- Review of surrogate recovery data to assess extraction efficiency, effectiveness of sample introduction, matrix effects, and possible loss during cleanup activities.
- Review of sample dates, preparation dates, and analysis dates to determine if maximum holding times were met or exceeded.

Pursuant to our discussions with the CENAE, all data validation will utilize an Automated Data Review (ADR) for EQuIS, in lieu of the Level II data validation for 100% of the data delivery groups (SDGs), which streamlines data validation.

5.0 FIELD OPERATIONS DOCUMENTATION

5.1 Field Logbook and Field Data Sheets

Field activities will be documented using a field logbook in accordance with the Field Notes SOP presented in Appendix C of this FSP. The documentation in the field logbook is designed to contain sufficient information to enable the sampling activity to be reconstructed without relying on the collector's memory.

For certain tasks, information will be recorded on pre-printed field data sheets (e.g., boring logs, well installation/development logs, or drum logs). This information should not be repeated in the field logbook, except in summary form to avoid transcription errors. Examples of field data sheets to be used during the activities are incorporated into the SOPs which are attached as Appendix C of this FSP.

5.2 Photographic Records

All sampling points will be documented by photograph in order to permit positive identification of the sampling point in the future and to document their validity as a representation of an existing situation. Photographs taken to document sampling points will include two or more reference points to facilitate relocating the point at a later date.

For each photograph taken, the following items should be noted in the field logbook:

- Date and time of photograph,
- Photographer name,
- Name of site,
- Sequential number of the photograph with unique identifier relating to digital file,
- Site sketch indicating location of photographer when picture was taken and the general direction faced, and
- General description of the subject.

5.3 Sample Documentation

5.3.1 Sample Numbering System

Site-specific sample identification numbers will be assigned prior to sample collection. Each sample will be identified in the field notebook and field sampling form by an alpha-numeric code following the identification scheme outline below. The site-specific sample number will consist of the following:

Groundwater Profile Samples

Notation: GP-XX-XX-YYY-Z

Where: GP indicates Groundwater Profile,
-XX-XX indicates boring/well location,
-YYY is 3-digit depth at which sample was collected, and
-Z is space to indicate Filtered or Unfiltered.

Ex: GP-10-01-095-U; Unfiltered groundwater profile sample from boring/well location SHM-10-01, at a depth of 95 ft below ground surface.

Groundwater Samples from Monitoring Wells

Notation: SHM-XX-XX-MMDDYY-Z

Where: SHM indicates Monitoring Well Sample,
-XX-XX indicates boring/well location,
-MMDDYY is the 6-digit date on which sample was collected,and
-Z is space to indicate Filtered or Unfiltered.

Ex: SHM-10-01-042110-F; filtered monitoring well sample from boring/well location SHM-10-01, collected on April 4, 2010.

Duplicate Samples

Notation: DUP- MMDDYY-Z

Where: DUP indicates blind DUPlicate sample
-MMDDYY is the 6-digit date on which sample was collected, and
-Z space to indicate Filtered or Unfiltered.

Ex: DUP-042110-F; Duplicate sample (filtered) collected on April 21, 2010.

5.3.2 Sample Labels

All samples containers will be identified using a label affixed to the container prior to transportation to the laboratory. Information on sample labels will include:

- the name of the project or site;
- a unique sample identification number (See Section 5.3.1),
- the sampler's name/signature/initials;
- the nature of the chemical preservative, if appropriate,
- the type of analysis requested, and
- the date and time the sample was taken.

5.3.3 Chain-of-Custody Records

All sample handling will be conducted using the appropriate chain-of-custody procedures detailed in the Chain-of-Custody SOP in Appendix C of this FSP and in the QAPP. Chain-of-Custody procedures provide documentation of the handling of each sample and are implemented so that a record of sample collection, transfer of samples between personnel, sample shipping, and receipt by the laboratory that will analyze the sample is maintained. A sample Chain-of-Custody Record is available in the QAPP.

6.0 NONCONFORMANCE/CORRECTIVE ACTIONS

Any USACE project team member may initiate the field corrective action process. This process consists of identifying a problem, acting to eliminate the problem, documenting the corrective action, monitoring the effectiveness of the corrective action, and verifying that the problem has been eliminated. Although not all inclusive, examples of corrective actions for field measurements may include the following:

- Repetition of a measurement to check the error;
- Check for all proper adjustments for ambient conditions such as temperature;
- Check of batteries;
- Calibration checks;
- Recalibration;
- Replace instruments or measurement devices;
- Stop work (if necessary);
- Revisions to information submitted on chain-of-custody forms; and
- Amendment of sampling procedures or Work Plans.

Technical staff and project personnel will be responsible for reporting all technical or QA nonconformances or suspected deficiencies of any activity or issued document by reporting the situation to the PM and the QA/QC Coordinator on a Nonconformance Report (NCR). The QA/QC Coordinator will be responsible for assessing the suspected deficiency based on the potential for the situation to impact the quality of the data.

The Field Team Leader, or a designee, will be responsible for correcting equipment malfunctions throughout the field sampling effort and resolving situations in the field that may result in nonconformance or noncompliance with the QAPP. All corrective measures will be immediately documented in the field logbook, and sample alteration forms will be completed.

Additional corrective actions, if necessary, will be determined by the Project Manager. The Project Manager has the authority to initiate stop work orders, if necessary, and is responsible for ensuring that a corrective action for a nonconformance is initiated.

If appropriate, the Project Manager will be responsible for ensuring that no additional work that is dependent on the nonconforming activity is performed until the corrective action(s) is completed.

Laboratory

All laboratories are required to comply with the standard operating procedures previously submitted to the Project Chemist. The laboratory project managers will be responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP. All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data.

The Project Chemist will be notified immediately if any QC sample exceeds the project-specified control limits. The analyst will identify and correct the anomaly before continuing with the sample analysis. The Laboratory Project Manager will document the corrective action taken in a memorandum submitted to the Project Chemist within five days of the initial notification. A narrative describing the anomaly, the steps taken to identify and correct it, and the treatment of the relevant sample batch (i.e., recalculation, reanalysis, re-extraction) will be submitted with the data package using a corrective action form. Copies of each laboratory's corrective action forms are found in their Quality Assurance Manuals.

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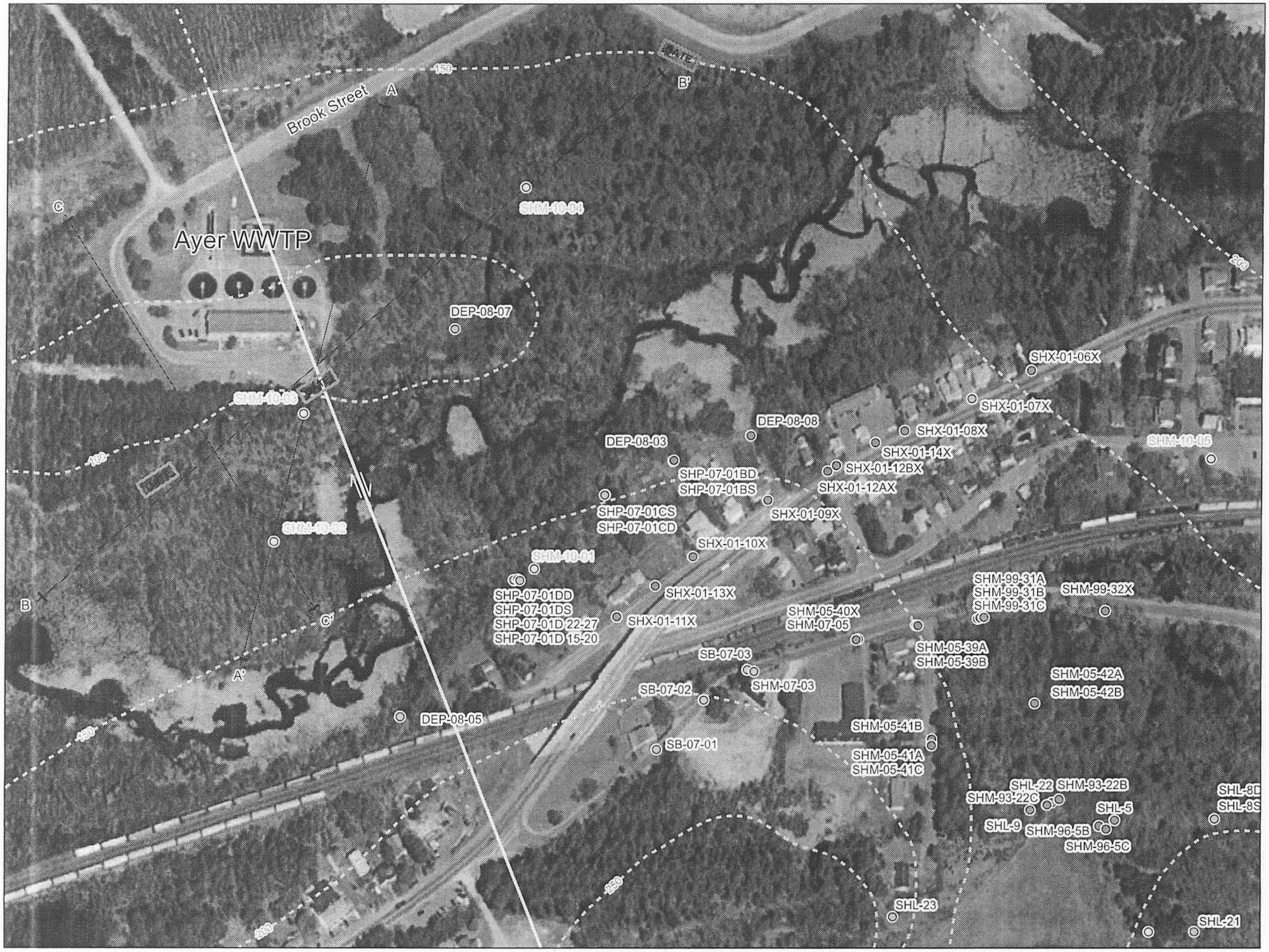
Figures



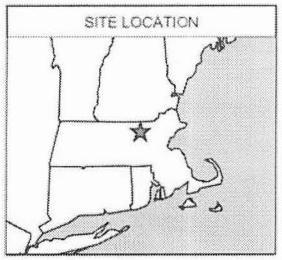
Proposed Investigations Near the Impacted Area

Devens
Ayer, Massachusetts

LEGEND

○	Dissolved Arsenic < MCL
●	Dissolved Arsenic > MCL
○	Proposed Boring / Well Location
- - -	Interpreted Bedrock Elevation (AMSL)
	Fault Line
+—+	Proposed Geophysical Survey Line
GATE	Fence Gate

SITE LOCATION



NOTES & SOURCES

Aerial Imagery: 1:5,000 Color Digital Ortho Images, Microsoft Bing Maps, 2008.

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Feet

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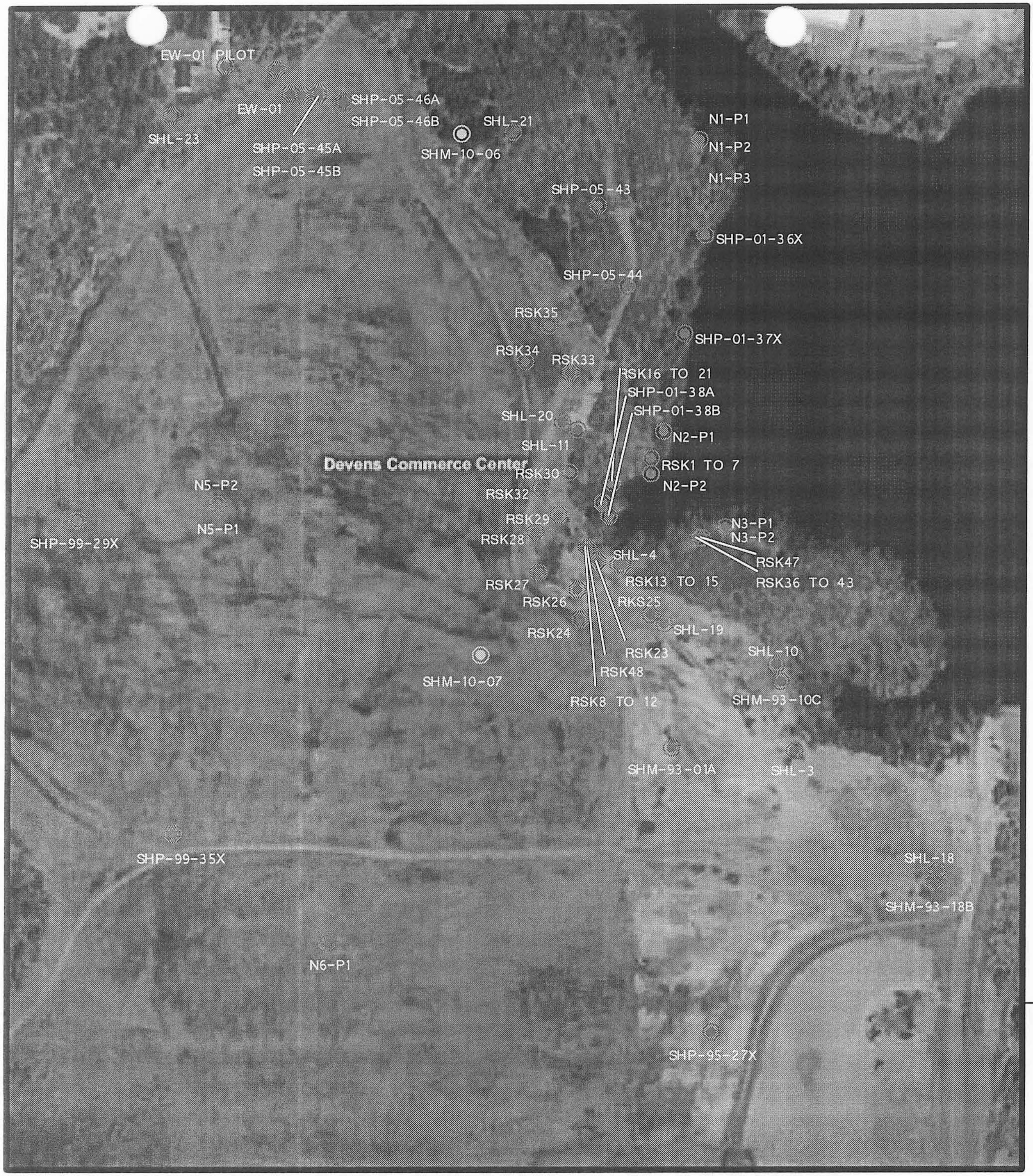
SOVEREIGN CONSULTING INC.
905B S. Main Street Unit 202 Mansfield, MA 02048
Tel: 508-339-3200 Fax: 508-339-3248
www.sovcon.com

FIGURE
1



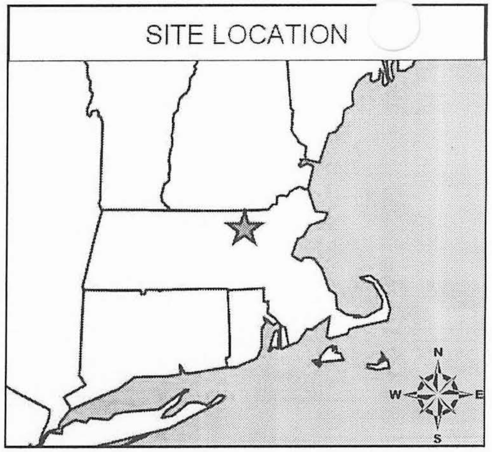

SITE LOCATION

Figure 2 - Proposed Well Locations
Shepley Hill Landfill - Fort Devens
Ayer, MA

Notes:

Base Map Source:
2009 Microsoft Corp.
Bing Maps Aerial Imagery

Legend

- ◉ **Existing Wells and Borings**
- ○ **Proposed Boring/Well Locations**

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905B S. Main Street Unit 202 Mansfield, MA 02048
Tel: 508-339-3200 Fax: 508-339-3248
www.sovcon.com

Tables

Table 1-1
Proposed Rationale for Selection of Sampling Locations
Supplemental Investigation Workplan Addendum
Shepley's Hill Landfill

AREA OF INTEREST	TECHNICAL AND DATA QUALITY OBJECTIVE(S)	TECHNICAL APPROACH	DATA EVALUATION	OUTCOME
1. Red Cove area.	• Extend monitoring network west beyond the area immediately adjacent to Red Cove. • Provide data on bedrock elevation. • Assess hydraulic gradients and flow patterns. • Determine arsenic concentrations (DL ≤ 10ug/l) and ORP values in groundwater in the probable source area of arsenic discharging to Red Cove. • Provide input for groundwater model	• Profiling arsenic concentrations in groundwater to bedrock. • Core sampling and detailed analysis of stratigraphy. • Collect samples for geotechnical analysis. • One temporary monitoring well constructed to allow for sampling and water level monitoring. • Collect water levels from new and existing wells.	• Update relevant interpretive maps and cross-sections. • Compare GW flow direction to predictions made with recalibrated groundwater model.	• Provide data to validate or refine prediction made with the groundwater model with respect to flow patterns and potential sources of Arsenic.
2. Area due east of the extraction wells.	• Explicitly define the eastern extent of the main northward trending lobe of the Arsenic plume. • Determine arsenic concentrations (DL ≤ 10ug/l) in the area at the margin of the extraction well influence. • Define SHL arsenic plume boundary (defined as arsenic ≈ 100pbb and negative ORP). • Provide input for groundwater model	• Profiling arsenic concentrations in groundwater to bedrock. • One temporary monitoring well constructed to allow for sampling and water level monitoring.	• Comparison to predicted capture zone for the extraction wells at current operational rates.	• Improved plume delineation to support performance assessment of Contingency Remedy with respect to containment of the primary Arsenic source.
3. Ayer residential area along W. Main St.	• Provide a bounding monitoring well to constrain the eastward extent of the north trending SHL arsenic plume lobe. • Determine arsenic concentrations (DL ≤ 10ug/l) and ORP values in groundwater in the region currently under-characterized. • Define SHL arsenic plume boundary (defined as arsenic ≈ 100pbb and negative ORP). • Provide input for groundwater model. • Acquire sufficient and appropriate plume information to develop institutional controls for groundwater use.	• Profiling arsenic concentrations in groundwater to bedrock. • Two temporary monitoring well constructed to allow for sampling and water level monitoring.	• Update relevant interpretive maps and cross-sections.	• Provide the basis for defining the extent of institutional controls required to manage risk to residents for exposure to impacted groundwater.
4. Nonacoicus Brook area	• Constrain the western plume extent by completing the 'necklace' of deep monitoring wells, established by DEP-08-03, DEP-08-05 and DEP-08-07, encircling the presumed discharge area. • Assess hydraulic gradients and flow patterns. • Determine arsenic concentrations (DL ≤ 10ug/l) and ORP values in groundwater. • Define SHL arsenic plume boundary (defined as arsenic ≈ 100pbb and negative ORP). • Provide input for groundwater model. • Determine if Nonacoicus Brook and associated wetland is a hydraulic barrier.	• Characterizebedrock elevations using geophysical techniques. • Profiling arsenic concentrations in groundwater to bedrock. • Six temporary monitoring wells constructed to allow for sampling and water level monitoring.	• Integrate bedrock elevations from borings and geophysical studies with existing information to select optimum well locations. • Update groundwater flow model and evaluate changes to predicted flow patterns and discharge locations.	• Improved plume delineation to support assessment of potential for Arsenic to migrate westward toward the MacPherson water supply well.

Locations for proposed boring\wells and geophysical transects are shown on Figures 1 and 2.

Table 4-1
Boring/Well Locations and Anticipated Depths
Supplemental Investigation Workplan Addendum
Shepley's Hill Landfill

	Latitude	Longitude	Anticipated Depth (ft bgs)	Anticipated Saturated Thickness (ft)
North Plume - Nonacoicus Brook Area				
SHM-10-01	42.55930	71.60124	80	60
SHM-10-02	42.55885	71.60315	90	85
SHM-10-03	42.55971	71.60297	115	100
SHM-10-04	42.55897	71.60413	85	75
SHM-10-05	42.55935	71.59561	80	60
SHM-10-08	42.55846	71.60323	55	45
SHM-10-09	42.55860	71.60136	70	50
SHM-10-10	42.55947	71.60001	65	55
North Plume - Capture Area				
SHM-10-06	42.55949	71.59616	110	75
East Plume				
SHM-10-07	42.55390	71.59598	80	40

Notes:

1) Locations are approximate and may be adjusted in the field based on observed conditions.
2) Northings and Eastings reference to NAD83 Massachusetts Mainland coordinate system, in feet.
3) ft bgs = feet below ground surface

Table [illegible]-2
Requirements for Sample Containers, Preservation, Volume, and Holding Time
Supplemental Investigation Workplan Draft Addendum
Shepley's Hill Landfill

Name	Analytical Method Reference	Container Type^1	Preservative	Sample Container Size^2	Maximum Holding Time
Water Samples					
Metals (Groundwater)	6020A	P	Nitric acid to pH <2	500 mL	180 days until analysis
Metals (Soil)	6010B,7470A	G	4°C	8 oz container	180 days until analysis
Anions (chloride, nitrate, sulfate)	300.0	P	4°C	250 mL	48 hours until analysis for nitrate, 28 days until analysis for chloride and sulfate
Ammonia	350.1	P	Sulfuric acid to pH <2, 4°C	500 mL	28 days until analysis
Nitrite	SM4500-NO_2B	P	4°C	250 mL	48 hours until analysis
Sulfide	SM4500-S AD, 376.2	P or G	Zinc acetate and NaOH, no headspace	250 mL	7 days until analysis
Alkalinity	SM2320B	P	4°C, no headspace	250 mL	14 days until analysis
Total Dissolved Solids (TDS)	SM2540C	P	4°C	1 liter	7 days until analysis
Total Suspended Solids (TSS)	SM2540D	P	4°C	1 liter	7 days until analysis
Total Organic Carbon (TOC) (Groundwater)	SM5310C, 415.1	G	Sulfuric acid or HCl to pH <2	2 – 40 mL vials	28 days until analysis
Total Organic Carbon (TOC) (Soil)	9060(M)	G	4°C	4 oz container	14 days until analysis
Chemical Oxygen Demand (COD)	SM5220D, 410.4	P	Sulfuric acid to pH <2, 4°C	250 mL	28 days until analysis
Hardness	SM2340B	P	Nitric acid to pH <2; 4°C	Combined with metals analysis	180 days until analysis

[1] G = Glass, amber; P = Polyethylene

[2] In some cases, multiple sample analyses can be combined into one sample container.

Table 4-3
Groundwater and Soil Sampling Summary
Supplemental Investigation Workplan Draft Addendum
Shepley's Hill Landfill

	Number of Borings/Wells	Number of Samples[5]	Analytical Parameters								
			Water Quality Parameters[1] (Field)	Water Quality Parameters[2] (Lab)	Arsenic	ROD Metals[3]		Limited Metals[4]		Soil Sampling	
					(Field Test Kits)	Total	Dissolved	Total	Dissolved	TAL Metals& TOC[6]	Visual Characteization
Groundwater											
Vertical Profiling											
North Plume/Nonocoicus Area	8	62	x		x			x			x
North Plume/ Capture Area	1	7	x		x			x			x
East Plume	1	4	x		x			x		x	x
New Wells											
North Plume/Nonocoicus Area	8	16	x	x		x	x				
North Plume/ Capture Area	1	2	x	x		x	x				
East Plume	1	2	x	x		x	x				

Notes:

[1] Field Water Quality Parameters consist of pH, temperature, conductivity, dissolved oxygen, redox potential and turbidity

[2] Water Quality (WQ) suite includes: anions (chloride, nitrate, sulfate) by Method 300.0; ammonia by Method 350.1; nitrite by SM4500N02B; sulfide by SM4500S2AD/376.2; alkalinity by SM2320B; total dissolved solids by SM2540C; total suspended solids by SM2540D; total organic carbon by SM5310C/415.1; chemical oxygen demand by SM5220D/410.4; and hardness by SM2340B.

[3] ROD Metals include metals for which groundwater cleanup levels were defined in the Record of Decision (i.e., Aluminum, Arsenic, Chromium, Iron, Lead, Manganese, Nickel, and Sodium by EPA Method 6010B)

[4] Limited metals includes Arsenic, Manganese, Iron, calcium, magnesium, potassium, sodium, chloride, sulfate, nitrate, nitrite, alkalinity, ammonia, and chemical oxygen demand

[5] Includes one sample/10'

[6] TAL -Target Analyte List Metals and TOC - Total Organic Carbon

Table 4-4
Field and Quality Control Sample Summary Table
Supplemental Investigation Workplan Addendum
Shepley's Hill Landfill

Medium/ Matrix	Analytical Parameter	Conc. Level	Analytical Method	No. of Sampling Locations	No. of Field Duplicate Pairs	Inorganic		No. of Equip. Blanks	No. of QA Split Samples[1]	Total No. of Samples to Lab [2]
						No. of Duplicates	No. of MS			
CHEMICAL ANALYSES										
Groundwater - New Monitoring Wells										
GW	Total Metals [3] ROD list	Low	6020A	20	2	1	1	Approx 6	None Proposed	Approx 30
GW	Dissolved Metals [3] ROD list	Low	6020A/	20	2	1	1	Approx 6	None Proposed	Approx 30
GW	Water Quality	Low	WQ Suite [4]	20	2	1	1[5]	Approx 6	None Proposed	Approx 30
Groundwater Profiles										
GW	Total Metals [3] Profile list	Low	6020A	Approx 62	7	3	3	Approx 25	None Proposed	Approx 100
Soil Sampling										
Soil	TAL Metals [6]	Low	6010B	Approx 5	1	1	1	NA	None Proposed	Approx 9
Soil	TOC [7]	Low	9060M	Approx 5	1	1	1	NA	None Proposed	Approx 9

Notes:

GW = Groundwater
MS = Matrix spike
MSD = Matrix spike duplicate

[1] Quality Assurance (QA) split samples (samples sent to a government designated independent testing laboratory) will be collected if directed by USACE-NAE, USEPA, or MassDEP.
[2] Total number of samples to lab consists of: number of sampling locations + number of field duplicate pairs + number of MS/MSD + number of equipment blanks.
[3] Metals lists include:
Record of Decision (ROD) metals = aluminum, arsenic, chromium, iron, lead, manganese, nickel, and sodium
Profile metals = arsenic, iron, and manganese
[4] Water Quality (WQ) suite includes: anions (chloride, nitrate, sulfate) by Method 300.0; ammonia by Method 350.1; nitrite by SM4500N0_2B; sulfide by SM4500S^{2}AD/376.2; ,alkalinity by SM2320B; total dissolved solids by SM2540C; total suspended solids by SM2540D; total organic carbon by SM5310C/415.1; chemical oxygen demand by SM5220D/410.4; and hardness by SM2340B.
[5] Matrix spike samples are applicable to all analyses except sulfide, TDS and TSS,
[6] Total Analyte List Metal – TAL Metals
[7] Total Organic Carbon – TOC

APPENDIX A

Landfill Cap Penetration Materials and Procedures Specifications

SECTION

CAP PENETRATION MATERIALS AND PROCEDURES SPECIFICATIONS

PART 1 - GENERAL

1.01 WORK INCLUDED

A. The work under this Section includes the furnishing of all labor, equipment and materials, and performing all operations in connection with installation of borings and wells within the Central Landfill Superfund Site relative to work associated with the Hot Spot Exploration that will penetrate the existing landfill cap.

B. The work under this Section shall be performed in accordance with all pertinent health and safety regulations with special emphasis on the hazards associated with work on a landfill.

C. The Contractor shall furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the installation and repair of 60 mil HDPE membranes as specified herein, as shown on the Detail.

D. The Contractor shall be prepared to install the geomembranes in conjunction with earthworks and other components of the liner system.

E. Furnishing and installation of all single wall HDPE pipe and appurtenances within around cap penetrations.

F. This specification does not include any description of the material or placement procedures for the Volclay Grout that will be used to fill the annular space between the landfill material and the well casing. Volclay grout and placement procedures are included in the work plan submitted under separate cover from this specification.

1.02 RELATED WORK

A. Central Landfill Hot Spot Explorations Work Plan

1.03 REFERENCES

A. HDPE Geomembrane Liner

1.	ASTM D 570:	Standard Test Method for Water Absorption of Plastics.
2.	ASTM D 638:	Standard Test Method for Tensile Properties of Plastics.

3. ASTM D 746: Standard Test Method for Brittleness, Temperature of Plastics and Elastomers by Impact.

4. ASTM D 792: Standard Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement.

5. ASTM D 882: Standard Test Methods for Tensile Properties of Thin Plastic Sheeting.

6. ASTM D 1004: Standard Test Method of Initial Tear Resistance of Plastic Film and Sheeting.

7. ASTM D 1204: Standard Plastics Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature

8. ASTM D 1238: Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer

9. ASTM D 1505: Standard Test Methods for Density of Plastics by Density Gradient Techniques

10. ASTM D 1593: Standard Specification for Nonrigid Vinyl Chloride Plastic Sheeting.

11. ASTM D 5199 Standard specification for testing of thickness for polyethylene sheeting.

12. ASTM D 1603: Standard Test Method for Carbon Black content.

13. NCL D 5397 Standard Test Method for Environmental Stress Cracking of Ethylene Plastics.

14. ASTM D 5596: Recommended Practice for Microscopical (Carbon Black) in Plastic Compounds.

15. ASTM D 4833: Standard Test Methods for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Geomembranes

16. ASTM D 4833: Federal Test Method Standard for Puncture Resistance and Elongation Test.

B. Bentonite Clay

1. ASTM D 4643 - Determination of Water (Moisture) Content of Soil by Microwave Oven Method

2.. ASTM D 5084 - Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter

3. ASTM D 5993- Test Method for Measuring the Bentonite Mass per Unit Area

C. HDPE PIPE (ASTM)

1.	ASTM D-638	Tensile Properties
2.	ASTM D-1238	Flow Rates of Thermal Plastics
3.	ASTM F-1248	Environmental Stress Crack Resistance (ESCR)
4.	ASTM D-1505	Density of Plastics by Gradient Technique
5.	ASTM D-2837	Hydrostatic Design Basis for Thermal Plastics
6.	ASTM D-3261	Butt Heat Fusion for Polyethylene (PE)
7.	ASTM D-3350	Specs for Polyethylene Pipe and Fittings
8.	ASTM F-714	Polyethylene Pipe (SDR-PR)
9.	ASTM D-2321	Underground Installation of Flexible Thermoplastic Sewer Pipe

1.04 QUALIFICATIONS

A. Manufacturer: Company specializing in the manufacturing of products specified in this section with a documented minimum of three year's experience.

B. Installer: Company specializing in applying the work of this Section with a documented minimum of 3 years experience. The Company shall provide satisfactory evidence demonstrating the approved and accepted installation of a minimum 50 acres of FML or comparable geosynthetic systems on a minimum of five different projects.

C. Additionally, the Liner Contractor must also have experience in the successful installation of FML materials for completing seams around liner penetrations and in forming membrane liners and other appurtenances.

D. The Geosynthetic Clay Liner (GCL) Manufacturer must have produced at least 10 million square feet of GCL, with at least 8 million square feet installed.

E. The GCL Installer must have either installed at least 1 million square feet of GCL, or must provide to the Engineer satisfactory evidence, through similar experience in the installation of other types of geosynthetics, that the GCL will be installed in a competent, professional manner.

F. The Contractor shall furnish to the Engineer manufacturer's notarized certificates of conformance stating that all materials to be furnished under this section of the specifications conform with all specification requirements, and each shipment of dual-wall pipe, valves and accessories meet all requirements of the specifications.

G. The pipe system supplier shall have a minimum of at least five- (5) years experience in the fabrication of HDPE pipe systems and materials as specified herein.

1.05 QUALITY CONTROL

A. An individual experienced in the installation of HDPE Geomembrane liners shall be onsite during the initial startup of exploration installation and membrane repair work. The designated individual shall be responsible for assuring that the Contractor is instructed in the proper method to prepare, install, and test the HDPE material repairs according to this Specification and the Drawings.

B. The appointment shall be subject to approval by the Engineer. The Engineer shall provide inspection services, described in this Specification, on behalf of the Owner.

1.06 WARRANTY

A. The manufacturer shall provide a ten (10) year warranty to the Owner against manufacturing defects. The warranty shall include defective areas where the product is found to be not in compliance with the requirements of Part 2. The warranty shall include replacement of the HDPE membrane with new material.

1.07 SUBMITTALS

A. Submittals

1. Material Data - Submit complete manufacturer's specifications, descriptive drawings, and literature for the geomembrane, including the product identification and supplier of the polymer resin and recommended method for handling and storage of all materials prior to installation.

2. Submit for review a complete description of the geomembrane manufacturer's and the installer's formal Quality Assurance/Quality Control programs for manufacturing, fabricating, handling, installing, and testing. The description shall include, but not be limited to, polymer resin supplier and product identification, acceptance testing, production testing, installation testing, documentation of changes, alterations, repairs, retests, and acceptance. The document shall include a complete description of seaming by extrusion welding and double fusion welding.

3. Production Dates - Submit statement of production dates for the resin and the geomembrane for this work.

4. Concrete Seal Mix Design- Submit a concrete mix design at least seven days prior to start of work for review by the engineer. The proposed

concrete mix design shall meet the minimum requirements described within section 2.04 of this specification.

B. The Contractor shall submit the following:

1. Geomembrane Fabricator pre-delivery information questionnaire completed in full by the Fabricator.

2. Copies of quality control certificates

C. Prior to transporting any geomembrane to the site, the Contractor shall submit to the Engineer in writing the following documentation of the resin used to manufacture the geomembranes:

1. Copies of quality control certificates issued by the resin supplier including production dates of the resin used to manufacture the geomembrane for the project.

2. Results of tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project.

3. Certification that no reclaimed polymer is added to the resin during the manufacture of the geomembrane to be used in this project. The use of polymer recycled during the manufacturing process will not exceed 5% by weight of the total polymer weight.

4. Certification that the extrudate to be used is comprised of the same resin as the geomembrane to be used.

D. The Contractor shall submit to the Engineer the following documentation on geomembrane material production prior to the shipment of the geomembrane rolls.

1. Manufacturing certificates for each shift's production of geomembrane, signed by responsible parties employed by the Manufacturer (such as the production manager), and notarized.

2. The quality control certificate shall include:

   a. Roll numbers, lot or batch numbers, and identification

   b. Sampling procedures; and

   c. Results of quality control tests, including descriptions of the test methods used.

E. Prior to commencement of the installation, the Contractor shall submit to the Engineer:

1. Geomembrane Installer pre-installation information questionnaire completed in full by the Installer.

2. A drawing showing the installation and repair detail, as well as any variance or additional details which deviate from the Engineering drawings. Installation drawings shall show geomembrane layout with proposed size, number, position, and sequence of material placement and shall indicate the location of field seams.

3. Installation schedule.

4. A list of personnel who shall perform field seaming operations and details of their prior experience along with a resume. A certification for each welder should also be included that provides the performance records that include linear feet of weld completed, number of samples tested and weld test failure rate, and that the requirements of Section 1.05 have been met.

5. Certification of Subsurface - Prior to liner installation, submit certification from the Geomembrane Contractor that the surface on which the geomembrane shall be placed is acceptable.

F. During the installation, the Contractor shall be responsible for the timely submission to the Engineer of:

1. Quality control documentation.

2. Subgrade acceptance certificates, signed by the installer, daily for each area to be covered by the geomembrane.

G. Upon completion of the installation, the Contractor shall be responsible for the submission to the Owner of:

1. Geomembrane installation certification.

2. The Contractor will provide a written warranty guaranteeing the materials of all products supplied on a pro-rated basis as a part for this work for a minimum period of twenty years following acceptance by the Owner. Said warranty will apply to normal use and service by the Rhode Island Resource Recovery Corporation (Owner) and will specifically exclude mechanical abuse or puncture by machinery, equipment or people,

exposure of the liner to harmful chemicals or catastrophe due to earthquake, flood or tornado. Such written warranty shall provide for the total and complete repair or replacement of the defect or defective area of lining material upon written notification and demonstration by the Owner of the specific non-conformance due to the lining material itself or its installation with respect to the project specifications. Such defects of non-conformance will be repaired or replaced within thirty days of written notification at no cost to the Owner provided that the portion of the area in question has been made available to the Contractor and that such areas have been cleared of all liquids, dirt, sand or gravel.

3. Record Drawings - Submit reproducible drawings for record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and sample taken from the installed geomembrane for testing.

4. Quality Control Record - Submit copies of all material and seam test results. Each test shall be identified by date of sample, date of test, sample location, name of individual who performed the test, and standard test method.

5. Weld Test Summary Report - Submit copies of report showing normal distribution of all test results, and individual test results identifying the high, low, and average of the five coupon samples in each test.

H. A Certificate of Calibration less than 12 months old shall be submitted for the field tensiometer referenced in Part 3.05.H-2 of this Section.

I. The Contractor shall submit to the Engineer six copies of a statement of materials identifying the brand name of the HDPE material used in the piping and its physical and chemical characteristics, obtained from the manufacturer.

J. Manufacturer's test results in accordance with paragraph 2.01 C for the bentonite clay material.

1.08 PRODUCT DELIVERY STORAGE AND HANDLING

A. Transportation of the material to the site and all handling on site shall be the responsibility of the Contractor.

B. The manufacturer's representative shall have the right to verify the following:

1. Proper handling equipment exists on site which does not pose any danger to installation personnel or risk of damage to the liner material itself.

2. Contractor's personnel are knowledgeable in the methods for handling the liner with care.

C. Upon delivery to the site, the Contractor and the Engineer shall have the right to conduct a surface inspection of all materials for apparent defects and damage resulting from shipment. This inspection shall be conducted without unrolling the liner materials. The Engineer shall indicate to the Contractor the following:

1. Materials which should be rejected due to irreparable damage.

2. Materials which should be re-inspected upon placement due to a suspected repairable flaw.

D. The storage of materials shall be the responsibility of the Contractor. The Engineer shall have the right to verify the following to insure proper storage:

1. HDPE membrane does not have any major rips or tears.

2. Products are stored either in closed box trailers or on dry ground (with perimeter drainage) and properly covered by a tarpaulin or similar protective moisture and sunlight barrier.

E. HDPE material damaged or otherwise determined to be unsuitable by the Engineer following initial storage shall be replaced by the Contractor at his expense.

1.09 HDPE MEMBRANE DEFINITIONS

A. Batch - A quantity of resin, usually the capacity of one rail car, used in the fabrication of high density polyethylene (HDPE) geomembrane rolls. The finished rolls are identified by a roll number corresponding to the resin batch used.

B. Bridging - Condition existing when the geomembrane is not in contact with the underlying material.

C. Extrudate - HDPE material produced in the form of a rod used by the Geomembrane Contractor to extrusion weld (repair) panels/patches of geomembrane together.

D. Geomembrane - Very low permeability synthetic flexible membrane liner (FML) barrier used to minimize fluid migration.

E. Contractor - The party responsible for manufacturing, shipping, field handling, transporting, storing, deploying, seaming, temporary restraining (against wind), and installing the geomembrane.

F. Geomembrane Subsurface - Material surface upon which geomembrane will be placed.

G. Quality Assurance Laboratory (Third Party laboratory) - Party, independent form the Owner, Manufacturer, and Geomembrane Contractor, responsible for conducting laboratory tests on samples of geomembrane obtained at the Site.

PART 2 - PRODUCTS

2.01 HDPE MEMBRANE

A. RESIN

1. The geomembrane shall be manufactured from new, first-quality polyethylene resin, and shall be designed and manufactured specifically for use in geomembranes. Reclaimed polymer shall not be added to the resin; however, the use of polymer recycled during the manufacturing process shall be permitted if performed with appropriate deadlines and if the recycled polymer does not exceed 5% by weight of the total polymer weight.

2. The resin material shall be tested at a frequency of one test per resin batch and shall meet the following high density polyethylene (HDPE) specified in Table 02771-1.

Table 02771-1

Resin Properties

Test	Test Method	Units	Requirements
Specific Gravity	ASTM D 1505 Condition A	g/cc	≥ .932
Melt Index	ASTM D 1238 Condition E	g/10 min.	≤1.0
Carbon Black Content	ASTM D 1603	%	2-3

B. GEOMEMBRANE PROPERTIES

1. The Geomembrane Manufacturer shall furnish geomembranes having properties that comply with the required property values shown in Tables 02771-2 through 02771-5.

Table 02771-4
Geomembrane Properties

Property	Test Method	Frequency (See Notes)	60 mil Smooth	60 mil Textured
Sheet Thickness, mils	Smooth – ASTM D5199	(1)	60	60
Density (g/cc)	ASTM D 1505-A	(4)	0.94	0.94
Tensile Properties (Typical) 1. Tensile Strength at Yield (ppi) 2. Tensile Strength at Break (ppi) 3. Elongation at Yield (%) 4. Elongation at Break (%)	ASTM D638 Type IV	(2)	 ≥ 138 ≥ 240 ≥ 13 ≥ 600	 ≥ 126 ≥ 100 ≥ 13 ≥ 200
Tear Resistance Initiation (lbs)	ASTM D 1004	(3)	≥ 42	≥ 42
Permeability (cm/sec)	ASTM E 96		2.3×10^{-14}	2.3×10^{-14}
Dimensional Stability % Change Each Direction	ASTM D 1204	(3)	± 1.0	± 1.0

Table 02771-5
Geomembrane Properties

Property	Test Method	Frequency (See Notes)	60 mil Smooth	60 mil Textured
Environmental Stress Crack Resistance (hrs)	NCR D 5397	(3)	≥ 2,000	≥ 2,000
Puncture Resistance (lbs)	ASTM D 4833	(5)	≥ 90	≥ 75
Carbon Black Content (%)	ASTM D 1603	(4)	±2.0	±2.0
Carbon Black Dispersion	ASTM D 5596	(4)	A-1	A-1

NOTES:

(1) Each roll
(2) 1 per 1,000 feet of manufactured sheet
(3) 1 per 3,000 feet of manufactured sheet
(4) 2 per resin batch number
(5) 1 per 2,000 feet of manufactured sheet

2. In addition to the property values listed in Table 02771-2, the geomembranes shall:

a. Consist of new, first-quality products designed and manufactured for use as a landfill liner, as satisfactory demonstrated by prior use. The geomembrane shall be an unmodified high density polyethylene (HPDE) containing no plasticizers, filler, chemical additives, reclaimed polymers, or extenders. The only other compound elements shall be anti-oxidants and heat stabilizers, of which up to 2 percent total, as required for manufacturing, may be added.

b. Be supplied as a single-ply continuous sheet with no factory seams, in rolls that shall have a minimum width of 15 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest field seams.

c. Not have striations, roughness (except in the case of textured HDPE geomembranes where a roughened surface is characteristic), pinholes, or bubbles on the surface or in the interior;

d. Be produced so as to be free of holes, blisters, modules, undispersed raw materials, or any sign of contamination by foreign matter; and

e. Be manufactured in a single layer (thinner layers shall not be welded together to produce the final required thickness).

C. MANUFACTURING QUALITY CONTROL

1. Resin:

a. The Geomembrane Manufacturer shall sample and test the resin to demonstrate that the resin complies with the Specifications. The Manufacturer shall certify in writing that the resin does meet the Specifications, and shall be held liable for any non-compliance.

b. Any geomembrane manufactured from noncomplying resin shall be rejected.

c. Additional conformance testing, as defined in Part 3.03 of this Section may be required at the Engineers discretion. If the Manufacturer's and the Engineers test results differ, the tests shall be repeated by the Engineer, and the Manufacturer shall be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

d. The Manufacturer shall comply with the submittal requirements of Part 1.06 of this Section.

2. Material

a. The Manufacturer shall continuously monitor geomembranes during the manufacturing process for inclusions, bubbles, or other defects.

b. No geomembrane shall be accepted which exhibits any defects.

c. The Manufacturer shall continuously monitor the geomembrane thickness during the manufacturing process.

d. No geomembrane shall be accepted which fails to meet the specified minimum thickness.

e. The Manufacturer shall sample and test the geomembrane to demonstrate that its properties conform to the values as specified in Tables 02771-2 through 02771-5.

    1. Samples taken from stored rolls shall be taken across the entire width of the roll and shall not include the first outer layer of the roll (about 3 ft.).

    2. Samples taken at the time of manufacturing can be obtained from the end of the roll.

    3. Unless otherwise specified, samples shall be 3 ft long by the roll width. The Manufacturer shall mark the machine direction on the samples with an arrow.

f. Samples not meeting the specified properties shall result in the rejection of the applicable rolls as described in this Section.

g. In the case of a failure, additional testing shall be performed on geomembrane as described in Section 3.3.

h. Additional testing may be performed at the Manufacturer's discretion and expense, to more closely identify the non-complying rolls and/or to quality individual rolls.

i. The Manufacturer shall comply with the submittal requirements of Part 1.07 of this Section.

2.02 BENTONITE CLAY

A. Prior to the installation of any bentonite materials, the Contractor shall provide the Engineer with the following information:

1. Bentonite Producer

   a. Bentonite producers name, production plant, bentonite brand name and specifications

   b. Certifications from the bentonite producer of conformance to the producer's specifications

B. Bentonite Clay is to be composed of contaminant resistant bentonite compatible with municipal solid waste landfill leachate. The contaminant resistance is to be obtained through phosphate or sodium based treatments. The use of polymer enhancement, without phosphate treatment, is not allowed. The bentonite clay may be granular or chipped clay at the discretion of the contractor.

C. The manufacturer shall conduct quality control testing for the following properties and at the indicated testing frequency; all values are in terms of Minimum Average Clay Values:

Free Swell	1/50 tons bentonite
Fluid Loss	1/50 tons bentonite

The GCL shall demonstrate the following values:

ITEM	CHARACTERISTICS
Clay Component*	Granular Sodium Bentonite
Free Swell ASTM D 5890	22 mL/2g (Min.)
Hydraulic Conductivity *1 ASTM D5084	5.0 x 10^{-9} cm./sec. (Max.)
Fluid Loss ASTM D 5891	18 ml max.

*1 Testing with deaired or distilled water at 80 psi cell pressure, 77 psi headwater pressure and 75 psi tailwater pressure

D. Prior to shipment, the manufacturer shall provide the Engineer with a quality control certificate for each lot of material to be shipped. The quality control certificate shall be signed by a responsible party employed by the manufacturer. The quality control certificates shall include:

1. Product Identification
2. Lot Number
3. Manufacturer's test results.

2.03 CONCRETE SEAL

A. Concrete seal material shall be as manufactured shall consist of cast-in-place concrete with a minimum compressive strength of 3000 psi. The concrete shall be a standard ¾-inch aggregate mix with an absolute water to cement ratio of .58 (as specified by ACI 318/318R-44 Table 5.4, 1992 for 3000 psi concrete).

2.04 HDPE PIPE

The pipe used around the cap penetration will be single wall pipe and shall be high density, extra high molecule weight polyethylene pipe. The pipe shall conform to ASTM D-3350 with a minimum cell classification value of 345434C. The pipe shall have a minimum SDR rating of 32.5 and shall be manufactured at the diameters specified on the Cap Penetration Detail. The pipe shall be made from the same polyethylene resin base that meets this specification. The locking cap shall be compatible with the pipe manufacture and shall form an air tight seal with the pipe.

A. Physical Properties:

Test Method	Nominal Value
1. Density – ASTM D-1505	0.955 g/cm^3
2. Melt Index – ASTM D-1238	0.11 gm/10 min
3. Flex Modulus – ASTM D-790	125,000 psi
4. Tensile Strength at Yield – ASTM D-638	3500 psi
5. ESCR-Environmental Stress Crack Resistance – ASTM D-1693	5000 F, hours
6. Hydrostatic Design Basis – ASTM D-2837	1600 psi
7. ESCR – Compressed Ring – ASTM F-1248	--
8. Cell Classification – ASTM D-3350; PE 345434C	--

B. Acceptable Manufacturers:

1. Plastic Fusion Fabrications, Inc
2. Plexco
3. Fluid Controls, Inc.
4. Other approved equal by Engineer

PART 3 - EXECUTION

3.01 MATERIAL DELIVERY AND STORAGE

A. HDPE liner material shall be delivered to the site and unloaded with equipment that can safely handle the material without causing damage. The material shall be stored on a clean, level, dry surface free of rocks or debris that could damage the material. The material shall be covered to prevent exposure to dust, mud, moisture, and sunlight until such time as the material will be used.

B. Bentonite clay material shall be delivered to the site during dry weather. The material shall be unloaded with equipment that can safely handle the material without causing damage. The material shall be delivered in individual bags not weighing more than 50 pounds and shall be safely stacked on wooden pallets. The pallets shall be stored on clean, level, dry surface away from areas of ponded water or areas that attract stormwater runoff. The material shall be covered and secured with a moisture protective tarpaulin to prevent premature hydration of the material. Bentonite clay that is hydrated prior to use will be removed and replaced with dry material at no cost to the Owner.

C. Piping and accessories delivered on site shall be clean, new and bear the manufacturer's identification and designation. Piping and accessories shall be unloaded and stored on site on pallets in accordance with the manufacturer's recommendations.

D. Piping and accessories damaged en route to the site or during the unloading will be rejected and shall be removed form the site and replaced with new piping meeting these specifications.

3.02 INSPECTIONS

A. The contractor shall be responsible for assuring that the materials have been placed in accordance with these Specifications and the Drawings.

B. The Engineer shall inspect the work of the contractor to verify that the Specifications have been met. The Engineer shall, at a minimum, inspect for: bedding layer condition, logging of identifying labels from materials, adherence to penetration detail, weather conditions, cap penetrations work, overlaps, wrinkles and creases, and damage to material or the adjacent landfill cap.

C. Before covering the cap penetration, the contractor shall obtain the approval of the Engineer. The Engineer's approval will be based on verifying that conditions specified above satisfactorily meet these Specifications. The Contractor shall be responsible for repairing any defect or damaged material at his own expense, when and if such damage or defect has been caused by the actions of the Contractor, as determined by the Engineer.

D. All piping and accessories shall be carefully inspected by the Contractor for defects before installation and all defective, unsound or damaged materials shall be rejected. The Engineer will make such additional inspection he deems necessary and the Contractor shall furnish all necessary assistance for such inspection.

E. Operating parts shall be operated several times to demonstrate proper operation and adjustment.

3.03 CAP PENETRATION PROCEDURES

A. General

1. Contractor shall verify the locations of all potentially conflicting utilities and structures as indicated on the Drawings prior to commencing cap penetration work.

2. Contractor shall have onsite the shop manufactured 24-inch diameter SDR 32.5 HDPE smooth pipe and 60-mil HDPE membrane boot connection, filter fabric, bentonite, concrete, and 36-inch diameter HDPE pipe with locking cap. Further, the contractor shall have a calibrated and operable landfill gas meter onsite operated by an individual trained in the proper use of such equipment.

3. Contractor shall clear an area at least 72 inches by 72 inches of existing landfill cover soil material using hand excavation techniques (square shovels). No picks, spade shovels, or other sharp pointed instruments shall be used. The cleared membrane area shall be carefully examined for visible damage. Any visible damage, outside the area to be covered by the new membrane boot, shall be tested and repaired (if necessary) prior to any other work being performed in accordance with the testing and welding procedures described herein. The air space immediately above the liner and the worker breathing space shall be monitored for the presence of methane, hydrogen sulfide, and oxygen deficiency prior to any penetration of the liner to establish background levels.

4. Contractor shall cut a 24-inch by 24-inch opening in the existing 60-mil HDPE liner at the location designated. Upon liner penetration, breathing

space monitoring using the landfill gas meter shall be performed at least once every 15 minutes. Should elevated levels of landfill gases or decreased levels of oxygen content be measured at any time during the work, then all work shall be stopped and implementation of health and safety measures to mitigate worker exposure shall commence. Measures such as, but not limited to, donning of level C (full face respirators, protective suits, etc) or level B (self-contained breathing apparatus) PPE should be anticipated.

5. The contractor shall then install the shop manufactured 24-inch HDPE pipe and 60-mil boot centered over the liner penetration. The top of the 24-inch HDPE pipe will be leveled and the 48-inch by 48-inch bottom sheet of the boot will then be extrusion welded to the existing 60-mil HDPE or LLDPE liner in accordance with the HDPE repair procedures described herein. Following extrusion welding, the contractor shall wait for the weld to cool and then perform vacuum testing of the weld in accordance with the testing procedures specified herein.

6. The contractor shall install a minimum 12-inch thick layer of bentonite clay around the 24-inch booted pipe covering all of the exposed HDPE membrane and up to the exposed edges of the cover soil materials (approximately 72 inches by 72 inches and as needed to fill the excavation from sidewall to sidewall). The bentonite shall be tamped in place. The exposed surface shall be free of standing water during installation of the bentonite.

7. The contractor shall then install the 36-inch diameter HDPE pipe over and centered around the 24-inch pipe and embedding the 36-inch pipe approximately 6-inches into the bentonite clay layer. The contractor shall then pour the concrete seal material over the bentonite in a minimum 12-inch thick layer around 36-inch pipe within a 72-inch by 72-inch wide by 12-inch deep form. The thickness of concrete will be varied to meet the elevation of the top of the adjacent cover soils. Forms shall be stripped no sooner than 24 hours after placement of concrete.

8. The contractor will install the air-tight, locking cover over the 36-inch pipe after the concrete has sufficiently cured and the pipe is stable and resistant to lateral movement.

3.04 FIELD SEAMING

A. Cap Penetration Boot and Repair Layout:

In general, boot repair shall be square and oriented at 45 degree angles to the slope of the area to prevent damming of water on top of the membrane. Whenever possible, no welds shall be perpendicular (horizontal) to the slope. No seams shall be located in an area of potential stress concentration.

B. Personnel:

1. All personnel performing seaming operations shall be qualified as indicated in Part 1.05-D of this Section. No seaming shall be performed unless a "master seamer" is present.

C. Weather Conditions for Welding:

1. Unless authorized in writing by the Engineer, welding shall not be attempted at ambient temperatures below thirty-five degrees Fahrenheit (35°F). At ambient temperatures between thirty-five degrees Fahrenheit (35°F) and forty degrees Fahrenheit (40°F), welding shall be allowed if the geomembrane is preheated either by the sun or a hot air device, and if there is no excessive cooling from the wind. At ambient temperatures above forty degrees Fahrenheit (40°F), no preheating shall be required. In all cases, the geomembrane shall be dry and protected from wind damage.

2. If the Contractor wishes to use methods that may allow welding at ambient temperatures below thirty-five degrees Fahrenheit (35°F) or above one hundred ten degrees Fahrenheit (110°F), he shall use a procedure approved by the Engineer. In addition, an addendum to the Contract between the Owner and the Contractor shall be required which shall specifically state that the seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long term damage to the geomembrane.

3. Ambient temperatures shall be measured six inches (6") above the geomembrane surface.

D. Overlapping and Temporary Bonding:

1. Geomembrane material shall be overlapped a minimum of 12-inches for all welds.

2. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane. The temperature of the air at the nozzle of spot welding apparatus shall be controlled such that the geomembrane is not damaged.

E. Weld Preparation:

1. Prior to welding, the area shall be clean and free of grease, moisture, dust dirt, debris of any kind, and other foreign material.

2. If material overlap grinding is required, the process shall be completed according to the Manufacturer's instructions within one hour of the seaming operation and in a manner that does not damage the geomembrane.

F. Welding Process:

1. Approved processes for field welding repairs are extrusion welding only. Welding equipment shall not damage the geomembrane. Only apparatus which the Engineer has specifically approved by make and model shall be used. Proposed alternate processes shall be documented and submitted to the Engineer for approval.

2. Extrusion Equipment and Procedures:

   a. The Contractor shall maintain at least one (1) spare operable seaming apparatus on site.

   b. Extrusion welding apparatus shall be equipped with gauges giving the temperature in the apparatus and at the nozzle.

   c. Prior to beginning a seam, the extruder shall be purged until all heat-degraded extrudate has been removed from the barrel. Whenever the extruder is stopped, the barrel shall be purged of all heat-degraded extrudate.

   d. The geomembrane surface shall be abraded a minimum of one-quarter inch (1/4") beyond the welded area, using a disc grinder, or equivalent, not more than one-half (1/2) hour before extruding seam. The top edges of geomembrane shall be beveled forty-five degrees Fahrenheit (45°F) using a hand held grinder. The ends of all seams, which are more than five (5) minutes old, shall be ground when restarting the weld. Grinding depth shall not exceed ten percent (10%) of the liner thickness.

   e. The Contractor shall provide documentation regarding the extrudate to the Engineer and shall certify that the extrudate is compatible with the Specifications, and consists of the same resins as the geomembrane.

   f. The electric generator shall be placed on rub or scrub sheets. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

G. Trial Welds:

1. Trial welds shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial welds shall be made at the beginning of each welding period, and at least once each five (5) hours, for each seaming apparatus used that day. Trial welds shall be made under the same conditions as actual seams. The trial weld sample shall be at least four feet long by two feet wide (4' long x 2' wide) (after seaming) with the seam centered lengthwise. weld overlap shall be as indicated in Part 3.04-D of this Section.

2. Six (6) specimens, each one inch (1") wide, shall be cut from the trial weld sample by the Contractor. Three specimens shall be tested in shear and three in peel, using a field tensiometer and in accordance with the criteria detailed below. The test specimens shall not fail in the weld. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for welding until the deficiencies are corrected and two (2) consecutive successful trial welds are achieved.

TABLE 02771-6

REQUIRED HDPE GEOMEMBRANE SEAM PROPERTIES

Properties	Qualifier	Specified Units	60 mil (1)
Shear Strength (at yield point)	Minimum	lb/in	120
Peel Test - Adhesion Extrusion Weld	Minimum	lb/in	78

   a. All tests shall exhibit a Film Tearing Bond type of separation in which the geomembrane material tears before the weld. At least five (5) coupons shall be tested by each test method. Five (5) of five(5) coupons shall meet minimum requirements. Coupons from each sample shall be selected alternately for testing (i.e., peel, shear, peel, shear….). For double wedge seam samples, both welds shall be tested in peel. Test results shall be provided verbally within twenty-four (24) hours after receiving samples and within seven (7) days in written form.

3. After completion of the above-described tests, the remaining portion of the trial weld sample will be discarded. Alternatively, the remaining portion of the trial weld can be subjected to destructive testing. If a trial weld sample fails a test, then a destructive test weld sample shall be taken from the welds completed by the extrusion welder during the shift related to the considered trial weld. These samples shall be forwarded to the Engineer and, if they fail the tests, the procedure indicated in Part 3.04-I of this

Section shall apply. The conditions of this paragraph shall be considered as met for a given weld if a destructive seam test sample has already been taken from the considered seam.

H. Nondestructive Seam Continuity Testing:

1. The Contractor shall nondestructively test all field seams over their full length using a vacuum test, air pressure test (for double fusion seams only), or other approved method. No vacuum testing shall be used on double fusion wells unless approved by the Engineer. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The installer shall complete any required repairs in accordance with Part 3.04-I of this Section. The following procedures shall apply to locations where seams cannot be nondestructively tested:

   a. If the seam is accessible to testing equipment prior to final installation, the seam shall be nondestructively tested prior to final installation.

   b. If the seam cannot be tested prior to final installation, the seaming operations shall be observed by the Engineer for uniformity and completeness.

2. Vacuum Testing:

   a. The equipment shall comprise the following :

      1. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and vacuum gauge.

      2. A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections.

      3. A rubber pressure/vacuum hose with fittings and connections.

      4. A bucket and applicator.

      5. A soapy solution.

   b. The following procedures shall be followed:

      1. Energize the vacuum pump and reduce the tank pressure to approximately five pounds per square inch (5 psi) gauge.

2. Wet a strip of geomembrane weld approximately four inches by 48 inches (4" x 48") with the soapy solution.

3. Place the box over the wetted area.

4. Close the bleed valve and open the vacuum valve.

5. Ensure that a leak tight seal is created.

6. Apply a vacuum pressure of approximately five pounds per square inch (5 psi).

7. Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than fifteen (15) seconds.

8. If no bubbles appear after fifteen (15) seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum three-inch (3") overlap, and repeat the process.

9. All areas where soap bubbles appear shall be marked with a marker that will not damage the geomembrane and repaired in accordance with Part 3.04-I of this Section.

I. Defects and Repairs:

1. The geomembrane will be inspected before and after seaming for evidence of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of inspection. The geomembrane surface shall be swept or washed by the Contractor if surface contamination inhibits inspection. The Contractor shall ensure that an inspection of the geomembrane precedes any seaming of that Section.

2. Each suspect location, both in seam and non-seam areas, shall be nondestructively testing using the methods described in Part 3.04-I of this Section, as appropriate. Each location which fails nondestructive testing shall be marked by the Engineer and repaired by the Contractor.

3. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the Engineer shall identify all excessive geomembrane wrinkles. The Contractor shall cut and reseam all wrinkles so identified. The seams thus produced shall be tested like any other seams.

4. Repair Procedures:

   a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Contractor. Several repair procedures exist. The final decision as to the appropriate repair procedure shall be agreed upon between the Engineer and the Contractor. The procedures available include:

      1. Patching, used to repair holes (over three-eight-inch [3/8"] diameter), tears (over two inches [2"] long), undispersed raw materials, and contamination by foreign matter;

      2. Abrading and re-seaming, used to repair small sections of extruded seams (less than twelve inches [12"] long);

      3. Spot seaming, used to repair small tears (less than two inches [2"] long), pinholes, or minor localized flaws and surface damage;

      4. Capping, used to repair long lengths of failed seams;

      5. Removing failed seam lengths and replacing with a strip of new material seamed into place (typically used with long lengths of fusion seams); and

      6. When sufficient overlap exists (one and one-half-inch [1.5"] or more), heat tacking the fusion seam flap and placement of an extrusion weld along the outer edge of the upper geomembrane sheet.

   b. In addition, the following shall be satisfied:

      1. Surfaces of the geomembrane which are to be repaired shall be abraded no more than one (1) hour prior to the repair;

      2. All surfaces must be clean and dry at the time of repair;

      3. All seaming equipment used in repair procedures must be approved;

      4. The repair procedures, materials, and techniques shall be approved in advance, for the specific repair, by the Engineer and Contractor;

5. Geomembrane surfaces to be repaired shall be abraded (extrusion welds only) no more than one-half (1/2) hour prior to the repair;

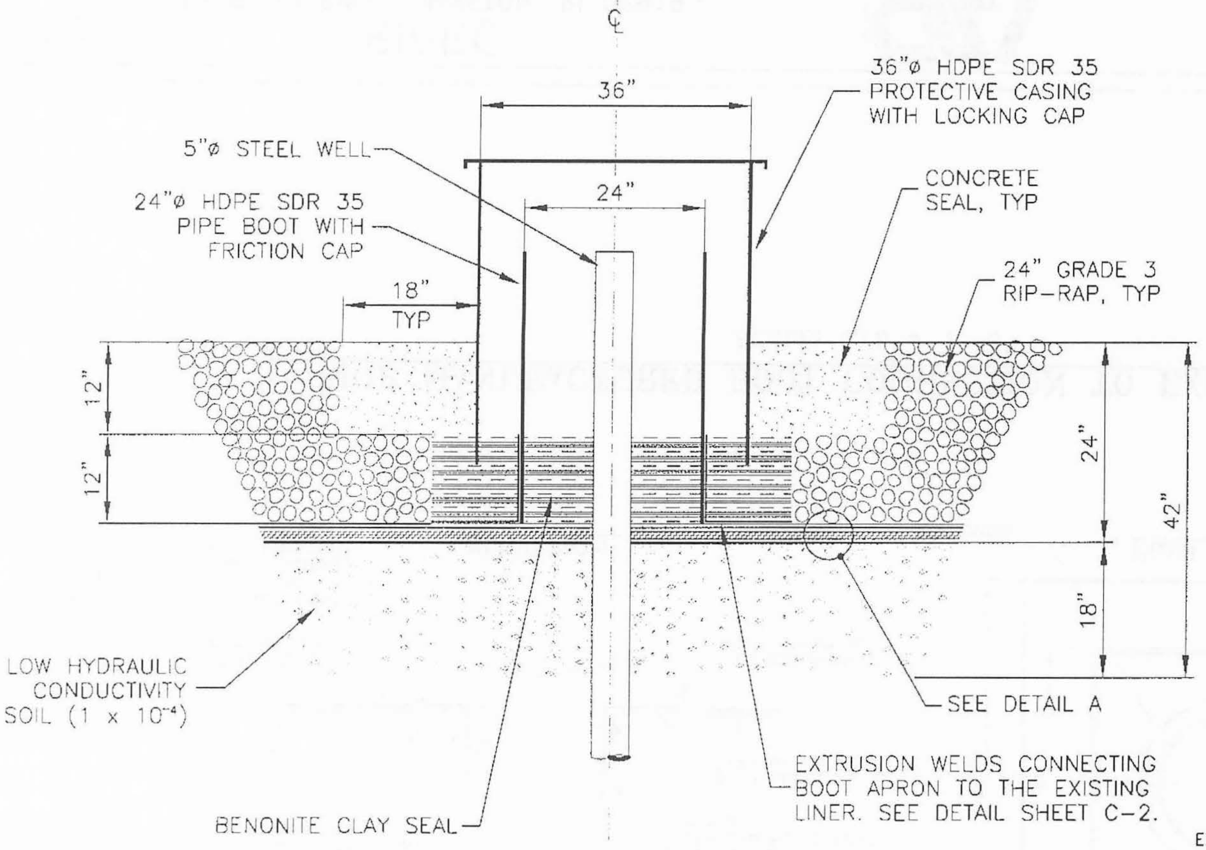
6. Patches or caps shall extend at least six inches (6") beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least three inches (3"); and

7. The geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two (2) sheets.

5. Repair Verification:

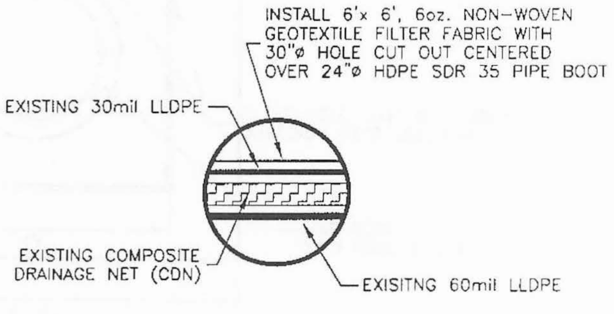
Each repair shall be numbered and logged and shall be nondestructively tested using the methods described in Part 3.05-I of this Section, as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Failed tests will require the repair to be redone and retested until a passing test results.

- END OF SECTION -



CAP PENETRATION AND SEALING DETAIL AT BENCHES

SCALE: 1/2"= 1'-0"



DETAIL A

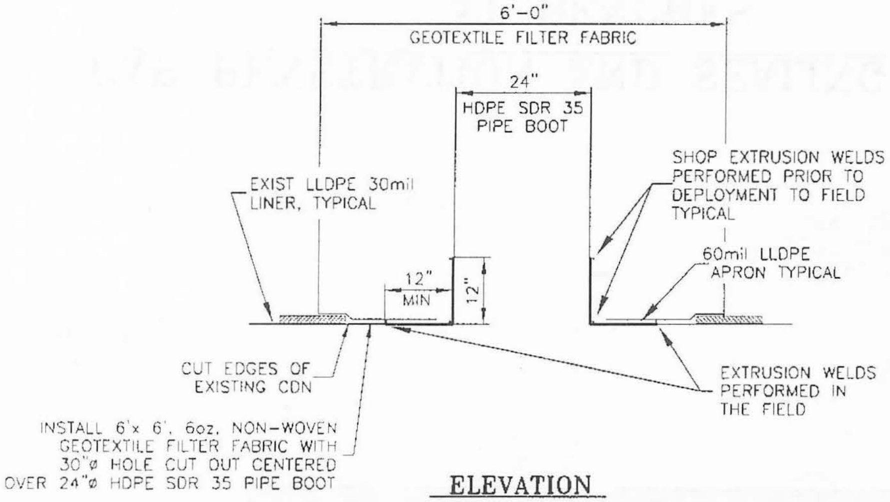
NTS

C-1

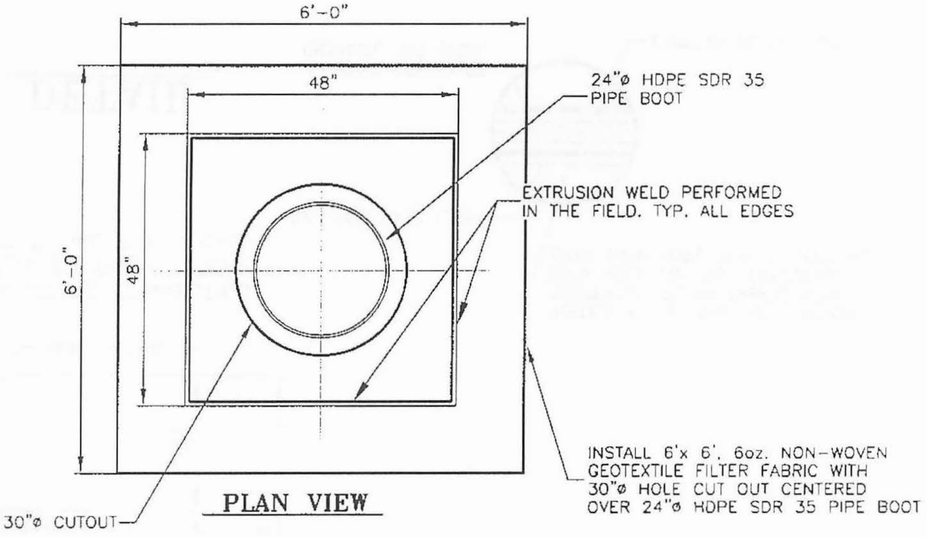
RIRRC
65 SHUN PIKE JOHNSTON, RI 02919
CAP PENETRATION AND
SEALING DETAIL

GeoEnvironmental, Inc.
140 BROADWAY
PROVIDENCE, RHODE ISLAND 02903
phone (401) 421-4140 fax (401) 751-8613

REV#	DESCRIPTION	BY	DATE



ELEVATION



PLAN VIEW

SHOP MANUFACTURED BOOT CONNECTION TO EXISTING LINER

SCALE: 3/8"= 1'-0"

C-2

RIRRC
65 SHUN PIKE JOHNSTON, RI 02919

CAP PENETRATION AND
SEALING DETAIL

GZA
GeoEnvironmental, Inc.
140 BROADWAY
PROVIDENCE, RHODE ISLAND 02903
phone (401) 421-4140 fax (401) 751-8613

REV#	DESCRIPTION	BY	DATE

APPENDIX B

Arsenic Quick^{tm} Test Kit Information

As^{+3} As^{+5}

QUICK™

Rapid Arsenic Test Kit

Kit Part Number: 481396
100 Tests
UNICEF Item Number: 00010

ETV®
EPA / ETV Test Verified Performance

FOR BEST RESULTS, FOLLOW KIT INSTRUCTIONS.

WARNING:
Hydrogen and Arsine gases are generated during the test. Work in a well-ventilated area away from open flames and other sources of ignition. Review the Material Safety Data Sheet before handling any chemicals.

Industrial Test Systems, Inc.
1875 Langston Street, Rock Hill, SC 29730 USA
Phone: (800) 861-9712, (803) 329-9712, **Fax:** (803) 329-9743
eMail: its@sensafe.com, **International:** www.ITSExport@sensafe.com
Web: www.sensafe.com

ITS Europe, LTD
Unit B Stanley Court, Glenmore Business Park, Telford Road
Churchfields Industrial Estate
Salisbury, Wiltshire SP2 7GL UK
Phone: +44 (0) 1722 329502, **Fax:** +44 (0) 1722 329880

481396-INST
Revision: 12/11/06

As^{+3} QUICK As^{+5} ™
Rapid Arsenic Test Kit

Part Number: 481396, 100 Tests

This test detects soluble inorganic Arsenic (As^{+3} and As^{+5})

This Arsenic Test Kit provides a safe, simple, and reliable way to test for Arsenic from 0 to 0.5 mg/L (up to 2.5mg/L when using 1/5 dilution method). Follow the instructions carefully to get reliable results. All components are supplied in the kit except for a timer and thermometer. This test tolerates up to 2.0 mg/L Hydrogen Sulfide without interference. No interference was found for this test kit for Antimony up to 0.5mg/L. No interference from Iron or Sulfate was found. It is recommended that the water sample be 22°C - 28°C. The color chart was standardized at 24°C. For reference purposes, record the temperature at which the sample was run. Use all reagents and test strips within the allowed shelf life as marked on each container.

Kit Components:

- 2 Reaction Bottles, clear PVC, with 20ml (lower) and 100ml (upper) lines *(Reorder # 481396-BTL)*
- 2 White Caps, with white turret, for holding test strip *(Reorder # 481396-WCP)*
- 3 Plastic Spoons (one large pink spoon for First Reagent; one small red spoon for Second Reagent; and one small white spoon for Third Reagent) *(Reorder # 481396-SPN)*
- 1 Large Bottle of First Reagent (380 gm) *(Reorder # 481396-R1)*
- 1 Small Bottle of Second Reagent (65 gm) *(Reorder # 481396-R2)*
- 1 Small Bottle of Third Reagent (180 gm) *(Reorder # 481396-R3)*
- 1 Bottle of Arsenic Test Strips (100 total) - Caution: Each test strip pad contains about 1 mg Mercuric Bromide ($HgBr_2$) *(Reorder # 481396-STP)*
- Instruction Booklet *(Reorder # 481396-INST)*
- Instruction Sticker *(Located inside Plastic Case, Reorder # 481396-STK)*
- Plastic Bag for Used Test Strips *(Not shown in below photograph, Reorder # 481396-BG)*
- 2 Yellow Caps for mixing *(Reorder # 481396-YCP)*
- Plastic Case for Components *(Reorder # 481396-PC)*
- Easy-Read™ Color Chart *(Reorder # 481396-EZCC)*

Options:

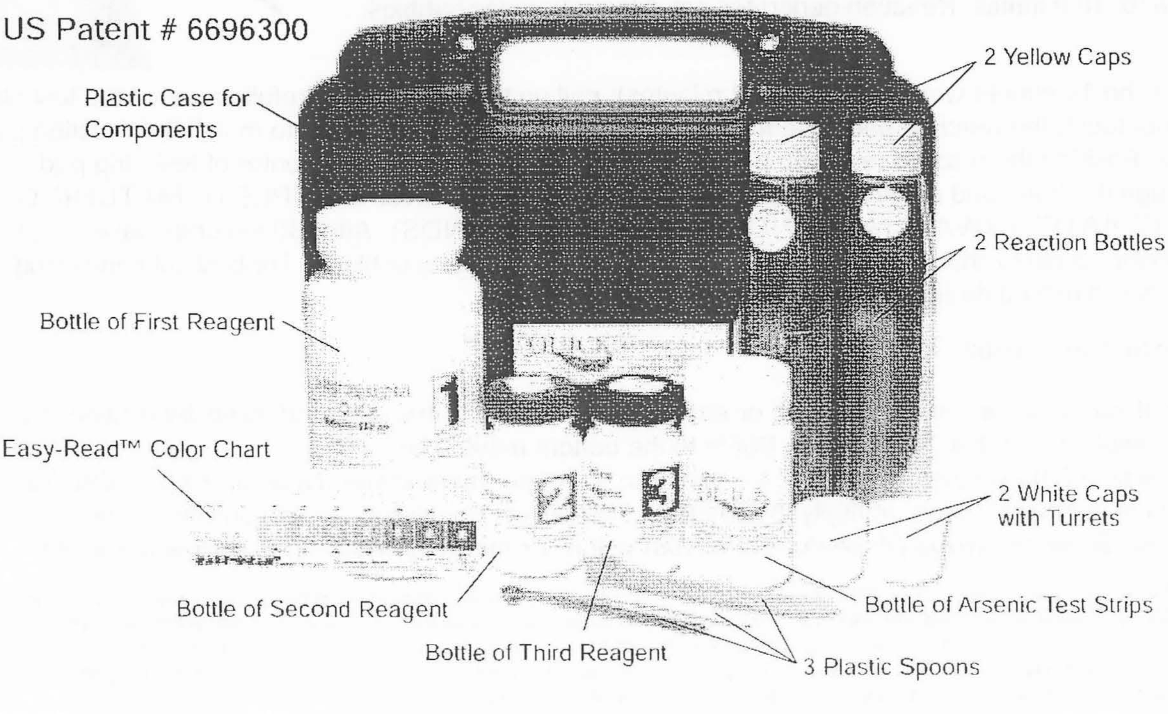
- Thermometer - mercury free *(US $3.99 each - sold separately, Order # 481396-T)*
- Stopwatch *(US $14.99 each - sold separately, Order # 481660)*

Chemistry of the Reaction (Modified Gutzeit method):

Inorganic Arsenic compounds in the water sample are converted to Arsine (AsH_3) gas by the reaction of Zinc Dust and Tartaric Acid. Ferrous and Nickel salts have been added to accelerate this reaction. The Arsine converts the Mercuric Bromide on the test strip to mixed Mercury halogens (such as AsH_2HgBr) that appear with a color change from white to yellow or brown. Potassium Peroxymonosulfate is added to oxidize Hydrogen Sulfide to Sulfate.

PRECAUTIONS: Hydrogen gas and Arsine gas are generated during the reaction. Work in a well-ventilated area away from fire and other sources of ignition. All reagents are unsuitable for human consumption.

US Patent # 6696300



WARNING: Hydrogen and Arsine gases are generated during the test. Work in a well-ventilated area away from open flames and other sources of ignition. Review the Material Safety Data Sheet before handling any chemicals.

For better accuracy, we recommend running the test in duplicate for each water sample.

As^{+3} QUICK™ As^{+5}
Rapid Arsenic Test Kit

FOLLOW KIT INSTRUCTIONS CLOSELY.
Part Number: 481396, 100 Tests

Test Procedure:

(See Instruction Sticker in plastic case cover for visual help.)

1. For best results, the water temperature should be between 22°C to 28°C. Use a thermometer to verify the temperature of the sample.
2. To the Reaction Bottle, slowly and carefully add the water sample to the upper marked line on the bottle (100 mL).
3. Add 3 <u>level</u> pink spoonfuls of First Reagent $\boxed{1}$ to the Reaction Bottle. Cap the bottle securely with yellow mixing cap and shake vigorously for 15 seconds.
4. Uncap the Reaction Bottle; add 3 <u>level</u> red spoonfuls of Second Reagent $\boxed{2}$. Cap the bottle securely with yellow mixing cap and shake vigorously with bottle upright for 15 seconds. Allow the sample to sit for 2 minutes to minimize Sulfide interference.
5. Uncap the Reaction Bottle and add 3 <u>level</u> white spoonfuls of Third Reagent $\boxed{3}$. Cap the bottle securely with yellow mixing cap and shake vigorously for 5 seconds.
6. Remove yellow mixing cap. Recap the bottle immediately and securely using the white cap (must be dry) with turret up (open).
7. Remove one Arsenic test strip from the test strip bottle and immediately recap the test strip bottle. In order for the results to be accurate, the test strip must be oriented correctly, and inserted to the correct depth. Insert the test strip into the turret as illustrated in Figure 1 and Figure 2:
   a) Position the strip so that the test pad and red line are facing the back of the white cap (see Figure 1).
   b) Insert the strip into the turret until the red line is even with the top of the turret, and close (flip down) the turret (see Figure 2). This will hold the test strip in place. ***(Note:** Steps 6 & 7 should be completed within 30 seconds.)*

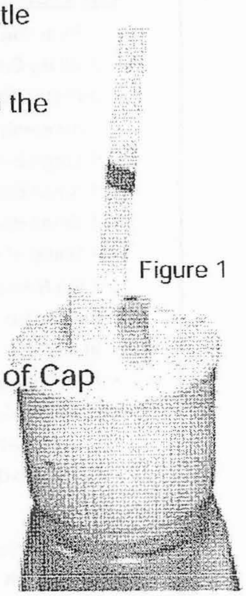


Figure 1

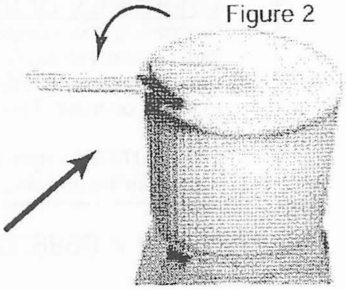


Figure 2

8. Using a timer, allow the reaction to occur in an undisturbed, well-ventilated area for 10 minutes. Reaction generates small hydrogen gas bubbles.
9. After the 10 minute wait (but before 12 minutes), pull up the turret and carefully remove the test strip. Do not touch the reaction pad. Use the Quick™ Easy-Read™ Color Chart to match the reaction pad color. Position the reacted test strip pad behind the punched holes, view center of test strip pad through the hole, and confirm precise color match and Arsenic level. COMPLETE MATCHING IMMEDIATELY (WAIT NO LONGER THAN 30 SECONDS). After 30 seconds have elapsed, the colors begin to change (yellow colors fade and browns turn grey or black). For best color matching results use natural daylight; avoid direct sunlight.
10. Record your result.

NOTE: If your Arsenic level is 200 ppb or above, you can confirm the elevated levels by diluting the water sample 1 to 5. Fill the Reaction Bottle to the bottom marked line with water sample (20 mL) and add Arsenic-free water to the upper marked line. Now run steps 3 thru 10. For your true Arsenic value, multiply the result by 5 to correct for dilution and record the value. ***(Mercuric Bromide strips (Arsenic test strips) will not react with arsine gas if they are wet!)***

ATTENTION: Soon after testing is completed, decant liquid from the bottle down a drain that is not used for food preparation and flush with water. Wet Zinc should be collected and disposed of according to local regulations. Rinse the bottle, white cap, and yellow cap with clean water. Shake off any excess water and dry the white cap with turret with a soft tissue. Drying the white turret cap is especially important if you plan to run the next test immediately. Store the used strips in the plastic bag marked "Used Mercuric Bromide ($HgBr_2$) Test Strips". Keep the used strips inaccessible to children and pets, and dispose according to local environmental regulations.

INSTRUCTIONS FOR BEST ACCURACY

1. To gain confidence in using this test kit for unknown samples, it is highly recommended that you use the kit on a sample with a known inorganic Arsenic concentration value, or with a sample that has been prepared using an Arsenic standard. By making a "practice run" of the test, you will familiarize yourself with all of the procedures necessary to ensure accurate testing results. Additionally, you will have the opportunity to become familiar with the process of color matching, which will help to ensure accurate test results. ITS suggests the test be run in duplicate for better accuracy.

2. The water sample must not be preserved with Nitric Acid or any other preservation method. Small amounts of strong acids will interfere with the test results; and therefore it is best that the water sample be freshly drawn and run within 8 hours. Water samples held for over 24 hours may read as much as 20% lower. The water sample should not contain any significant amount of buffers. If you are planning to send a duplicate sample for ICP laboratory verification, follow preservation requirements for that sample only.

3. The water and ambient temperature are very important to ensure accurate results. As an example, a water temperature of 15°C can result in the color development on the test strip pad to be as much as 3 color blocks lighter than the actual Arsenic concentration in the tested sample (a false low reading occurs). When the water is cold, warm water sample to 22°C to 28°C before testing. If the water temperature is above 28°C your result will read low (accelerator chemistry reacts too fast). To correct for accelerator effect when water is above 28°C, use 2 level pink spoonfuls of First Reagent instead of 3 spoonfuls in step 3, page 3. This slows the chemistry to allow better results. Use the normal amount (3 spoonfuls) of Second and Third Reagents. Consideration must also be made for the air temperature when running the test. Best results are from 22°C to 28°C (water and air). The color chart and Arsenic Scan instrument chart are calibrated at 24°C.

4. After the test has been run, try to rinse out the reaction bottle with clean tap water as soon as possible. When the reaction chemicals are allowed to sit in the reaction bottle after the reaction time, the zinc may begin to adhere to the bottom of the bottle. When this occurs, you may need to clean the reaction bottle with a bottlebrush. Another method for zinc removal is to use a 20% Hydrochloric Acid (reusable) rinse. Be sure to rinse the reaction bottle with clean tap water before running the next test.

5. When matching your test strip pad with the colors on the Easy-Read™ color chart, it may be helpful to find a color that is clearly lighter than the test strip pad and make note of it (as an example, we will use a value of 10 ppb). Next, find a color that is clearly darker than the test strip pad (as an example, we will use a value of 30 ppb). By defining a lowest and highest possible value range we can assume that the correct color match is 20 ppb. If the 20 ppb color matches, then you have determined your Arsenic level. In some cases, however, an exact color match will not be available. As an example, if your test strip pad is slightly darker than 20 ppb and slightly lighter than 30 ppb, you can estimate a value of 25 ppb as your result. Following these easy steps can make color matching more precise. Careful color matching will assure the best possible result.

6. Excessive levels of Hydrogen Sulfide (above 2 mg/L) can interfere with the results of this test. Excess Hydrogen Sulfide will usually result in elevated Arsenic readings. Our test kit will eliminate up to 2 mg/L of Sulfide interference. You can overcome Hydrogen Sulfide levels above 2 mg/L in two ways: Allow the water sample to sit at room temperature, exposed to air for 8 hours (about 50% of the H_2S gas dissipates for every 8 hours), or double (6 red spoonfuls) the amount of Second Reagent used so the Hydrogen Sulfide gas elimination of the test is increased.

Industrial Test Systems, Inc. sells Hydrogen Sulfide detection kits (part # 481197-20) for quick, accurate verification of this interfering ion. The test kit detects levels of 0.3, 0.5, 1.0, and 2.0 mg/L (ppm). The Hydrogen Sulfide test kit contains all components necessary to run the test, and is economically priced at $15.99 for 30 tests.

7. It has been determnined that irrigation of crops with arsenic water increases the soil arsenic levels which can increase the arsenic content in the crop. This Arsenic kit can be used for screening of Arsenic levels in soil. See procedure on Page 8.

8. If you have any questions or comments, please feel free to contact our R&D Department at 1-803-329-0162 ext 210 or by email at: *research@sensafe.com.*

QUICK™ ARSENIC TEST KIT TROUBLESHOOTING

As^{+3} QUICK™ As^{+5}
Rapid Arsenic Test Kit

Problem	Possible Causes/Solutions
Low or no color development on reaction pad after 10 minute reaction time.	1. Temperature of the sample may be below 20°C. 2. The strip may not have been inserted correctly. Run test again and verify strip pad is exposed to arsine gas. 3. Correct amount of reagents may not have been added. Run test again. 4. The reaction cap may have been loose. Run test again. 5. The sample may contain organic arsenic or the arsenic is bound. Kit only tests for soluble inorganic arsenic. 6. pH of the sample during 10 minute incubation is incorrect. pH should be between 1.5 to 1.7 at step 5, page 3. 7. Test strip pad is very wet, which inhibits colorimetric reaction. Moist pad at end of test is normal.
Only part of the strip reaction pad has color.	1. Strip pad may not be facing properly. Run test again. 2. Reaction cap may have leaked. Run test again.
Little or no Hydrogen gas bubbles occur after Reagent 3 addition.	1. Addition of Reagent 1 could have been omitted, run test again. 2. Excess oil and grease will hinder or suppress rate of gassing, dilute sample and run test again. 3. Strong acid may be present in sample as a preservative or from sample source because of where and how the sample was collected. Strong acids interfere with test. 4. pH of water sample is too alkali. For proper Hydrogen gas reaction the water sample with all three reagents added should be around a pH of 1.5 to 1.7 at step 5, page 3.
Color on the pad suggests more arsenic is present than is expected.	1. Possible interference, check for sulfide. 2. Dilute sample 1:5 and run test again.
Interference due to elevated Sulfide.	1. Allow sample to sit at room temperature, exposed to air for up to 8 hours (typically 50% of the hydrogen sulfide gas is dissipated every 8 hours). 2. Run test again, using double the amount of Second Reagent
Color on the pad is darker than the highest concentration on the chart.	1. Dilute the sample with arsenic/sulfide free water, run test again.
Color on the Arsenic test pad suggests arsenic recovery is below arsenic level expected.	1. Cap may have leaked, run test again. 2. Arsenic may be bound, insoluble, or organic. This kit only tests for soluble inorganic arsenic. 3. Interference due to elevated nitrate, nitrite, Hydrogen Sulfide or lead (Pb^{+2}) in water sample. 4. Temperature may be too low. Run test again. 5. The strip pad may be very wet. Be sure water temperature is below 28°C. 6. Sample was preserved with strong acids. Run test again without preservative acids.

ADDITIONAL TROUBLESHOOTING IDEAS

If the "Quick™ Arsenic Test Kit Troubleshooting at a Glance" section does not resolve the questionable result, then proceed as follows (in order given):

1. Initial Verification Check
   a. Verify against the parts list that the correct kit and components were received.
   b. Verify that the storage time for the sample is within the recommended 8- hour window. Clean glass or plastic containers are acceptable for storage. Longer storage time is possible only when microbiological activity is not present.
   c. Verify that the sample is not preserved by acidification, with strong acids (especially nitric acid). Strong acids will interfere with the chemistry of the test kit.
2. Standard Solution Check
   a. Run a known standard solution (such as a dilution of ITS' Cat# 800-4, 1000 ppm Arsenic standard), through the test procedure.
   The result of the standard solution check should meet kit specification (+/- 18 ppb or +/-30%).
3. Test Procedure and Test Kit Check
   a. Verify that the correct test procedure matches the kit being used.
   b. Verify that the color chart is correct for the kit in use.
   c. Verify that the correct reaction vessel and volume are being used.
   d. Verify that the amount of reagents are correct for the sample size and kit being used.
   e. Verify that the dilution factor, if used, is correct.
   f. If using the optional Quick™ Arsenic Scan, verify that the density value is set to "Y".
   If any part of the test kit and/or procedure is incorrect, correct the problem and repeat the test.
4. Test Kit Reagents and Analytical Technique Check
   If the standard solution check still does not match the expected results, check the reagents used in the test and the analytical technique as follows:
   a. Verify that the reagents have not expired. While most reagents have a reasonable shelf life, storage temperature and storage conditions may affect it. Replace suspect reagents and run the standard solution check (Step #2 above) again.
   b. Examine the test strip. Verify that the pads on the strips are white and dry.
   c. If the strips are out of date or do not pass the visual check above, obtain fresh strips and repeat the test.
5. Reagent Contamination Check
   a. Run a water blank (arsenic and sulfide-free) through the entire process, using the correct test procedure for your kit; include sampling, storage, digestion, and colorimetric determination when applicable. Color development on the test pad may indicate a contaminated reagent. Substitute the reagents one by one with new reagents until the reacted pad is white (shows no arsenic).
6. Unexplained differences to Reference Arsenic Test
   If you run ITS's Arsenic kit and find an unexplained difference when compared to a reference arsenic test method take the following steps:

   1. Confirm that you are running the test according to the correct procedure.
   2. Make sure your questionable sample is within the range of the test. (A sample out of range for the method may give erroneous results because of overdeveloped color.)
   3. Try a 1:5 dilution of the sample with distilled or deionized water and retest the sample.
   4. Test a known standard (for example, a 100 ppb Arsenic standard) to see if it is within specifications.
   5. Confirm that organic arsenic is not the cause of the difference in results.

If the test with a known standard solution gives the correct value in comparison with the reference method, then the sample with questionable results may have an interfering substance. The issue may possibly be resolved by a common analytical technique known as the Spiked Recovery Test Method for Interferences outlined below. (Note: Because this method is somewhat technical you should have already performed the easier steps listed above.)

ADDITIONAL TROUBLESHOOTING IDEAS - CONTINUED

7. Spiked Recovery Test Method for Interferences:
   1. Add a known amount of Standard Solution to the questionable sample. This is now the "spiked sample." To avoid test results being underdeveloped, it is recommended to add the Standard Solution amount that is at least equivalent to three times the minimum detectable limit of the test (15 ppb).
   2. Test the spiked and un-spiked (original) sample using the same reagents, instruments, and technique or test method. The spiked sample should show an increase equal to the amount of standard added. The value received is called the Recovery. Ideally the % recovery is 100%. Results are acceptable if % recovery is in the range of +/- 30%. The formula for Calculating Percent Recovery is below.
   3. If the percent recovery is not in the acceptable range there may be interferences. If it is not possible to dilute the sample past the point of interference, and still be within the detection limit of the test kit, a different test kit with a different detection specification may be needed.

Calculating percent recovery :

The percent recovery formula is as follows:

$$\%\text{Recovery} = \frac{100(C_s - C_u)}{K}$$

Where:

C_S = concentration found when testing the spiked sample

C_u = concentration found when testing the unspiked sample (NOTE: result should be adjusted for the dilution of the spike volume if volume change is more then 5%)

K = concentration of the spike added to the sample

Example 1:

An unspiked sample measures 30 ppb Arsenic. A separate 1000 ml portion of the questionable sample was spiked by adding 0.1 ml or 100 L of a 1000 ppm Arsenic Standard Solution. This is the equivalent of adding 100 ppb Arsenic to the water sample. The spiked solution was measured by the same method as the original sample. The Spiked result was 150 ppb (C_S)

C_S = 150 ppb

C_u = 30 ppb

K = 100 ppb

$$\%\text{Recovery} = \frac{100(150-30)}{100} = 120\%$$ (Recovery result acceptable)

Acceptable percent recovery values are 70-130% (+/– 30 %)

Example 2:

In another water sample using a similar spiked method as in Example 1 the results were

C_S = 75 ppb

C_u = 50 ppb

K = 100 ppb

$$\%\text{Recovery} = \frac{100(75-50)}{100} = 25\%$$ (Recovery result unacceptable)

This percent recovery value is low and would suggest that the water sample using this test is about 75 % below expected value for Arsenic. So in this example, you can calculate the Arsenic in this sample to be 200 ppb. This is determined as follows: multiply the correction interference factor (for this example the 100 divided by 25 equals 4.0) Then multiply the 4.0 X 50 (As concentration found in this sample or C_U). Note: This example has never been known to occur; but is included as a theoretical possibility.

SOIL SCREENING METHOD FOR ARSENIC

(Non-Digestion Method)

Scope and Application:

1. This method is valid for detection of Inorganic Arsenic in soil.
2. The minimum Arsenic detection with 0.5 g of soil is 1.0 mg/kg.

Sample Handling and Preparation (Recommended but not required):

3. Dry soil for at least 1 hour at 60°C or until completely dry.
4. Remove visible debris/stones from dried soil.
5. Grind the dried soil into a fine powder and mix until homogenous using a coffee grinder or a mortar and pestle. (a Coffee Grinder works well)

Interferences:

6. Test tolerates up to 2 mg/kg of Hydrogen Sulfide, 9000 mg/kg of Iron, and 1500 mg/kg of Lead.

Test Procedure:

7. Weigh out 0.5 g of the dried soil and transfer to the Reaction Bottle supplied in the Arsenic Quick™ Kit (Part # 481396). Note: If the Sample Handling and Preparation steps are omitted, then use 1g of soil. One gram is used on assumption that soil is 50% moisture by weight.)
8. Fill the bottle to the upper marked line on the Reaction Bottle with 100 mL of Arsenic-free tap water or Distilled water.
9. Follow the standard test procedure for the Arsenic Quick™ Kit starting with Step 3 on page 3.

Calculation:

10. Multiply the test result by 300 (correction multiplier) to get the Arsenic concentration in the soil as mg Arsenic/kg Soil. (Example: 40 g/L x 300 = 12 mg Arsenic/kg Soil)

NOTE: Because when compared to Acid Digestion/ICP-MS Arsenic analysis, this soil screening method gives typically 50% lower value; a correction multiplier of 300 is used (use 200 as a multiplier if you desire actual measured level).

SOIL SCREENING METHOD FOR ARSENIC

(Digestion Method)

Scope and Application:

1. This method is applicable to the determination of Inorganic Arsenic in soil.
2. The method is applicable in the range from 5 to 500 mg As/kg soil.

Sample Handling and Preparation:

3. Dry soil for at least 1 hour at 60°C or until completely dry.
4. Grind the dried soil into a fine powder using a coffee grinder or mortar and pestle and mix until sample is pulverized. (a Coffee Grinder works well)

Interferences:

5. Test can eliminate up to 2 ppm of Hydrogen Sulfide.
6. Iron concentrations above 9000 mg Fe/kg in soil will give low Arsenic results.
7. Lead concentrations above 1500 mg Pb/kg in soil will give low Arsenic results. (Note: Lead levels of 5000 ppm or greater are considered as Superfund Contamination.) The lead poisons the zinc reaction and suppresses the generation of Hydrogen and Arsine gas. To minimize lead interference, 0.2 g of Potassium Iodide (KI) should be added in the digestion procedure.

Equipment/Apparatus Needed:

8. Heating Block (Hach® COD Reactor Model 45600 or Equivalent)
9. Borosilicate screw cap style glass test tube (16 x 125 mm, Pyrex # 99449-16x or 99449-16xx or Equivalent) with Teflon lined screw cap (Pyrex # 9998-15 or Equivalent)
10. Transfer Pipette
11. Thermometer
12. 50 mL or 100 mL Volumetric Flask

Reagents Needed:

13. 50% (v/v) Hydrochloric Acid [HCl]
14. Distilled Water (or Arsenic-free Tap Water)

Safety Considerations:

15. Use a well-ventilated fume hood when handling Hydrochloric Acid (concentrated or 50%).
16. Wear Personal Protective Equipment (Gloves, Safety Glasses/Goggles, Lab Coat or Apron) when handling Hydrochloric Acid.

Digestion Procedure:

17. Weigh 0.5 g of the dried soil and transfer to a glass test tube.
18. Pipette 4.5 mL of 50% (v/v) HCl into the test tube, secure the screw cap tightly on the test tube and shake upright for 5 seconds. (To minimize particles clinging to the upper walls of test tube and cap, it is recommended not to invert the test tube.)
19. Place test tube in heating block for 1 hour at 95°C. Mix sample at least twice during digestion by carefully shaking test tube upright.
20. After digesting the soil for 1 hour, remove the test tube from the heating block and allow to cool.
21. Cautiously open test tube containing Digested Soil Sample and point cap away from eyes and body. Transfer the cooled digest to a 50 mL volumetric flask. Wash the test tube several times with Distilled or Arsenic-free water and add wash water to the flask without exceeding 50 mL volume. Fill to 50 mL volume with distilled water.

Test Procedure:

22. Transfer 10 mL of the 50 mL diluted digest to the Reaction Bottle supplied in the Arsenic Quick™ Kit (Part # 481396). Fill the Reaction Bottle to the upper marked line with Arsenic-free tap water or Distilled water.
23. Follow the standard test procedure for the Arsenic Quick™ Kit starting with Step 3 on page 3.

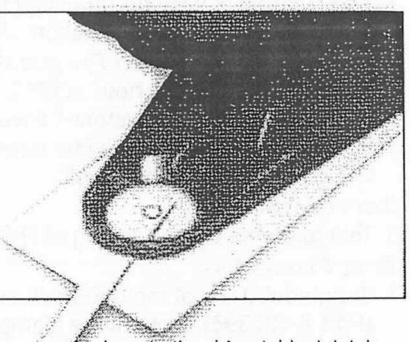
Calculation:

24. Multiply test result by 1000 (Example: 50 g/L becomes 50 mg/kg)

QUICK™ ARSENIC SCAN INSTRUCTIONS (INSTRUMENT SOLD SEPARATELY) FOR USE WITH ARSENIC QUICK™ TEST KIT (481396):

Instrument Components:

1. Quick™ Arsenic Scan Unit (R710 Color Reflection Densitometer, part number 481305)
2. Operation Manual (109 page book)
3. Calibration Reference Card
4. 18 Month Limited Warranty and Registration Card
5. AC Adapter (110VAC)
6. Carrying Case
7. White Opaque Plastic Card (2 ³/₈" x 7")
8. Conversion Table for the Following Arsenic Test Kits:
   Arsenic Quick™ Test Kit (part number 481396)



1. Instrument setup for Arsenic measurement:
   a. Remove the instrument from the case and turn the instrument over with the bottom facing up. Locate the ridged, black latch between the two (2) screws near the round end of the measurement shoe. Slide it forward. The measurement shoe is now unlocked, and will lift up by spring action from the body of the instrument.
   b. Locate the "OFF/ON" switch at the square end of the instrument where the data port and DC 9V connector ports are located. Gently slide the switch to "ON".
   c. Turn the instrument upright so that the LCD screen and six soft keys (3 black buttons, menu, exit, help) are facing upward.
   d. Depress once any one of the six soft keys on top of the unit. The LCD display will turn on.
   e. The instrument is now ready to make density measurements.

Notes:

a. The instrument is calibrated, and ready for use when received.
b. The AC adapter (supplied) may be used while performing color density measurements. Be sure the power switch is "OFF" before connecting the adapter to prevent any surge in power.
c. When the unit will stand unused for a long period of time slide the power switch to "OFF".
d. Typically, over 100 measurements can be made when using the battery pack only.

2. Strip measurement:
   a. Run the test sample according to the arsenic kit instructions.
   b. Read the strip with the Quick™ Arsenic Scan instrument within 30 seconds of completing the test.
      i. Place the reacted strip with colored test pad facing upward on the white opaque plastic card (2 ³/₈" x 7"). It is very important that the white opaque plastic card provided (or a white sustance) is placed under the reacted strip for accurate measuring.
      ii. Position the target circle of the base shoe over the color pad so that the pad is centered in the black outlined circle (as illustrated).
      iii. Press the body of the instrument down until the optical head is in contact with the target circle. The message "Measuring..." will appear in the LCD. A "Y" and a number next to the "Y" will appear in the LCD (For example, Y = 0.19 indicates a yellow color density of 0.19).
      iv. Use the number in the LCD (in the example 0.19) and compare with the Data Table provided to determine the concentration of arsenic in the sample. Be sure that you are using the appropriate Data Table for your test kit. 0.19 equals 20 µg/L or ppb Arsenic.
      v. Record the "Y" value and the concentration of Arsenic from the appropriate Data Table for future reference. Note: Use of the Quick™ Arsenic Scan unit will yield more precise results when compared to using the Easy-Read™ color chart for color matching determinations.

3. Calibration of Instrument:
   See details on pages 34-40 in the Color Reflection Densitometer Operation Manual. It is recommended that "Quick Cal" (pages 39-40) be performed weekly. It is also recommended that "Standard Calibration" (steps 4, 5, & 8 in the manual) be performed when "Quick Cal" results are not within the allowed +/- variance of the "Y" values (White, Black, & Solid {Yellow}) listed in the reference table below:

Step 1: White	Step 2: Black	Step 3: Solid (Yellow)
Y value +/- 0.01	Y value +/- 0.06	Y value +/- 0.03

The Conversion Table below is valid for (Zinc) Reagent 3 lot 9035.

**Note: For best accuracy dilute and retest samples with values >0.65

Conversion Table for Arsenic Quick™ Kit Part # 481396

Match the instrument reading to the corresponding As level (in ppb) as found in the table below: "Ihara (Y) Reading" = Yellow density value

Ihara (Y) Reading	As Level (ppb)	Ihara (Y) Reading	As Level (ppb)	Ihara (Y) Reading	As Level (ppb)	Ihara (Y) Reading	As Level (ppb)	Ihara (Y) Reading	As Level (ppb)	Ihara (Y) Reading	As Level (ppb)	Ihara (Y) Reading	As Level (ppb)
0.00	*BDL	0.15	10	0.30	57	0.45	105	0.60	175	0.75	265	0.90	>400
0.01	BDL	0.16	12	0.31	60	0.46	110	0.61	180	0.76	270	0.91	>400
0.02	BDL	0.17	14	0.32	63	0.47	115	0.62	185	0.77	280	0.92	>400
0.03	BDL	0.18	17	0.33	67	0.48	120	0.63	190	0.78	290	0.93	>400
0.04	BDL	0.19	20	0.34	70	0.49	124	0.64	195	0.79	300	0.94	>400
0.05	BDL	0.20	22	0.35	73	0.50	128	**0.65	200	0.80	>300	0.95	>400
0.06	BDL	0.21	24	0.36	77	0.51	132	0.66	205	0.81	>300	0.96	>500
0.07	BDL	0.22	27	0.37	80	0.52	136	0.67	210	0.82	>300	0.97	>500
0.08	BDL	0.23	30	0.38	83	0.53	140	0.68	215	0.83	>300	0.98	>500
0.09	BDL	0.24	35	0.39	86	0.54	145	0.69	220	0.84	>300	0.99	>500
0.10	BDL	0.25	40	0.40	89	0.55	150	0.70	225	0.85	>300	1.00	>500
0.11	3	0.26	43	0.41	91	0.56	155	0.71	230	0.86	>300	----	----
0.12	5	0.27	47	0.42	94	0.57	160	0.72	240	0.87	>300		
0.13	7	0.28	50	0.43	97	0.58	165	0.73	245	0.88	>400		
0.14	9	0.29	53	0.44	100	0.59	170	0.74	255	0.89	>400		

MSDS 1
Material Safety Data Sheet

Section 1 Chemical Identification

Catalog # / Description: Part Number 481196-D
Name: First Reagent

Section 2 Composition / Information on Ingredients

CAS#: 87-69-4	L-Tartaric Acid	98.7%
CAS#: 7720-78-7	Iron (II) Sulfate • $7H_2O$	0.7%
CAS#: 10101-97-0	Nickel (II) Sulfate • $6H_2O$	0.6%

Section 3 Hazards Identification

Precautionary Statements:

- May be irritating to eyes and nasal passages.
- Low toxicity orally, moderately toxicity intravenously.
- Tartaric Acid is reported to have an oral rabbit LD50 at 5000 mg/kg, and a dermal rat LD50 at 485 mg/kg. Tartaric Acid Reagent has minimal toxicological effect. However, inhalation may cause irritation of respiratory tract; ingestion in large amounts may cause gastrointestinal upset; skin or eye contact may cause mild irritation; prolonged exposure may cause allergic reaction. Wash hands after use.
- Iron (II) Sulfate is harmful if swallowed or inhaled. Causes irritation to skin, eyes, and respiratory tract. Affects the liver. Oral mouse LD50: 1520 mg/kg.
- Nickel Sulfate is toxic. Harmful if swallowed. Possible risk of irreversible effects. May cause sensitization by inhalation and skin contact. Possible carcinogen. Toxicity data: oral rat LD50: 264 mg/kg.

Section 4 First-Aid Measures

- If swallowed, wash out mouth with water. Call a physician or the Poison Control Center as a precaution.
- In case of skin contact, flush with copious amounts of water for at least 15 minutes.
- In case of contact with eyes, flush with copious amounts of water for at least 15 minutes.
- If inhaled, remove to fresh air. If breathing is difficult, give oxygen and seek medical advice.

Section 5 Fire Fighting Measures

Not Applicable since the amount of First Reagent per kit is negligible.

Section 6 Exposure Controls / Personal Protection

Do not expose to eyes, skin, or clothing. Keep away from children and pets. Wash hands thoroughly after handling. Maintain general hygienic practices when using this product.

Section 7 Physical and Chemical Properties

Appearance and Odor:

- Solid/semi-solid, white powder. Soluble in water.

Physical Properties:

- Melting Point: Not Applicable
- Vapor Pressure: Not Applicable
- Specific Gravity: Not Applicable
- Vapor Density: Not Applicable

Stability:

- Stable when stored under proper conditions.

Hazardous Polymerization:

- Will not occur.

Incompatibilities:

- Reaction with silver, zinc, aluminum in the presence of water or moisture will release explosive Hydrogen gas.

Section 8 Toxicological Information

Acute Effects:

- Do not breathe dust! Avoid contact with eyes, skin, and clothing. Avoid prolonged or repeated exposure.

Section 9 Other Information

The above information is believed to be correct but does not purport to be all-inclusive and shall be used ONLY as a guide. Keep away from children and pets. Store in a dry, cool place. Keep container tightly closed.

MSDS 2
Material Safety Data Sheet

Section 1 Chemical Identification

Catalog # / Description: Part Number 481196-E
Name: Second Reagent

Section 2 Composition / Information on Ingredients

CAS#	10058-23-8	Potassium Peroxymonosulfate	43%
CAS#	7646-93-7	Potassium Bisulfate	23%
CAS#	7778-80-5	Potassium Sulfate	29%
CAS#	7727-21-1	Potassium Peroxydisulfate	3%
CAS#	546-93-0	Magnesium Carbonate	2%

Comments: NOTE: CAS# for mixture is 70693-62-8

Section 3 Hazards Identification

Emergency Overview:

- Physical Appearance: White, granular material
- Immediate Concerns: DANGER. CORROSIVE. Causes skin and eye damage. Wear goggles or face shield and rubber gloves when handling. May be fatal if swallowed. Irritating to nose and throat. Avoid inhalation or dust. Remove and wash contaminated clothing before reuse.

Potential Health Effects:

- Eyes: DANGER. Corrosive. Causes eye damage. Do not get in eyes.

Section 4 First-Aid Measures

EYES: If contact with eyes occurs: Immediately flush with cold water for at least 15 minutes. Then get immediate medical attention.
SKIN: If contact with skin: Rinse off excess chemical and flush skin with cold water for at least 15 minutes. If skin irritation develops, seek medical attention.
INGESTION: If swallowed: Do not induce vomiting. Drink 1-2 glasses of water to dilute the stomach contents. Never give anything by mouth to an unconscious person. Call a physician immediately.
INHALATION: If inhaled: Remove to fresh air. If breathing is difficult, have trained person administer oxygen. If not breathing, give artificial respiration. Call a physician immediately.

Section 5 Fire Fighting Measures

- This product is not flammable or combustible.
- Will release oxygen when heated, intensifying a fire. Acidic mist may be present.
- Exercise caution when fighting any chemical fire.
- Extinguishing Media: Water

Section 6 Exposure Controls / Personal Protection

Do not expose to eyes, skin, or clothing. Keep away from children and pets. Wash hands thoroughly after handling. Maintain general hygienic practices when using this product.

Section 7 Physical and Chemical Properties

Appearance and Odor:

- Solid. Granular, free-flowing solid. White.
- Odorless

Physical Properties:

- Melting Point: Not Applicable
- Vapor Pressure: Not Volatile
- Specific Gravity: 1.1 to 1.4
- Vapor Density: Not Volatile

Stability:

- Stable when stored under proper conditions.

Hazardous Polymerization:

- Will not occur.

Incompatibilities:

- Mixing with compounds containing halides or active halogens can cause release of the respective halogens if moisture is present. Mixing with cyanides can cause release of hydrogen cyanide gas. Mixing with heavy metal salts such as those of cobalt, nickel, copper, or manganese can cause decomposition with release of oxygen and heat.

Section 8 Toxicological Information

Acute Effects:

- Skin Absorption: >11,000 mg/kg in rabbits
- Oral LD50: 2,000 mg/kg (rat)
- Inhalation LC50: >5 mg/l (rats) (4-hour)

Section 9 Other Information

The above information is believed to be correct but does not purport to be all-inclusive and shall be used ONLY as a guide. Keep away from children and pets.

MSDS 3
Material Safety Data Sheet

Section 1 Chemical Identification

Catalog # / Description: Part Number 481196-F
Name: Third Reagent

Section 2 Composition / Information on Ingredients

CAS #: 7440-66-6
Chemical Name: Zinc >99%
Synonyms:

- Blue powder, granular zinc, zinc dust, zinc powder

Section 3 Hazards Identification

Precautionary Statements:

- Flammable solid. This material, like many powders, is capable of causing a dust explosion.
- If inhaled, remove to fresh air. If breathing is difficult, give oxygen and seek medical advice.

Section 4 First-Aid Measures

- If swallowed, wash out mouth with water. Call a physician or the Poison Control Center.
- In case of skin contact, flush with copious amounts of water for at least 2 minutes. Remove contaminated clothing and shoes.
- In case of contact with eyes, flush with copious amounts of water for at least 5 minutes. Call a physician.
- If inhaled, remove to fresh air. If breathing is difficult, give oxygen and seek medical advice.

Section 5 Fire Fighting Measures

Fire/Explosion Hazard:

- Dust may form a flammable/explosive mixture with air. May form explosive mixture with oxidizers. Extinguishing Media:
- Sand or inert dry powder. Do not use water.

Section 6 Exposure Controls / Personal Protection

Do not get in eyes, on skin, on clothing. Keep away from children and pets. Wash hands thoroughly after handling. Use with adequate ventilation. Maintain general hygienic practices when using this product.

Section 7 Physical and Chemical Properties

Appearance and Odor:
Solid bluish-gray powder
Physical Properties:

- Melting Point: 419°C
- Vapor Pressure: Not Applicable
- Specific Gravity: 7,14
- Vapor Density: Not Applicable

Stability:

- Stable when stored dried and at room temperature.

Hazardous Polymerization:

- Will not occur.

Section 8 Toxicological Information

- Skin and eye irritation may result from intermittent exposure.
- Avoid creating dust. DO NOT breathe dust.

Section 9 Other Information

The above information is believed to be correct but does not purport to be all-inclusive and shall be used ONLY as a guide. Dispose of empty bottle as normal trash. Keep away from children and pets.

MSDS 4
Material Safety Data Sheet

Section 1 Chemical Identification

Catalog # / Description: Part Number 481196-G
Name: Arsenic Test Strips

Section 2 Composition / Information on Ingredients

CAS #: 7789-47-1
Synonyms:

- Toxic ingredient is: Mercuric Bromide.

Section 3 Hazards Identification

Precautionary Statements:

- Toxic poison is contained in test strip pad (about 1mg / strip).
- Mercuric Bromide is reported to have an oral rat LD50 at 40mg/kg, and a dermal rat LD50 at 100mg/kg.

Section 4 First-Aid Measures

- If swallowed, wash out mouth with water. Call a physician or the Poison Control Center as a precaution.
- In case of skin contact, flush with copious amounts of water for at least 2 minutes. Remove contaminated clothing and shoes.
- In case of contact with eyes, flush with copious amounts of water for at least 5 minutes.
- If inhaled, remove to fresh air. If breathing is difficult, give oxygen and seek medical advice.

Section 5 Fire Fighting Measures

Not Applicable since the amount of Mercury per kit is negligible.

Section 6 Exposure Controls / Personal Protection

Do not expose to eyes, skin, or clothing. Keep away from children and pets. Wash hands thoroughly after handling. Maintain general hygienic practices when using this product.

Section 7 Physical and Chemical Properties

Appearance and Odor:

- Solid/semi-solid, white paper pad (containing Mercuric Bromide) attached to plastic strip.

Physical Properties:

- Melting Point: Not Applicable
- Vapor Pressure: Not Applicable
- Specific Gravity: Not Applicable
- Vapor Density: Not Applicable

Stability:

- Stable when stored under proper conditions.

Hazardous Polymerization:

- Will not occur.

Section 8 Toxicological Information

Acute Effects:

- Each strip contains about 1mg Mercuric Bromide so toxicological effect is minimal because of the amount. However, material is toxic and should be handled carefully to minimize exposure. Place all used test strips into plastic bag labeled "Used Test Strips". Dispose of used strips per environmental and regulatory requirements in your community. Wash hands after use.

Section 9 Other Information

The above information is believed to be correct but does not purport to be all-inclusive and shall be used ONLY as a guide. Dispose of the used test strips as regulations require. Keep away from children and pets.

LETTER FROM THE KIT INVENTOR

Thank you for purchasing our U.S. Patented (# 6,696,300) Arsenic Quick™ Kit. Our company has trademarked the kits Quick™ because of the short 14 minute time for analysis.

The Drinking Water standard of the US EPA and the World Health Organization (WHO) allows a maximum contaminant level of 10 ppb (µg/L) for Arsenic. The old US EPA level of 50 ppb (µg/L) remains as the maximum contaminant level for many countries in the world.

For several years, Industrial Test Systems, Inc. (ITS) committed a major research & development effort to provide better and safer arsenic test kits. The goal was achieved. The test was made safer by using tartaric acid, instead of strong acids, for the reduction of inorganic arsenic (As^{+3}/As^{+5}) to arsine gas. For these efforts a US Patent was granted for the acceleration of the arsenic detection chemistry by the addition of metal enhancers, iron and nickel salts. This permits Arsenic field tests to be completed faster. The Quick™ II series of kits use a modified Turret cap which allows detection of arsenic below 10 ppb (µg/L). The reduction reactions utilized in all kits are as follows:

$Zn + 2H^+ \quad Zn^{+2} + H_2$ (gas) and $As_4O_6 + 12\ Zn + 24H^+ \quad 4AsH_3$(gas) $+ 12\ Zn^{+2} + 6H_2O$ (pH 1.6)

The analysis is performed in a closed reaction bottle (plastic) with an appropriate volume of sample (50 to 500 ml). After the 10 minute reduction reaction, the mercuric bromide strip or testing pad is removed and matched to the color chart or color analyzed by the Quick™ Arsenic Scan instrument. A light yellow to brown color change indicates that arsenic is present. The color intensity is proportionately related to the concentration of arsenic in the sample. NOTE: ITS test kits detect free inorganic arsenic only. ICP-MS methods detect inorganic and organic arsenic. If organic arsenic is present, ITS kit results can be expected to give lower values when compared to ICP-MS results.

Specifications of our different arsenic field test kits:

PRODUCT NAME	NO. OF TESTS	ETV® PERFORMANCE VERIFIED	OPTIMUM RANGE* ppb (µg/L)	TYPICAL COLOR CHART DETECTION LEVELS ppb (g/L)	TYPICAL ACCURACY** OF DUPLICATES USING QUICK™ ARSENIC SCAN	PRICE IN US $
Arsenic Econo-Quick™ (481298)	300 tests	NO	50 to 300	0, 0.010, 0.025, 0.050, 0.1, 0.2, 0.3, 0.5, 1.0 ppm (mg/L)	+/-40 ppb or +/-40%	$179.99
Arsenic Quick™ Kit† (481396)	100 tests	YES	10 to 200	5, 10, 20, 30, 40, 50, 60, 80, 100, 150, 200, 250, 300, 400, 500, >500	+/-18 ppb or +/-30%	$169.99
Arsenic Low Range Quick™-I (481297-1)	50 tests	YES	7 to 80	<2, 4, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 100, >150, >300	+/-8 ppb or +/-25%	$179.99
Arsenic Econo-Quick™ II (481304)	100 tests	NO	4 to 30	<2, 3, 5, 7, 8, 9, 10, 12, 16, 20, 25, 30, 40, 50, 80, >80, >90, >100	+/-2 ppb or +/-18%	$299.99
Arsenic Quick™ II (481303)	50 tests	YES	3 to 20	<1, 2, 3, 4, 5, 6, 7, 8, 10, 13, 20, 25, 30, 40, >50, >80, >120, >160	+/-1.2 ppb or +/-16%	$219.99
Arsenic Low Range Quick™ II (481301)	50 tests	YES	1 to 10	<0.5, 1.0, 1.5, 2.0, 3.0, 4, 5, 6, 7, 8, 12, >20, >30, >50	+/-0.8 ppb or +/-14%	$349.99
Arsenic Ultra-Low Quick™ II (481300)	25 tests	YES	0.5 to 6	0, 0.3, 0.7, 1.0, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6, 8, 10, 13, 20, >20	+/-0.4 ppb or +/-12%	$299.99
Quick™ Arsenic Scan Instrument (481305)	1 meter	YES	N/A	0.01 to >1.00 color density ppb (µg/L) (as low as 0.2 ppb (µg/L) arsenic)	(see above)	$1,599.99

Specifications subject to change without notice. † This kit can also be used for soil analysis with modified procedure.

*Range can be expanded by diluting the sample with Arsenic-free water.

** As with any test, actual results will fall within a range around the actual value. The Typical Accuracy listed is from data generated by a technician in our lab using the Quick™ Arsenic Scan instrument measuring interference-free aqueous arsenic standards. Kit expected accuracy is the larger of the two values listed. {Example using Quick™: If the mean is 40 ppb, then the typical accuracy is +/-18 ppb which is larger than +/-12 ppb (40 ppb X 30%)}.
For independent evaluation data for selected kits see the ETV verification reports at www.epa.gov/etv, verified technologies.

Where precision is important, ITS recommends that you run the water sample in duplicate, since the typical color matching is within one color block. For best precision consider the purchase of our Quick™ Arsenic Scan instrument. This unit is ideal for use with all test kits. Please contact our sales department at 803-329-9712 for more information or to order the Quick™ Arsenic Scan instrument.

Typical shelf life of kits is over 12 months. The kit includes First Reagent (Tartaric acid with iron and nickel salts); Second Reagent (MPS, an oxidizer); Third Reagent (zinc dust); and mercuric bromide strips, which contains about 1mg mercury per strip. After use, the strips should be discarded according to local environmental regulations. The Second Reagent must <u>not</u> be shipped by passenger airlines. Valuable information about the kit is in the MSDS literature. As a safeguard to minimize the operator š exposure to arsine and hydrogen gas, please run all tests in a well-ventilated area away from open flames and other sources of ignition. Arsine gas is highly toxic; and this precaution becomes more urgent if the water sample has high arsenic levels.

Cordially yours,

Ivars Jaunakais, Analytical Chemist
email: Ivars@sensafe.com

APPENDIX C

Field Activities SOPs

U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP:	2044
PAGE:	1 of 8
REV:	0.1
DATE:	10/23/01

MONITOR WELL DEVELOPMENT

CONTENTS

*These sections affected by Revision 0.1.

SUPERCEDES: SOP #2044; Revision 0.0; 2/18/00; U.S. EPA Contract 68-C99-223.

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to provide an overview of monitor well development practices. The purpose of monitor well development is to ensure removal of fine grained sediments (fines) from the vicinity of the well screen. This allows the water to flow freely from the formation into the well, and also reduces the turbidity of the water during sampling. The most common well development methods are: surging, jetting, overpumping, and bailing.

Surging involves raising and lowering a surge block or surge plunger inside the well. The resulting surging motion forces water into the formation and loosens sediment, pulled from the formation into the well. Occasionally, sediments must be removed from the well with a sand bailer to prevent sand locking of the surge block. This method may cause the sand pack around the screen to be displaced to a degree that damages its value as a filtering medium. Channels or voids may form near the screen if the filter pack sloughs away during surging (Keel and Boating, 1987).

Surging with compressed air is done by injecting a sudden charge of compressed air into the well with an air line so that water is forced through the well screen. The air is then turned off so that the water column falls back into the well and the process is repeated. Periodically, the air line is pulled up into a pipe string (educator) and water is pumped from the well using air as the lifting medium (air-lift pumping). The process is repeated until the well is sediment free. Method variations include leaving the air line in the pipe string at all times or using the well casing as the educator pipe.

Jetting involves lowering a small diameter pipe into the well and injecting a high velocity horizontal stream of water or air through the pipe into the screen openings. This method is especially effective at breaking down filter cakes developed during mud rotary drilling. Simultaneous air-lift pumping is usually used to remove fines.

Overpumping involves pumping at a rate rapid enough to draw the water level in the well as low as possible, and then allowing the well to recharge to the original level. This process is repeated until sediment-free water is produced.

Bailing includes the use of a simple manually operated check-valve bailer to remove water from the well. The bailing method, like other methods, should be repeated until sediment free water is produced. Bailing may be the method of choice in a shallow well or well that recharges slowly.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with a final report.

Mention of trade names or commercial products does not constitute United States Environmental Protection

Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

After installation, development of a well should occur as soon as it is practical. It should not occur any sooner than 48 hours after grouting is completed, especially if a vigorous well development method (i.e. surging) is being used. If a less vigorous method (i.e bailing) is used, it may be initiated shortly after installation. The method used for development should not interfere with the setting of the well seal.

Several activities must take place prior to well development. First, open the monitor well, take initial measurements (i.e., head space air monitoring readings, water level, total depth of the well) and record results in the site logbook. Develop the well by the appropriate method to accommodate site conditions and project objectives. Continue until the development water is clear and free of sediments, or until parameters such as pH, temperature, and specific conductivity stabilize. Containerize all purge water from wells with known or suspected contamination. Record final measurements in the site logbook. Decontaminate equipment as appropriate prior to use in the next well.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The following problems may be associated with well development:

1. Overpumping is not as vigorous as surging and jetting, and is probably the most desirable method for monitor well development. The possibility of disturbing the filter pack is greatest with surging and jetting well development methods.

2. The introduction of external water or air by jetting may alter the hydro chemistry of the aquifer.

3. Surging with air may produce "air locking" in some formations, preventing water from flowing into the well.

4. The use of surge blocks in formations containing clay may cause plugging of the screen.

5. Small (2-inch nominal diameter) submersible pumps that will fit in 2-inch diameter well casing are especially susceptible to clogging if used in well development applications.

6. Chemicals/reagents used during the decontamination of drilling equipment may complicate well development.

5.0 EQUIPMENT/APPARATUS

The type of equipment used for well development is dependent on the diameter of the well and the development method. For example, the diameter of most submersible pumps is too large to fit into a two-inch inner diameter (I.D.) well, and other development methods should be used. Obtaining the highest possible yield is not usually an objective in developing monitor wells and vigorous development is not always necessary. Many monitor wells are constructed in fine-grained formations that would not normally be considered aquifers. Specifications for the drilling contract should include the necessary well development equipment (air compressors, pumps, air lines, surge blocks, generators).

6.0 REAGENTS

The use of chemicals in developing wells that will be used to monitor groundwater quality should be avoided if possible; however, polyphosphates (a dispersing agent), acids, or disinfectants are often used in general well development. Polyphosphates should not be used in thinly bedded sequences of sands and clays. The use of decontamination solutions may also be necessary. If decontamination of equipment is required at a well, refer to Environmental Response Team/Response Engineering and Analytical Contract (ERT/REAC) SOP #2006, *Sampling Equipment Decontamination* and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Coordinate site access and obtain keys to well locks.
2. Obtain information on each well to be developed (i.e., drilling method, well diameter, well depth, screened interval, anticipated contaminants).
3. Obtain a water level meter, a depth sounder, air monitoring instruments, materials for decontamination, and water quality instrumentation capable of measuring, at a minimum, pH, specific conductivity, temperature, and turbidity. Dissolved oxygen (DO) and salinity are also useful parameters.
4. Assemble containers for temporary storage of water produced during well development. Containers must be structurally sound, compatible with anticipated contaminants, and easy to manage in the field. The use of truck-mounted or roll-off tanks may be necessary in some cases; alternately, a portable water treatment unit (i.e., activated carbon) may be used to decontaminate the purge water.

7.2 Operation

Development should be performed as soon as it is practical after the well is installed, but no sooner than 48 hours after well completion.

1. Assemble necessary equipment on a plastic sheet surrounding the well.

2. Record pertinent information in the site or personal logbook (personnel, time, location ID, etc.).

3. Open monitor well, take air monitor reading at the top of casing and in the breathing zone as appropriate.

4. Measure depth to water and the total depth of the monitor well. Calculate the water column volume of the well (Equation 1, Section 8.0).

5. Begin development and measure the initial pH, temperature, turbidity, and specific conductivity of the water and record in the site logbook. Note the initial color, clarity, and odor of the water.

6. Continue to develop the well and periodically measure the water quality parameters indicated in step 5 (above). Depending on project objectives and available time, development should proceed until these water quality parameters stabilize, or until the water has a turbidity of less than 50 nephelometric turbidity units (NTUs).

7. All water produced by development of contaminated or suspected contaminated wells must be containerized or treated. Each container must be clearly labeled with the location ID, date collected, and sampling contractor. Determination of the appropriate disposal method will be based on the analytical results from each well.

8. No water shall be added to the well to assist development without prior approval by the appropriate U.S. EPA ERT Work Assignment Manager (WAM) and/or appropriate state personnel. In some cases , small amounts of potable water may be added to help develop a poor yielding well. It is essential that at least five times the amount of water injected must be recovered from the well in order to assure that all injected water is removed from the formation.

9. Note the final water quality parameters in the site or personal logbook along with the following data:

   - Well designation (location ID)
   - Date(s) of well installation
   - Date(s) and time of well development

- Static water level before and after development
- Quantity of water removed, and initial and completion time
- Type and capacity of pump or bailer used
- Description of well development techniques

7.3 Post-Operation

1. Decontaminate all equipment;

2. Secure holding tanks or containers of development water;

3. Review analytical results and determine the appropriate water disposal method. Actual disposal of the purge water is generally carried out by the On-Scene Coordinator (OSC).

8.0 CALCULATIONS

To calculate the volume of water in the well, the following equation is used:

Well Volume (V) = • r^2 h (cf) [Equation 1]

where:

• = pi (3.14)
r = radius of monitoring well in feet (ft)
h = height of the water column in ft. [This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
cf = conversion factor in gallons per cubic foot (gal/ft^3) = 7.48 gal/ft^3. [In this equation, 7.48 gal/ft^3 is the necessary conversion factor.]

Monitor well diameters are typically 2-, 3-, 4-, or 6-inches. A number of standard conversion factors can be used to simplify the above equation using the diameter of the monitor well. The volume, in gallons per linear foot, for various standard monitor well diameters can be calculated as follows:
where:

V (gal/ft) = • r^2 (cf) [Equation 2]

• = pi
r = radius of monitoring well (feet)
cf = conversion factor (7.48 gal/ft^3)

For example, a two inch diameter well, the volume per linear foot can be calculated as follows:

$$\mathbf{V\ (gal/ft)} \quad = \quad \bullet\, \mathbf{r^2\ (cf)} \qquad \textbf{[Equation 2]}$$
$$= \quad \mathbf{3.14\ (1/12\ ft)^2\ \ 7.48\ gal/ft^3}$$
$$= \quad \mathbf{0.1631\ gal/ft}$$

NOTE: The diameter must be converted to the radius in feet as follows:

$$\mathbf{\frac{Well\ Diameter\ (inches)}{12} \times 0.5 = Well\ Radius\ (feet)} \qquad \textbf{[Equation 3]}$$

The volume in gallons/feet for the common size monitor wells are as follows:

Well diameter (inches)	2	3	4	6
Volume (gal/ft)	0.1631	0.3670	0.6524	1.4680

If you utilize the volumes for the common size wells above, Equation 1 is modified as follows:
where:

$$\textbf{Well volume} = \mathbf{(h)(f)} \qquad \textbf{[Equation 4]}$$

h = height of water column (feet)
f = the volume in gal/ft calculated from Equation 2

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance activities, which apply to the implementation of these procedures. However, the following general quality assurance/quality control (QA/QC) procedures apply:

1. All data must be documented in site and/or personal logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, Occupational Safety and Health (OSHA), and corporate health and safety practices.

12.0 REFERENCES

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Keel, J.F. and Kwasi Boating. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 1: Conceptualizations".*Groundwater,* 25(3):300-313.

Keel, J.F. and Kwasi Boating. 1987. "Monitoring Well Installation, Purging, and Sampling Techniques - Part 2: Case Histories". *Groundwater*, 25(4):427-439.

13.0 APPENDICES

This section is not applicable to this SOP.

CONTENTS

SUPERCEDES: SOP #2043; Revision 0.0; 10/03/94; U.S. EPA Contract 68-C4-0022.

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to set guidelines for the determination of the depth to water and separate phase chemical product (i.e., gasoline, oil, PCE, TCE) in an open borehole, cased borehole, monitor well, or piezometer. These standard operating procedures may be varied or changed as required, dependent on site conditions , and equipment limitations. In all instances, the actual procedures employed will be documented and described in an appropriate site report. Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

Generally, water-level measurements taken in boreholes, piezometers, or monitor wells are used to construct water table or potentiometric surface maps and to determine flow direction as well as other aquifer characteristics. Therefore, all water level measurements at a given site should preferably be collected within a 24 hour period. However, certain situations may produce rapidly changing groundwater levels that necessitate taking measurements as close in time as possible. Large changes in water levels among wells may be indicative of such a condition . Rapid groundwater level changes may occur due to:

! Atmospheric pressure changes

! Tidal influences

! Changes in river stage, impoundments levels, or flow in unlined ditches

! Pumping of nearby wells

! Precipitation

2.0 METHOD SUMMARY

A survey mark should be placed on the top of the riser pipe or casing as a reference point for groundwater level measurements. If the lip of the riser pipe is not flat, the reference point may be located on the grout apron or the top of the outer protective casing (if present). The measurement reference point should be documented in the site logbook and on the groundwater level data form (Appendix A), if used. All field personnel must be made aware of the measurement reference point being used in order to ensure the collection of comparable data.

Before measurements are made, water levels in piezometers and monitor wells should be allowed to stabilize for a minimum of 24 hours after well construction and development. In low yield situations, recovery of water levels to equilibrium may take longer. All measurements should be made to an accuracy of 0.01 feet. Water level measuring equipment must be decontaminated and, in general, measurements should proceed from the least to the most contaminated wells.

Open the well and monitor the headspace with the appropriate air monitoring instrument to determine the presence of volatile organic compounds. For electrical sounders lower the device into the well until the water surface is reached as indicated by a tone or meter deflection. Record the distance from the water surface to the reference point. Measurement with a chalked tape will necessitate lowering the tape below the water level and holding a convenient foot marker at the reference point. Record both the water level as indicated on the chalked tape section and the depth mark held at the reference point The depth to water is the difference between the two readings. Remove measuring device, replace riser pipe cap, and decontaminate equipment as necessary. Note that if a separate phase is present, an oil/water indicator probe is required for measurement of product thickness and water level.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING AND STORAGE

This section is not applicable to this standard operating procedure (SOP).

4.0 POTENTIAL PROBLEMS

1. Cascading water, particularly in open-hole or rock wells, may interfere with the measurement.
2. Some older types of electric sounders are only marked at five-foot intervals. A surveyor's tape is necessary to extrapolate between the 5-foot marks.
3. Oil or other product floating on the water column can insulate the contacts of the probe on an electric sounder and give false readings. For accurate level measurements in wells containing floating product, a special oil/water level indicator is required.
4. Tapes (electrical or surveyor's) may have damaged or missing sections, or may be spliced inaccurately.
5. An airline may be the only available means to make measurements in sealed production wells but the method is generally accurate only to approximately 0.2 foot.
6. When using a steel tape, it is necessary to lower the tape below the water level in order to make a measurement. This assumes knowledge of the approximate groundwater level.

5.0 EQUIPMENT

The electric water level indicator and the chalked steel tape are the devices commonly used to measure water levels. Both have an accuracy of 0.01 feet. Other field equipment may include:

- Air monitoring instrumentation

- Well depth measurement device
- Chalk
- Ruler
- Site logbook
- Paper towels and trash bags
- Decontamination supplies as outlined in Section 7.2 or the current approved site specific work plan
- Groundwater level data forms

6.0 REAGENTS

No chemical reagents are used in this procedure; however, decontamination solutions may be necessary. If decontamination of equipment is required, refer to ERT/REAC SOP #2006 Rev 0.0 08/11/94, *Sampling Equipment Decontamination*, and the current approved site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the number of measurements needed, the methods to be employed, and the equipment and supplies needed.
2. Decontaminate or pre-clean equipment, and ensure that it is in working order.
3. Coordinate schedule with staff, clients, and regulatory agency, if appropriate.
4. If this is an initial visit, perform a general site survey prior to site entry in accordance with the current approved site specific Health and Safety Plan.
5. Identify sampling locations.

7.2 Procedures

Procedures for determining water levels are as follows:

1. If possible, and when applicable, start at those wells that are least contaminated and proceed to those wells that are most contaminated.

2. Clean all the equipment entering the well(s) by the following decontamination procedure:

    - Triple rinse equipment with deionized water.

    - Wash equipment with an Alconox solution which is followed by a deionized water rinse.

    - Rinse with an approved solvent (e.g., methanol, isopropyl alcohol, acetone) as per the work plan, if organic contamination is suspected.

    - Place equipment on clean surface such as a teflon or polyethylene sheet to air dry.

3. Remove locking well cap, note well ID, time of day, and date in site logbook or an appropriate groundwater level data form.

4. Remove well cap.

5. If required by site-specific condition, monitor headspace of well with a photoionization detector (PID) or flame ionization detector (FID) to determine presence of volatile organic compounds, and record results in site logbook.

7. Lower water-level measuring device into the well. Electrical tapes are lowered to the water surface whereas chalked steel tapes are lowered generally a foot or more below the water surface. Steel tapes are generally chalked so that a 1-to 5-foot long section will fall below the expected water level.

8. For electrical tapes record the distance from the water surface, as determined by the audio signal or meter, to the reference measuring point and record in the site logbook. For chalked tapes, an even foot mark is held at the reference point, once the chalked section of the tape is below the water level. Both the water level on the tape and the foot mark held at the reference point is recorded. The depth to the water is then the difference between the two readings. In addition, note the reference point used (top of the outer casing, top of the riser pipe, ground surface, or some other reproducible position

on the well head). Repeat the measurement.

9. Remove all downhole equipment, replace well cap and locking steel caps.

10. Rinse all downhole equipment and store for transport to the next well. Decontaminate all equipment as outlined in Step 2 above.

11. Note any physical changes, such as erosion or cracks in protective concrete pad or variation in total depth of well, in field logbook or on groundwater level data form.

8.0 CALCULATIONS

To determine groundwater elevation above mean sea level, use the following equation:

$$E_W = E - D$$

where:

E_W = Elevation of water above mean sea level (feet) or local datum
E = Elevation above sea level or local datum at point of measurement (feet)
D = Depth to water (feet)

9.0 QUALITY ASSURANCE/QUALITY CONTROL

The following general quality assurance/quality control (QA/QC) procedures apply:

1. All data must be documented on field data sheets, groundwater level data forms, or within personal or site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan.

3. Each well should be tested at least twice in order to compare results. If results do not agree to within 0.02 feet, a third measurement should be taken and the readings averaged. Consistent failure of consecutive readings to agree suggests that levels are changing because of one or more conditions as indicated in Section 1.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

The results of monitoring the well head and breathing zone with a FID or PID, as per section 7.2, may indicate the need to upgrade the personal protection level according to the current approved site Health and Safety Plan.

12.0 REFERENCES

Driscoll, F.G. 1986. Groundwater and Wells. Second Edition. Chapter 16. *Collection and Analysis of Pumping Test Data.* pp 534-579. Johnson Filtration Systems Inc. St. Paul, Minnesota.

U.S. Environmental Protection Agency, 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document, pp. 207.

U.S. Environmental Protection Agency, 1987, A Compendium of Superfund Field Operations Methods. EPA/540/p-87/001 Office of Emergency and Remedial Response Washington, D.C. 20460.

APPENDIX A
Groundwater Level Data Form
SOP #2043
February 2000

FORM 1. Groundwater Level Data Form

PAGE __ OF __

SITE NAME:____________ LOGGER NAME:____________

LOG DATE: ____________ WBS #: RIA____________

Well I.D.	Time	Elevation of well(1) (T.O.C.)	Depth to bottom of well (ft)	Depth to water (ft)	Depth to product (ft)	COMMENTS (pH, temperature, specific conductance)

TOC: top of casing (1) feet above mean sea level

MEASUREMENT REFERENCE POINT FROM __ GROUND SURFACE OR __ TOP OF CASING

Weather Conditions: Temperature(°C):__________ Rain: Heavy Medium Light (Circle one)

Other significant observations:

SEDIMENT SAMPLING

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) is applicable to the collection of representative sediment samples. Analysis of sediment may be biological, chemical, or physical in nature and may be used to determine the following:

- toxicity;
- biological availability and effects of contaminants;
- benthic biota;
- extent and magnitude of contamination;
- contaminant migration pathways and source;
- fate of contaminants;
- grain size distribution.

The methodologies discussed in this SOP are applicable to the sampling of sediment in both flowing and standing water. They are generic in nature and may be modified in whole or part to meet the handling and analytical requirements of the contaminants of concern, as well as the constraints presented by site conditions and equipment limitations. However, if modifications occur, they should be documented in a site or personal logbook and discussed in reports summarizing field activities and analytical results.

For the purposes of this procedure, sediments are those mineral and organic materials situated beneath an aqueous layer. The aqueous layer may be either static, as in lakes, ponds, and impoundments; or flowing, as in rivers and streams.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

Sediment samples may be collected using a variety of methods and equipment, depending on the depth of the aqueous layer, the portion of the sediment profile required (surface vs. subsurface), the type of sample required (disturbed vs. undisturbed), contaminants present, and sediment type.

Sediment is collected from beneath an aqueous layer either directly, using a hand held device such as a shovel, trowel, or auger; or indirectly, using a remotely activated device such as an Ekman or Ponar dredge. Following collection, sediment is transferred from the sampling device to a sample container of appropriate size and construction for the analyses requested. If composite sampling techniques are employed, multiple grabs are placed into a container constructed of inert material, homogenized, and transferred to sample containers appropriate for the analyses requested. The homogenization procedure should not be used if sample analysis includes volatile organics; in this case, sediment, or multiple grabs of sediment, should be transferred directly from the sample collection device or homogenization container to the sample container.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING AND STORAGE

1. Chemical preservation of solids is generally not recommended. Cooling to 4°C is usually the best approach, supplemented by the appropriate holding time for the analyses requested.

2. Wide mouth glass containers with Teflon lined caps are utilized for sediment samples. The sample volume is a function of the analytical requirements and will be specified in the Work Plan.

3. If analysis of sediment from a discrete depth or location is desired, sediment is transferred directly from the sampling device to a labeled sample container(s) of appropriate size and construction for the analyses

requested. Transfer is accomplished with a stainless steel or plastic lab spoon or equivalent.

4. If composite sampling techniques or multiple grabs are employed, equal portions of sediment from each location are deposited into a stainless steel, plastic, or other appropriate composition (e.g., Teflon) containers. The sediment is homogenized thoroughly to obtain a composite representative of the area sampled. The composite sediment sample is transferred to a labeled container(s) of appropriate size and construction for the analyses requested. Transfer of sediment is accomplished with a stainless steel or plastic lab spoon or equivalent. Samples for volatile organic analysis must be transferred directly from the sample collection device or pooled from multiple areas in the homogenization container prior to mixing. This is done to minimize loss of contaminant due to volatilization during homogenization.

5. All sampling devices should be decontaminated, then wrapped in aluminum foil. The sampling device should remain in this wrapping until it is needed. Each sampling device should be used for only one sample. Disposable sampling devices for sediment are generally impractical due to cost and the large number of sediment samples which may be required. Sampling devices should be cleaned in the field using the decontamination procedure described in the Sampling Equipment Decontamination SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Substrate particle size and organic matter content are a direct consequence of the flow characteristics of a waterbody. Contaminants are more likely to be concentrated in sediments typified by fine particle size and a high organic matter content. This type of sediment is most likely to be collected from depositional zones. In contrast, coarse sediments with low organic matter content do not typically concentrate pollutants and are generally found in erosional zones. The selection of a sampling location can, therefore, greatly influence the analytical results and should be justified and specified in the Work Plan.

5.0 EQUIPMENT/APPARATUS

Equipment needed for collection of sediment samples may include:

C Maps/plot plan
C Safety equipment
C Compass
C Tape measure
C Survey stakes, flags, or buoys and anchors
C Camera and film
C Stainless steel, plastic, or other appropriate composition bucket
C 4-oz., 8-oz., and one-quart wide mouth jars w/Teflon lined lids
C Ziploc plastic bags
C Logbook
C Sample jar labels
C Chain of Custody records, field data sheets
C Cooler(s)
C Ice
C Decontamination supplies/equipment
C Spade or shovel
C Spatula
C Scoop
C Trowel
C Bucket auger
C Tube auger
C Extension rods
C "T" handle
C Sediment coring device (tube, drive head, eggshell check value, nosecone, acetate tube, extension rods, "T" handle)
C Ponar dredge
C Ekman dredge
C Nylon rope or steel cable
C Messenger device

6.0 REAGENTS

Reagents are not used for preservation of sediment samples. Decontamination solutions are specified in the Sampling Equipment Decontamination SOP.

7.0 PROCEDURES

7.1 Preparation

1. Determine the objective(s) and extent of the sampling effort. The sampling methods to be employed, and the types and amounts of equipment and supplies required will be a function of site characteristics and objectives of the study.

2. Obtain the necessary sampling and monitoring equipment.

3. Prepare schedules, and coordinate with staff, client, and regulatory agencies, if appropriate.

4. Decontaminate or preclean equipment, and ensure that it is in working order.

5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.

6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors including flow regime, basin morphometry, sediment characteristics, depth of overlying aqueous layer, contaminant source, and extent and nature of contamination should be considered when selecting sample locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

7.2 Sample Collection

Selection of a sampling device is most often contingent upon: (1) the depth of water at the sampling location, and (2) the physical characteristics of the sediment to be sampled. The following procedures may be utilized:

7.2.1 Sampling Surface Sediment with a Trowel or Scoop from Beneath a Shallow Aqueous Layer

For the purpose of this method, surface sediment is considered to range from 0 to six inches in depth and a shallow aqueous layer is considered to range from 0 to 12 inches in depth. Collection of surface sediment from beneath a shallow aqueous layer can be accomplished with tools such as spades, shovels, trowels, and scoops. Although this method can be used to collect both unconsolidated/consolidated sediment, it is limited somewhat by the depth and movement of the aqueous layer. Deep and rapidly flowing water render this method less accurate than others discussed below. However, representative samples can be collected with this procedure in shallow sluggish water provided care is demonstrated by the sample team member. A stainless steel or plastic sampling implement will suffice in most applications. Care should be exercised to avoid the use of devices plated with chrome or other materials; plating is particularly common with garden trowels.

The following procedure will be used to collect sediment with a scoop, shovel, or trowel:

1. Using a decontaminated sampling implement, remove the desired thickness and volume of sediment from the sampling area.

2. Transfer the sample into an appropriate sample or homogenization container. Ensure that non-dedicated containers have been adequately decontaminated.

3. Surface water should be decanted from the sample or homogenization container prior to sealing or transfer; care should be taken to retain the fine sediment fraction during this procedure.

7.2.2 Sampling Surface Sediment with a Bucket Auger or Tube Auger from Beneath a Shallow Aqueous Layer

For the purpose of this method, surface sediment is considered to range from 0 to six inches in depth and a shallow aqueous layer is considered to range from 0 to 24 inches in depth. Collection of surface sediment from beneath a shallow aqueous layer can be accomplished with a system consisting of bucket auger or tube auger, a series of extensions, and a "T" handle (Figure 1, Appendix A). The use of additional extensions in conjunction with a bucket auger can increase the depth of water from which sediment can be collected from 24 inches to 10 feet or more. However, sample handling and manipulation increases in difficulty with increasing depth of water. The bucket auger or tube auger is driven into the sediment and used to extract a core. The various depths represented by the core are homogenized or a subsample of the core is taken from the appropriate depth.

The following procedure will be used to collect sediment samples with a bucket auger or tube auger:

1. An acetate core may be inserted into the bucket auger or tube auger prior to sampling if characteristics of the sediments or waterbody warrant. By using this technique, an intact core can be extracted.
2. Attach the auger head to the required length of extensions, then attach the "T" handle to the upper extension.
3. Clear the area to be sampled of any surface debris.
4. Insert the bucket auger or tube auger into the sediment at a 0° to 20° angle from vertical. This orientation minimizes spillage of the sample from the sampler upon extraction from the sediment and water.
5. Rotate the auger to cut a core of sediment.
6. Slowly withdraw the auger; if using a tube auger, make sure that the slot is facing upward.
7. Transfer the sample or a specified aliquot of sample into an appropriate sample or homogenization container. Ensure that non-dedicated containers have been adequately decontaminated.

7.2.3 Sampling Deep Sediment with a Bucket Auger or Tube Auger from Beneath a Shallow Aqueous Layer

For the purpose of this method, deep sediment is considered to range from six to greater than 18 inches in depth and a shallow aqueous layer is considered to range from 0 to 24 inches. Collection of deep sediment from beneath a shallow aqueous layer can be accomplished with a system consisting of a bucket auger, a tube auger, a series of extensions and a "T" handle. The use of additional extensions can increase the depth of water from which sediment can be collected from 24 inches to five feet or more. However, water clarity must be high enough to permit the sampler to directly observe the sampling operation. In addition, sample handling and manipulation increases in difficulty with increasing depth of water. The bucket auger is used to bore a hole to the upper range of the desired sampling depth and then withdrawn. The tube auger is then lowered down the borehole, and driven into the sediment to the lower range of the desired sampling depth. The tube is then withdrawn and the sample recovered from the tube. This method can be used to collect firmly consolidated sediments, but is somewhat limited by the depth of the aqueous layer, and the integrity of the initial borehole.

The following procedure will be used to collect deep sediment samples with a bucket auger and a tube auger:

1. Attach the bucket auger bit to the required lengths of extensions, then attach the "T" handle to the upper extension.
2. Clear the area to be sampled of any surface debris.
3. Begin augering, periodically removing any accumulated sediment (i.e., cuttings) from the auger bucket. Cuttings should be disposed of far enough from the sampling area to minimize cross contamination of various depths.
4. After reaching the upper range of the desired depth, slowly and carefully remove bucket auger from the boring.
5. Attach the tube auger bit to the required lengths of extensions, then attach the "T" handle to the upper extension.
6. Carefully lower tube auger down borehole using care to avoid making contact with the borehole sides and, thus, cross contaminating the sample. Gradually force tube auger into sediment to the lower range of the desired sampling depth. Hammering of the tube auger to facilitate coring should be avoided as the vibrations may cause the boring walls

to collapse.

7. Remove tube auger from the borehole, again taking care to avoid making contact with the borehole sides and, thus, cross contaminating the sample.

8. Discard the top of core (approximately 1 inch); as this represents material collected by the tube auger before penetration to the layer of concern.

9. Transfer sample into an appropriate sample or homogenization container. Ensure that non-dedicated containers have been adequately decontaminated.

7.2.4 Sampling Surface Sediment with an Ekman or Ponar Dredge from Beneath a Shallow or Deep Aqueous Layer

For the purpose of this method, surface sediment is considered to range from 0 to six inches in depth. Collection of surface sediment can be accomplished with a system consisting of a remotely activated device (dredge) and a deployment system. This technique consists of lowering a sampling device (dredge) to the surface of the sediment by use of a rope, cable, or extended handle. The mechanism is activated, and the device entraps sediment in spring loaded or lever operated jaws.

An Ekman dredge is a lightweight sediment sampling device with spring activated jaws. It is used to collect moderately consolidated, fine textured sediment. The following procedure will be used for collecting sediment with an Ekman dredge (Figure 2, Appendix A):

1. Attach a sturdy nylon rope or stainless steel cable through the hole on the top of the bracket, or secure the extension handle to the bracket with machine bolts.

2. Attach springs to both sides of the jaws. Fix the jaws so that they are in open position by placing trip cables over the release studs. Ensure that the hinged doors on the dredge top are free to open.

3. Lower the sampler to a point 4 to 6 inches above the sediment surface.

4. Drop the sampler to the sediment.

5. Trigger the jaw release mechanism by lowering a messenger down the line, or by depressing the button on the upper end of the extension handle.

6. Raise the sampler and slowly decant any free liquid through the top of the sampler. Care should be taken to retain the fine sediment fraction during this procedure.

7. Open the dredge jaws and transfer the sample into a stainless steel, plastic or other appropriate composition (e.g., Teflon) container. Ensure that non-dedicated containers have been adequately decontaminated. If necessary, continue to collect additional sediment grabs until sufficient material has been secured to fulfill analytical requirements. Thoroughly homogenize and then transfer sediment to sample containers appropriate for the analyses requested. Samples for volatile organic analysis must be collected directly from the bucket before homogenization to minimize volatilization of contaminants.

A Ponar dredge is a heavyweight sediment sampling device with weighted jaws that are lever or spring activated. It is used to collect consolidated fine to coarse textured sediment. The following procedure will be used for collecting sediment with a Ponar dredge (Figure 3, Appendix A):

1. Attach a sturdy nylon rope or steel cable to the ring provided on top of the dredge.

2. Arrange the Ponar dredge with the jaws in the open position, setting the trip bar so the sampler remains open when lifted from the top. If the dredge is so equipped, place the spring loaded pin into the aligned holes in the trip bar.

3. Slowly lower the sampler to a point approximately two inches above the sediment.

4. Drop the sampler to the sediment. Slack on

the line will release the trip bar or spring loaded pin; pull up sharply on the line closing the dredge.

5. Raise the dredge to the surface and slowly decant any free liquid through the screens on top of the dredge. Care should be taken to retain the fine sediment fraction during this operation.

6. Open the dredge and transfer the sediment to a stainless steel, plastic or other appropriate composition (e.g., Teflon) container. Ensure that non-dedicated containers have been adequately decontaminated. If necessary, continue to collect additional sediment until sufficient material has been secured to fulfill analytical requirements. Thoroughly homogenized and then transfer sediment to sample containers appropriate for the analyses requested. Samples for volatile organic analysis must be collected directly from the bucket before homogenization to minimize volatilization of contaminants.

7.2.5 Sampling Subsurface Sediment with a Coring Device from Beneath a Shallow Aqueous Layer

For purposes of this method, subsurface sediment is considered to range from 6 to 24 inches in depth and a shallow aqueous layer is considered to range from 0 to 24 inches in depth. Collection of subsurface sediment from beneath a shallow aqueous layer can be accomplished with a system consisting of a tube sampler, acetate tube, eggshell check valve, nosecone, extensions, and "T" handle, or drivehead. The use of additional extensions can increase the depth of water from which sediment can be collected from 24 inches to 10 feet or more. This sampler may be used with either a drive hammer for firm sediment, or a "T" handle for soft sediment. However, sample handling and manipulation increases in difficulty with increasing depth of water.

The following procedure describes the use of a sample coring device (Figure 4, Appendix A) used to collect subsurface sediments.

1. Assemble the coring device by inserting the acetate core into the sampling tube.

2. Insert the "egg shell" check valve into the lower end of the sampling tube with the convex surface positioned inside the acetate core.

3. Screw the nosecone onto the lower end of the sampling tube, securing the acetate tube and eggshell check valve.

4. Screw the handle onto the upper end of the sampling tube and add extension rods as needed.

5. Place the sampler in a perpendicular position on the sediment to be sampled.

6. If the "T" handle is used, place downward pressure on the device until the desired depth is reached. After the desired depth is reached, rotate the sampler to shear off the core at the bottom. Slowly withdraw the sampler from the sediment and proceed to Step 15.

7. If the drive hammer is selected, insert the tapered handle (drive head) of the drive hammer through the drive head.

8. Drive the sampler into the sediment to the desired depth.

9. Record the length of the tube that penetrated the sample material, and the number of blows required to obtain this depth.

10. Remove the drive hammer and fit the keyhole-like opening on the flat side of the hammer onto the drive head. In this position, the hammer serves as a handle for the sampler.

11. Rotate the sampler to shear off the core at the bottom.

12. Lower the sampler handle (hammer) until it just clears the two ear-like protrusions on the drive head, and rotate about 90°.

13. Slowly withdraw the sampler from the sediment. If the drivehead was used, pull the hammer upwards and dislodge the sampler from the sediment.

14. Carefully remove the coring device from the water.

15. Unscrew the nosecone and remove the eggshell check valve.

16. Slide the acetate core out of the sampler tube. Decant surface water, using care to retain the fine sediment fraction. If head space is present in the upper end, a hacksaw may be used to shear the acetate tube off at the sediment surface. The acetate core may then be capped at both ends. Indicate on the acetate tube the appropriate orientation of the sediment core using a waterproof marker. The sample may be used in this fashion, or the contents transferred to a sample or homogenization container.

17. Open the acetate tube and transfer the sediment to a stainless steel, plastic or other appropriate composition (e.g., Teflon) container. Ensure that non-dedicated containers have been adequately decontaminated. If necessary, continue to collect additional sediment until sufficient material has been secured to fulfill analytical requirements. Thoroughly homogenize and then transfer sediment to sample containers appropriate for the analyses requested. Samples for volatile organic analysis must be collected directly from the bucket before homogenization to minimize volatilization of contaminants.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA/OSHA and Corporate health and safety procedures.

More specifically, when sampling sediment from waterbodies, physical hazards must be identified and adequate precautions must be taken to ensure the safety of the sampling team. The team member collecting the sample should not get too close to the edge of the waterbody, where bank failure may cause loss of balance. To prevent this, the person performing the sampling should be on a lifeline, and be wearing adequate protective equipment. If sampling from a vessel is determined to be necessary, appropriate protective measures must be implemented.

12.0 REFERENCES

Mason, B.J., Preparation of Soil Sampling Protocol: Technique and Strategies. 1983 EPA-600/4-83-020.

Barth, D.S. and B.J. Mason, Soil Sampling Quality Assurance User's Guide. 1984 EPA-600/4-84-043.

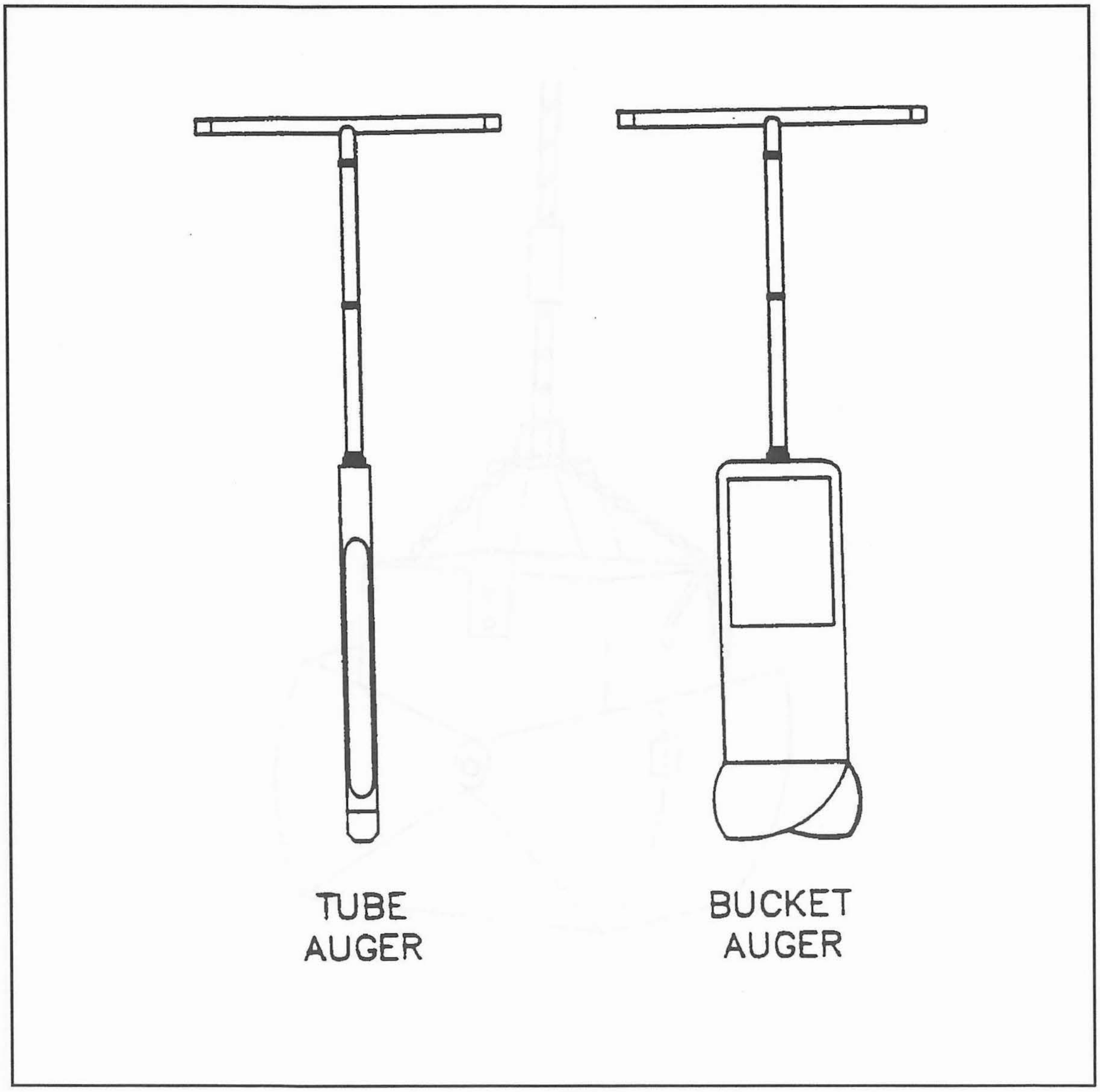
U.S. EPA. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. 1984 EPA-600/4-84-076.

de Vera, E.R., B.P. Simmons, R.D. Stephen, and D.L. Storm. Samplers and Sampling Procedures for Hazardous Waste Streams. 1980 EPA-600/2-80-018.

APPENDIX A

Figures

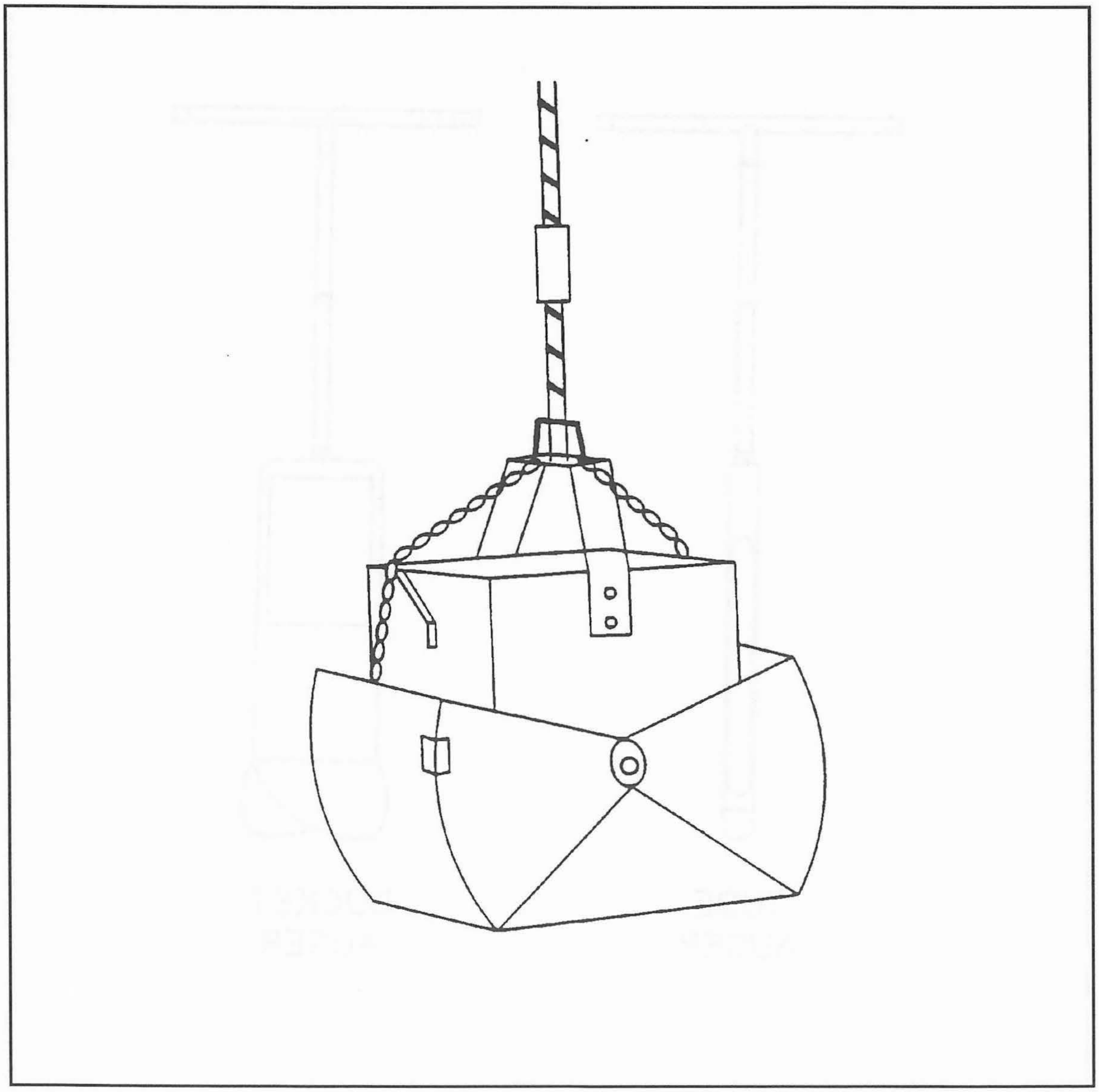
FIGURE 1. Sampling Auger



APPENDIX A (Cont'd)

Figures

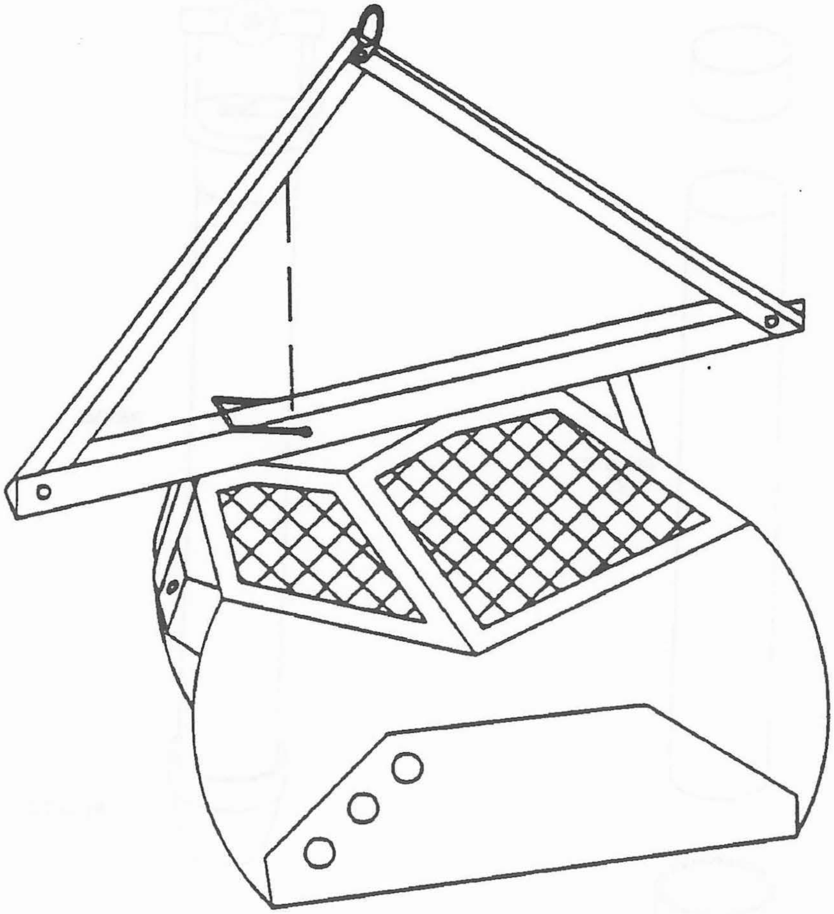
FIGURE 2. Ekman Dredge



APPENDIX A (Cont'd)

Figures

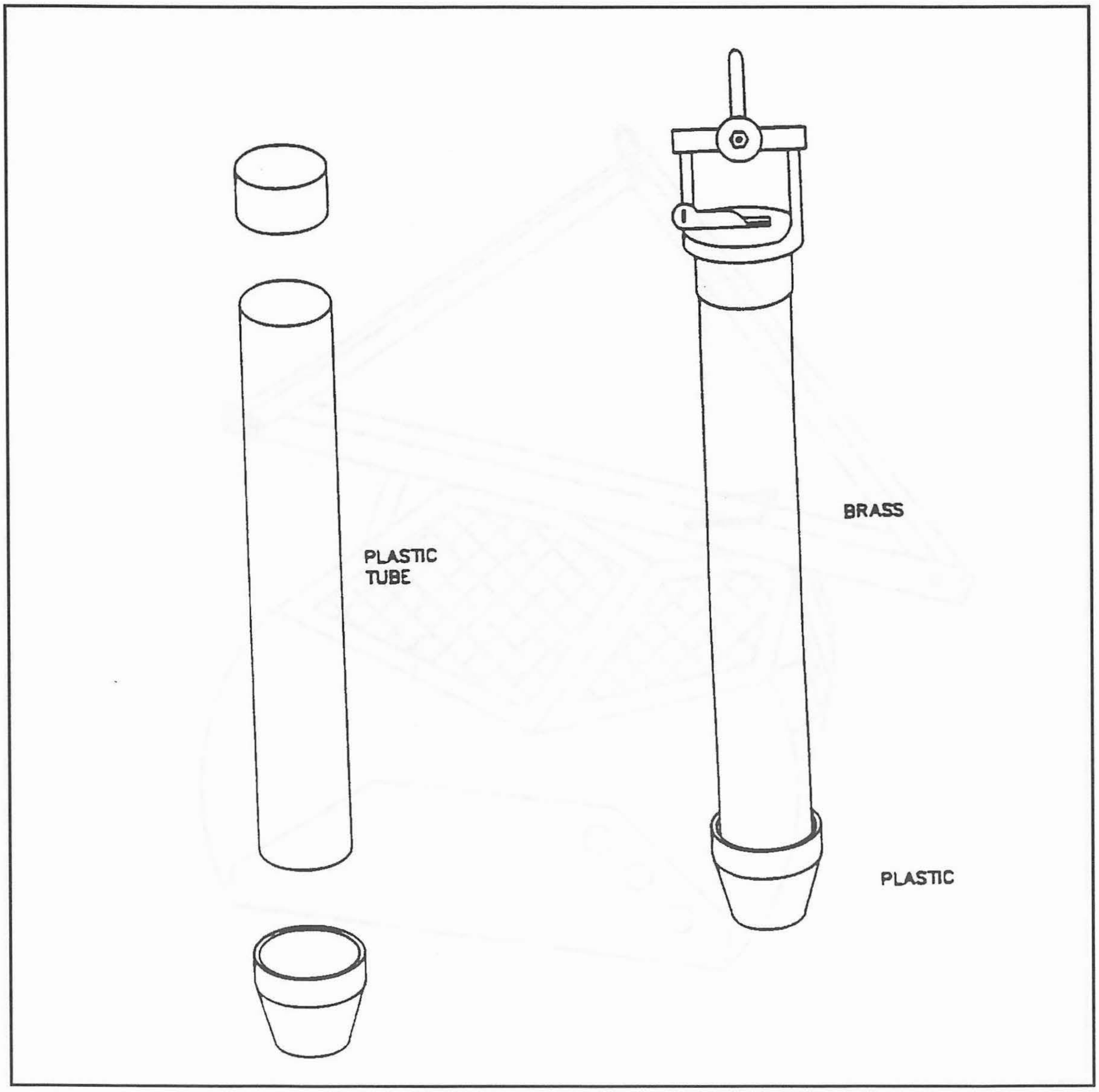
FIGURE 3. Ponar Dredge



APPENDIX A (Cont'd)

Figures

FIGURE 4. Sample Coring Device



SOP#: 2013
DATE: 11/17/94
REV. #: 0.0

SURFACE WATER SAMPLING

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) is applicable to the collection of representative liquid samples, both aqueous and non-aqueous from streams, rivers, lakes, ponds, lagoons, and surface impoundments. It includes samples collected from depth, as well as samples collected from the surface.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure or other procedure limitations. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Sampling situations vary widely, therefore, no universal sampling procedure can be recommended. However, sampling of both aqueous and non-aqueous liquids from the above mentioned sources is generally accomplished through the use of one of the following samplers or techniques:

C Kemmerer bottle
C Bacon bomb sampler
C Dip sampler
C Direct method

These sampling techniques will allow for the collection of representative samples from the majority of surface waters and impoundments encountered.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Once samples have been collected, the following procedure should be followed:

1. Transfer the sample(s) into suitable, labeled sample containers.
2. Preserve the sample if appropriate, or use pre-preserved sample bottles. Do not overfill bottles if they are pre-preserved.
3. Cap the container, place in a ziploc plastic bag and cool to 4°C.
4. Record all pertinent data in the site logbook and on field data sheets.
5. Complete the Chain of Custody record.
6. Attach custody seals to cooler prior to shipment.
7. Decontaminate all sampling equipment prior to the collection of additional samples with that sampling device.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary interferences or potential problems with surface water sampling. These include cross contamination of samples and improper sample collection.

1. Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Refer to the Sampling Equipment Decontamination SOP.

2. Improper sample collection can involve using contaminated equipment, disturbance of the stream or impoundment substrate, and sampling in an obviously disturbed area.

Following proper decontamination procedures and minimizing disturbance of the sample site will eliminate these problems.

5.0 EQUIPMENT/APPARATUS

Equipment needed for collection of surface water samples may include (depending on technique chosen):

C Kemmerer bottles
C Bacon bomb sampler
C Dip sampler
C Line and messengers
C Sample bottles/preservatives
C Ziploc bags
C Ice
C Coolers
C Chain of Custody records, custody seals
C Field data sheets
C Decontamination equipment
C Maps/plot plan
C Safety equipment
C Compass
C Tape measure
C Survey stakes, flags, or buoys and anchors
C Camera and film
C Logbook/waterproof pen
C Sample bottle labels

6.0 REAGENTS

Reagents will be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.

2. Obtain the necessary sampling and monitoring equipment.

3. Decontaminate or pre-clean equipment, and ensure that it is in working order.

4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.

5. Perform a general site survey prior to site entry, in accordance with the site specific Health and Safety Plan.

6. Use stakes, flagging, or buoys to identify and mark all sampling locations. If required the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. If collecting sediment samples, this procedure may disturb the bottom.

7.2 Representative Sampling Considerations

In order to collect a representative sample, the hydrology and morphometrics of a stream or impoundment should be determined prior to sampling. This will aid in determining the presence of phases or layers in lagoons, or impoundments, flow patterns in streams, and appropriate sample locations and depths.

Water quality data should be collected in impoundments, and to determine if stratification is present. Measurements of dissolved oxygen, pH, and temperature can indicate if strata exist which would effect analytical results. Measurements should be collected at one-meter intervals from the substrate to the surface using the appropriate instrument (i.e., a Hydrolab or equivalent).

Water quality measurements such as dissolved oxygen, pH, temperature, conductivity, and oxidation-reduction potential can assist in the interpretation of analytical data and the selection of sampling sites and depths when surface water samples are collected.

Generally, the deciding factors in the selection of a sampling device for sampling liquids in streams, rivers, lakes, ponds, lagoons, and surface impoundments are:

1. Will the sample be collected from shore or from a boat?
2. What is the desired depth at which you wish to collect the sample?
3. What is the overall depth and flow direction of river or stream?
4. What type of sample will be collected (i.e., water or lagoon liquids)?

7.2.1 Sampler Composition

The appropriate sampling device must be of a proper composition. Selection of samplers constructed of glass, stainless steel, PVC or PFTE (Teflon) should be based upon the analyses to be performed.

7.3 Sample Collection

7.3.1 Kemmerer Bottle

A Kemmerer bottle (Figure 1, Appendix A) may be used in most situations where site access is from a boat or structure such as a bridge or pier, and where samples at depth are required. Sampling procedures are as follows:

1. Use a properly decontaminated Kemmerer bottle. Set the sampling device so that the sampling end pieces (upper and lower stoppers) are pulled away from the sampling tube (body), allowing the substance to be sampled to pass through this tube.
2. Lower the pre-set sampling device to the predetermined depth. Avoid bottom disturbance.
3. When the Kemmerer bottle is at the required depth, send down the messenger, closing the sampling device.
4. Retrieve the sampler and discharge from the bottom drain the first 10-20 mL to clear any potential contamination of the valve. Transfer the sample to the appropriate sample container.

7.3.2 Bacon Bomb Sampler

A bacon bomb sampler (Figure 2, Appendix A) may be used in situations similar to those outlined for the Kemmerer bottle. Sampling procedures are as follows:

1. Lower the bacon bomb sampler carefully to the desired depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line until taut. This will allow the sampler to fill.
2. Release the trigger line and retrieve the sampler.
3. Transfer the sample to the appropriate sample container by pulling up on the trigger.

7.3.3 Dip Sampler

A dip sampler (Figure 3, Appendix A) is useful in situations where a sample is to be recovered from an outfall pipe or along a lagoon bank where direct access is limited. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:

1. Assemble the device in accordance with the manufacturer's instructions.
2. Extend the device to the sample location and collect the sample by dipping the sampler into the substance.
3. Retrieve the sampler and transfer the sample to the appropriate sample container.

7.3.4 Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples from the surface directly into the sample bottle. This method is not to be used for sampling lagoons or other impoundments where contact with contaminants is a concern.

Using adequate protective clothing, access the sampling station by appropriate means. For shallow stream stations, collect the sample under the water surface while pointing the sample container upstream; the container must be upstream of the collector. Avoid disturbing the substrate. For lakes and other impoundments, collect the sample under the water surface avoiding surface debris and the boat wake.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.
2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and corporate health and safety procedures.

More specifically, when sampling lagoons or surface impoundments containing known or suspected hazardous substances, adequate precautions must be taken to ensure the safety of sampling personnel. The sampling team member collecting the sample should not get too close to the edge of the impoundment, where bank failure may cause him/her to lose his/her balance. The person performing the sampling should be on a lifeline and be wearing adequate protective equipment. When conducting sampling from a boat in an impoundment or flowing waters, appropriate boating safety procedures should be followed.

12.0 REFERENCES

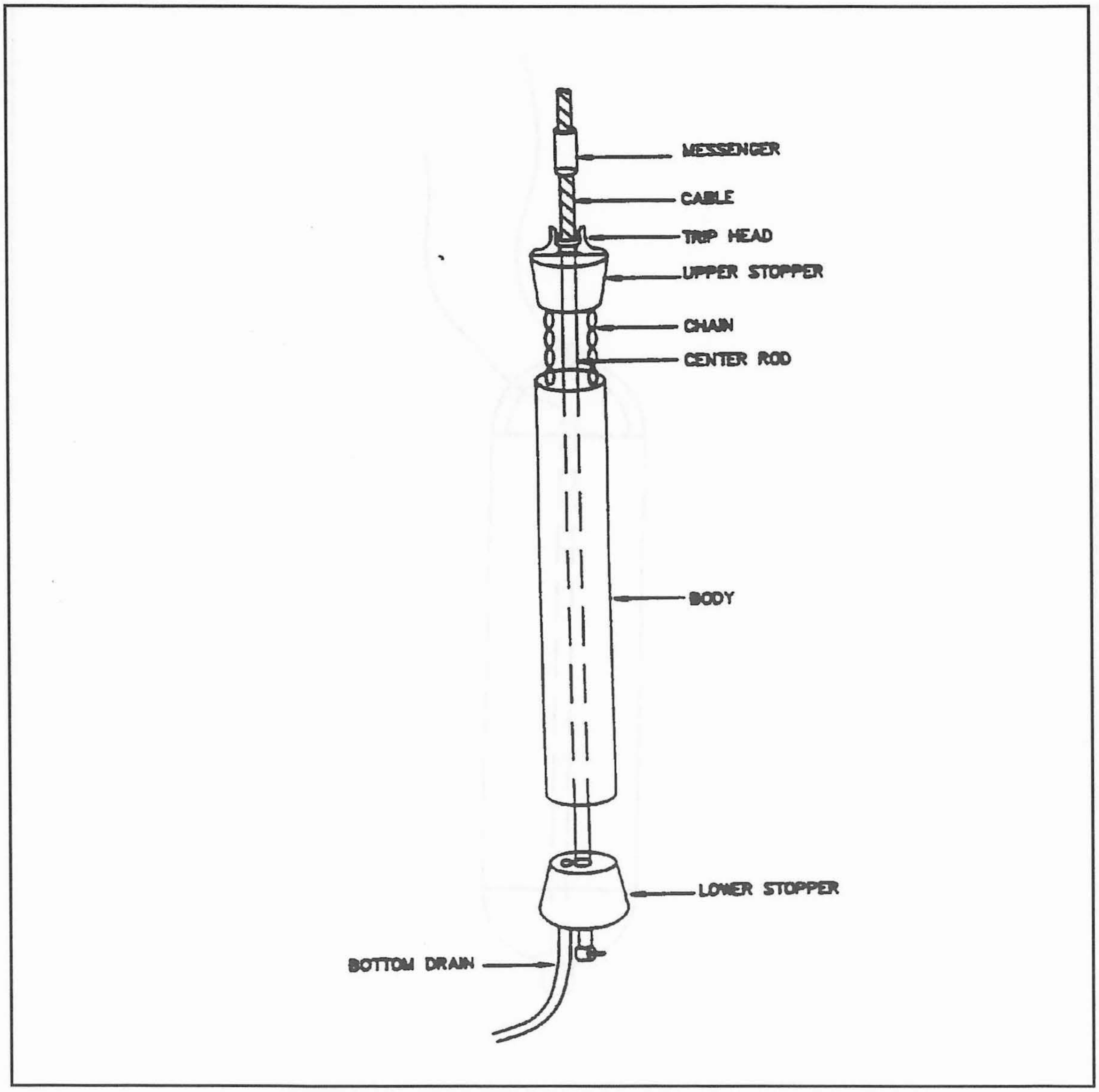
U.S. Geological Survey. 1977. National Handbook or Recommended Methods for Water Data Acquisition. Office of Water Data Coordination Reston, Virginia. (Chapter Updates available).

U.S. Environmental Protection Agency. 1984. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. EPA/600/4-84-076.

APPENDIX A

Figures

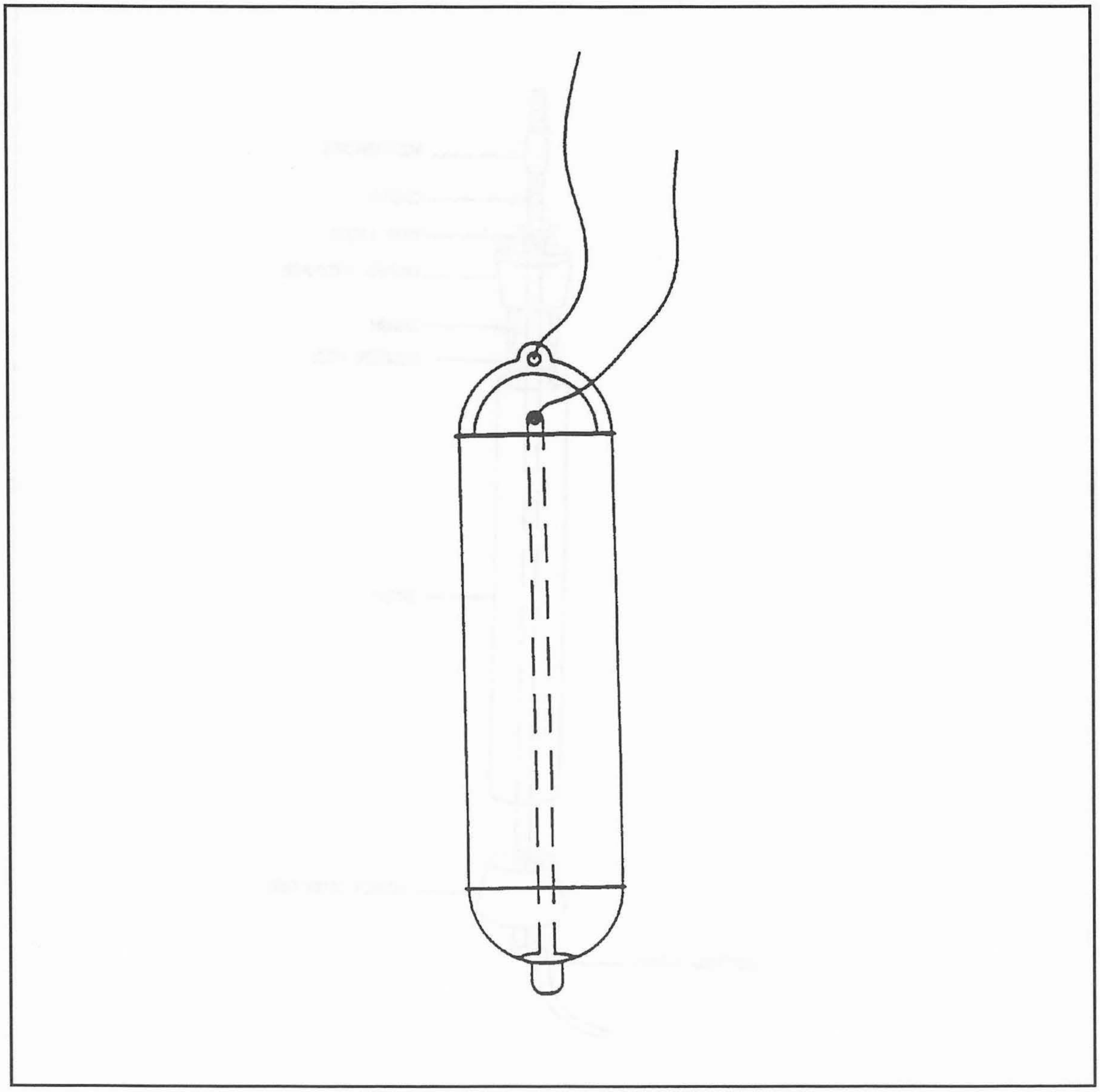
FIGURE 1. Kemmerer Bottle



APPENDIX A (Cont'd)

Figures

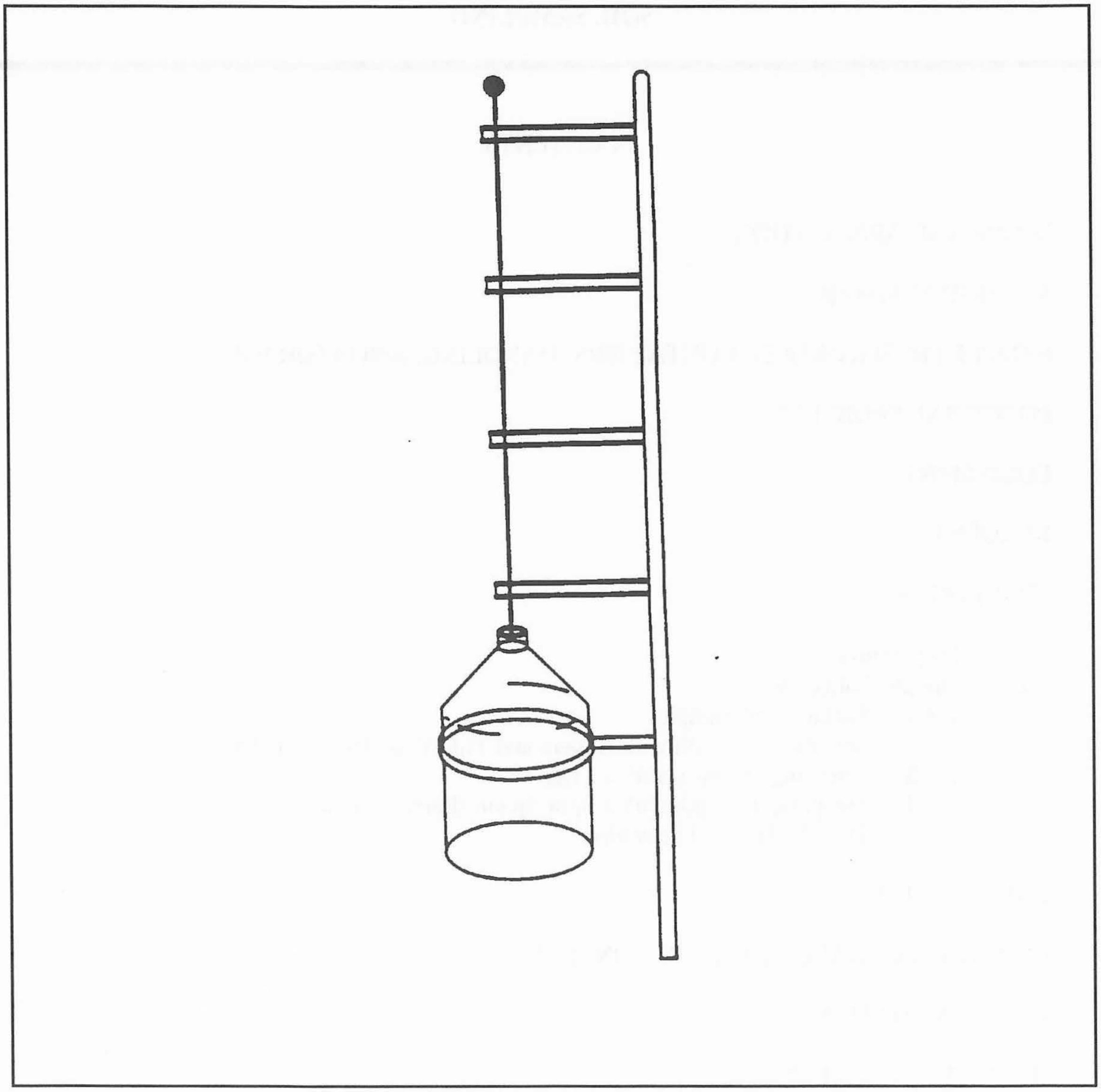
FIGURE 2. Bacon Bomb Sampler



APPENDIX A (Cont'd)

Figures

FIGURE 3. Dip Sampler



U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 1 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

CONTENTS

SUPERCEDES: SOP #2012; Revision 0.0; 11/16/94; U.S. EPA Contract 68-C4-0022.

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to describe the procedures for the collection of representative soil samples. Sampling depths are assumed to be those that can be reached without the use of a drill rig, direct-push, or other mechanized equipment (except for a back-hoe). Analysis of soil samples may determine whether concentrations of specific pollutants exceed established action levels, or if the concentrations of pollutants present a risk to public health, welfare, or the environment.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be easily sampled using a spade, trowel, and scoop. Sampling at greater depths may be performed using a hand auger, continuous flight auger, a trier, a split-spoon, or, if required, a backhoe.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Chemical preservation of solids is not generally recommended. Samples should, however, be cooled and protected from sunlight to minimize any potential reaction. The amount of sample to be collected and proper sample container type are discussed in ERT/REAC SOP #2003 Rev. 0.0 08/11/94, *Sample Storage, Preservation and Handling.*

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary potential problems associated with soil sampling - cross contamination of samples and improper sample collection. Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample, or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

5.0 EQUIPMENT

Soil sampling equipment includes the following:

- Maps/plot plan
- Safety equipment, as specified in the site-specific Health and Safety Plan
- Survey equipment or global positioning system (GPS) to locate sampling points
- Tape measure
- Survey stakes or flags
- Camera and film
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- Appropriate size sample containers
- Ziplock plastic bags
- Logbook
- Labels
- Chain of Custody records and custody seals
- Field data sheets and sample labels
- Cooler(s)
- Ice
- Vermiculite
- Decontamination supplies/equipment
- Canvas or plastic sheet
- Spade or shovel
- Spatula
- Scoop
- Plastic or stainless steel spoons
- Trowel(s)
- Continuous flight (screw) auger
- Bucket auger
- Post hole auger
- Extension rods
- T-handle
- Sampling trier
- Thin wall tube sampler
- Split spoons
- Vehimeyer soil sampler outfit
    - Tubes
    - Points
    - Drive head
    - Drop hammer
    - Puller jack and grip
- Backhoe

6.0 REAGENTS

Reagents are not used for the preservation of soil samples. Decontamination solutions are specified in ERT/REAC SOP #2006 Rev. 0.0 08/11/94, *Sampling Equipment Decontamination*, and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment, and ensure that it is in working order.
4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.
6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator (OSC) prior to soil sampling; and utility clearance should always be confirmed before beginning work.

7.2 Sample Collection

7.2.1 Surface Soil Samples

Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. Surface material is removed to the required depth and a stainless steel or plastic scoop is then used to collect the sample.

This method can be used in most soil types but is limited to sampling at or near the ground surface. Accurate, representative samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member. A flat, pointed mason trowel to cut a block of the desired soil is helpful when undisturbed profiles are required. Tools plated with chrome or other materials should not be used. Plating is particularly common with garden implements such as potting trowels.

The following procedure is used to collect surface soil samples:

1. Carefully remove the top layer of soil or debris to the desired sample depth with a pre-cleaned spade.

2. Using a pre-cleaned, stainless steel scoop, plastic spoon, or trowel, remove and discard a thin layer of soil from the area which came in contact with the spade.

3. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.2 Sampling at Depth with Augers and Thin Wall Tube Samplers

This system consists of an auger, or a thin-wall tube sampler, a series of extensions, and a "T" handle (Figure 1, Appendix A). The auger is used to bore a hole to a desired sampling depth, and is then withdrawn. The sample may be collected directly from the auger. If a core sample is to be collected, the auger tip is then replaced with a thin wall tube sampler. The system is then lowered down the borehole, and driven into the soil to the completion depth. The system is withdrawn and the core is collected from the thin wall tube sampler.

Several types of augers are available; these include: bucket type, continuous flight (screw), and post-hole augers. Bucket type augers are better for direct sample recovery because they provide a large volume of sample in a short time. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

The following procedure is used for collecting soil samples with the auger:

1. Attach the auger bit to a drill rod extension, and attach the "T" handle to the drill rod.

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first three to six inches of surface soil for an area approximately six inches in radius around the drilling location.

3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the hole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.

4. After reaching the desired depth, slowly and carefully remove the auger from the hole. When sampling directly from the auger, collect the sample after the auger is removed from the hole and proceed to Step 10.

5. Remove auger tip from the extension rods and replace with a pre-cleaned thin wall tube sampler. Install the proper cutting tip.

6. Carefully lower the tube sampler down the borehole. Gradually force the tube sampler into the soil. Do not scrape the borehole sides. Avoid hammering the rods as the vibrations may cause the boring walls to collapse.

7. Remove the tube sampler, and unscrew the drill rods.

8. Remove the cutting tip and the core from the device.

9. Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.

10. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly.

    When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

11. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and follow steps 3 through 11, making sure to decontaminate the auger and tube sampler between samples.

12. Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

7.2.3 Sampling with a Trier

The system consists of a trier, and a "T" handle. The auger is driven into the soil to be sampled and used to extract a core sample from the appropriate depth.

The following procedure is used to collect soil samples with a sampling trier:

1. Insert the trier (Figure 2, Appendix A) into the material to be sampled at a 0° to 45° angle from horizontal. This orientation minimizes the spillage of sample.

2. Rotate the trier once or twice to cut a core of material.

3. Slowly withdraw the trier, making sure that the slot is facing upward.

4. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.4 Sampling at Depth with a Split Spoon (Barrel) Sampler

Split spoon sampling is generally used to collect undisturbed soil cores of 18 or 24 inches in length. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted.

When split spoon sampling is performed to gain geologic information, all work should be performed in accordance with ASTM D1586-98, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils".

The following procedures are used for collecting soil samples with a split spoon:

1. Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.

2. Place the sampler in a perpendicular position on the sample material.

3. Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.

4. Record in the site logbook or on field data sheets the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.

5. Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler is typically available in 2 and 3 1/2 inch diameters. A larger barrel may be necessary to obtain the required sample volume.

6. Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

7.2.5 Test Pit/Trench Excavation

A backhoe can be used to remove sections of soil, when detailed examination of soil characteristics are required. This is probably the most expensive sampling method because of the relatively high cost of backhoe operation.

The following procedures are used for collecting soil samples from test pits or trenches:

1. Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities.

2. Review the site specific Health & Safety plan and ensure that all safety precautions including appropriate monitoring equipment are installed as required.

3. Using the backhoe, excavate a trench approximately three feet wide and approximately one foot deep below the cleared sampling location. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.

4. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.

5. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket.

6. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7. Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration

activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OHSA and corporate health and safety procedures, in addition to the procedures specified in the site specific Health & Safety Plan..

12.0 REFERENCES

Mason, B.J. 1983. Preparation of Soil Sampling Protocol: Technique and Strategies. EPA-600/4-83-020.

Barth, D.S. and B.J. Mason. 1984. Soil Sampling Quality Assurance User's Guide. EPA-600/4-84-043.

U.S. Environmental Protection Agency. 1984 Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. EPA-600/4-84-076.

de Vera, E.R., B.P. Simmons, R.D. Stephen, and D.L. Storm. 1980. Samplers and Sampling Procedures for Hazardous Waste Streams. EPA-600/2-80-018.

ASTM D 1586-98, ASTM Committee on Standards, Philadelphia, PA.

APPENDIX A
Figures
SOP #2012
February 2000

FIGURE 1. Sampling Augers

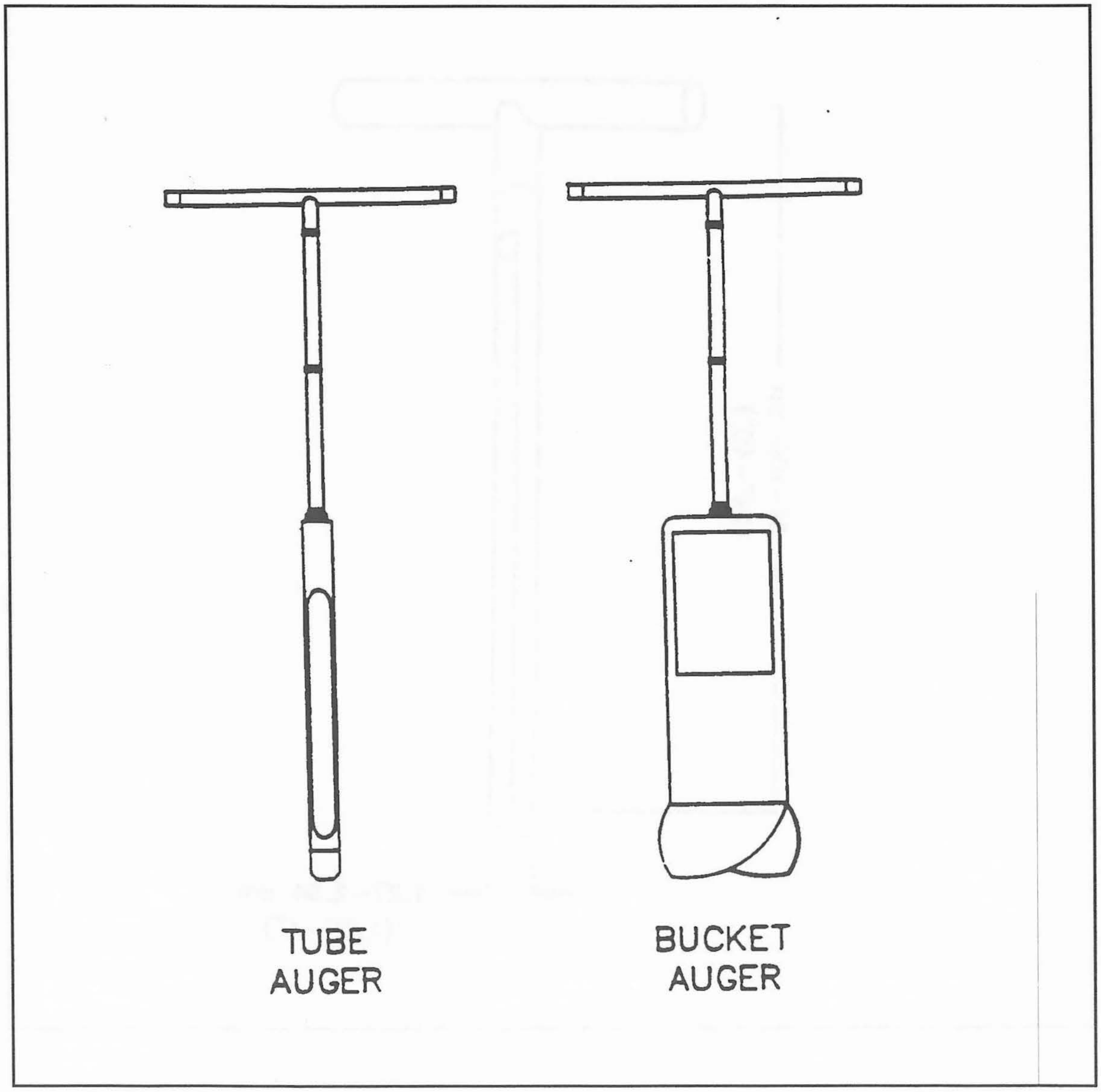
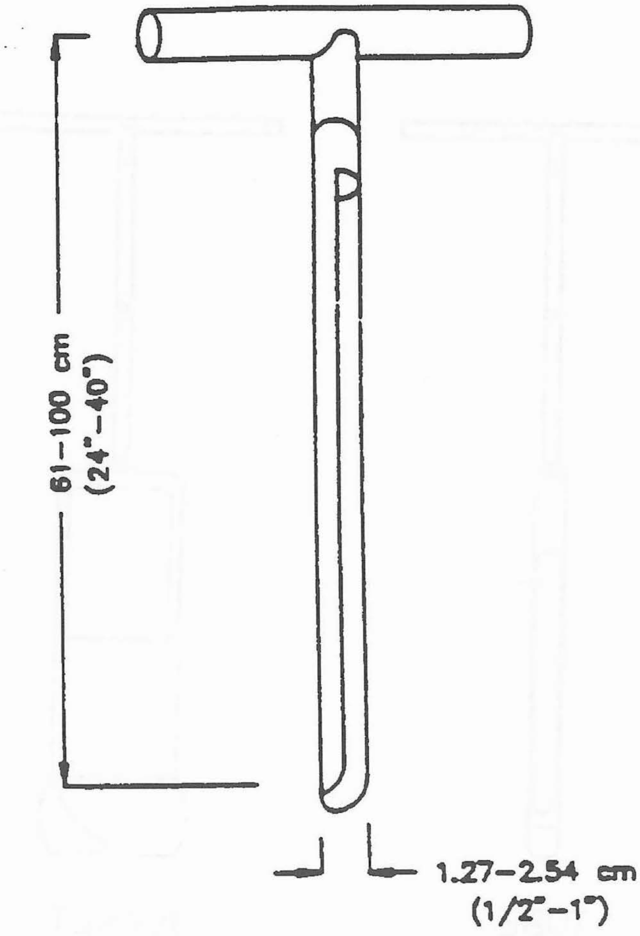


FIGURE 2. Sampling Trier



SAMPLING EQUIPMENT DECONTAMINATION

SOP#: 2006
DATE: 08/11/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide a description of the methods used for preventing, minimizing, or limiting cross-contamination of samples due to inappropriate or inadequate equipment decontamination and to provide general guidelines for developing decontamination procedures for sampling equipment to be used during hazardous waste operations as per 29 Code of Federal Regulations (CFR) 1910.120. This SOP does not address personnel decontamination.

These are standard (i.e. typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitation, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

2.0 METHOD SUMMARY

Removing or neutralizing contaminants from equipment minimizes the likelihood of sample cross contamination, reduces or eliminates transfer of contaminants to clean areas, and prevents the mixing of incompatible substances.

Gross contamination can be removed by physical decontamination procedures. These abrasive and non-abrasive methods include the use of brushes, air and wet blasting, and high and low pressure water cleaning.

The first step, a soap and water wash, removes all visible particulate matter and residual oils and grease. This may be preceded by a steam or high pressure water wash to facilitate residuals removal. The second step involves a tap water rinse and a distilled/deionized water rinse to remove the detergent. An acid rinse provides a low pH media for trace metals removal and is included in the decontamination process if metal samples are to be collected. It is followed by another distilled/deionized water rinse. If sample analysis does not include metals, the acid rinse step can be omitted. Next, a high purity solvent rinse is performed for trace organics removal if organics are a concern at the site. Typical solvents used for removal of organic contaminants include acetone, hexane, or water. Acetone is typically chosen because it is an excellent solvent, miscible in water, and not a target analyte on the Priority Pollutant List. If acetone is known to be a contaminant of concern at a given site or if Target Compound List analysis (which includes acetone) is to be performed, another solvent may be substituted. The solvent must be allowed to evaporate completely and then a final distilled/deionized water rinse is performed. This rinse removes any residual traces of the solvent.

The decontamination procedure described above may be summarized as follows:

1. Physical removal
2. Non-phosphate detergent wash
3. Tap water rinse
4. Distilled/deionized water rinse
5. 10% nitric acid rinse
6. Distilled/deionized water rinse
7. Solvent rinse (pesticide grade)
8. Air dry
9. Distilled/deionized water rinse

If a particular contaminant fraction is not present at the site, the nine (9) step decontamination procedure specified above may be modified for site specificity. For example, the nitric acid rinse may be eliminated if metals are not of concern at a site. Similarly, the solvent rinse may be eliminated if organics are not of concern at a site. Modifications to the standard procedure should be documented in the site specific work plan or subsequent report.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest.
More specifically, sample collection and analysis of decontamination waste may be required before beginning proper disposal of decontamination liquids and solids generated at a site. This should be determined prior to initiation of site activities.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

- The use of distilled/deionized water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment provided that it has been verified by laboratory analysis to be analyte free (specifically for the contaminants of concern).

- The use of an untreated potable water supply is not an acceptable substitute for tap water. Tap water may be used from any municipal or industrial water treatment system.

- If acids or solvents are utilized in decontamination they raise health and safety, and waste disposal concerns.

- Damage can be incurred by acid and solvent washing of complex and sophisticated sampling equipment.

5.0 EQUIPMENT/APPARATUS

Decontamination equipment, materials, and supplies are generally selected based on availability. Other considerations include the ease of decontaminating or disposing of the equipment. Most equipment and supplies can be easily procured. For example, soft-bristle scrub brushes or long-handled bottle brushes can be used to remove contaminants. Large galvanized wash tubs, stock tanks, or buckets can hold wash and rinse solutions. Children's wading pools can also be used. Large plastic garbage cans or other similar containers lined with plastic bags can help segregate contaminated equipment. Contaminated liquid can be stored temporarily in metal or plastic cans or drums.

The following standard materials and equipment are recommended for decontamination activities:

5.1 Decontamination Solutions

- Non-phosphate detergent
- Selected solvents (acetone, hexane, nitric acid, etc.)
- Tap water
- Distilled or deionized water

5.2 Decontamination Tools/Supplies

- Long and short handled brushes
- Bottle brushes
- Drop cloth/plastic sheeting
- Paper towels
- Plastic or galvanized tubs or buckets
- Pressurized sprayers (H_2O)
- Solvent sprayers
- Aluminum foil

5.3 Health and Safety Equipment

Appropriate personal protective equipment (i.e., safety glasses or splash shield, appropriate gloves, aprons or coveralls, respirator, emergency eye wash)

5.4 Waste Disposal

- Trash bags
- Trash containers
- 55-gallon drums
- Metal/plastic buckets/containers for storage and disposal of decontamination solutions

6.0 REAGENTS

There are no reagents used in this procedure aside from the actual decontamination solutions. Table 1 (Appendix A) lists solvent rinses which may be required for elimination of particular chemicals. In general, the following solvents are typically utilized for decontamination purposes:

C 10% nitric acid is typically used for inorganic compounds such as metals. An acid rinse may not be required if inorganics are not a contaminant of concern.

C Acetone (pesticide grade)(1)

C Hexane (pesticide grade)(1)

C Methanol(1)

(1) - Only if sample is to be analyzed for organics.

7.0 PROCEDURES

As part of the health and safety plan, a decontamination plan should be developed and reviewed. The decontamination line should be set up before any personnel or equipment enter the areas of potential exposure. The equipment decontamination plan should include:

C The number, location, and layout of decontamination stations.

C Decontamination equipment needed.

C Appropriate decontamination methods.

C Methods for disposal of contaminated clothing, equipment, and solutions.

C Procedures can be established to minimize the potential for contamination. This may include: (1) work practices that minimize contact with potential contaminants; (2) using remote sampling techniques; (3) covering monitoring and sampling equipment with plastic, aluminum foil, or other protective material; (4) watering down dusty areas; (5) avoiding laying down equipment in areas of obvious contamination; and (6) use of disposable sampling equipment.

7.1 Decontamination Methods

All samples and equipment leaving the contaminated area of a site must be decontaminated to remove any contamination that may have adhered to equipment. Various decontamination methods will remove contaminants by: (1) flushing or other physical action, or (2) chemical complexing to inactivate contaminants by neutralization, chemical reaction, disinfection, or sterilization.

Physical decontamination techniques can be grouped into two categories: abrasive methods and non-abrasive methods, as follows:

7.1.1 Abrasive Cleaning Methods

Abrasive cleaning methods work by rubbing and wearing away the top layer of the surface containing the contaminant. The mechanical abrasive cleaning methods are most commonly used at hazardous waste sites. The following abrasive methods are available:

Mechanical

Mechanical methods of decontamination include using metal or nylon brushes. The amount and type of contaminants removed will vary with the hardness of bristles, length of time brushed, degree of brush contact, degree of contamination, nature of the surface being cleaned, and degree of contaminant adherence to the surface.

Air Blasting

Air blasting equipment uses compressed air to force abrasive material through a nozzle at high velocities. The distance between nozzle and surface cleaned, air pressure, time of application, and angle at which the abrasive strikes the surface will dictate cleaning efficiency. Disadvantages of this method are the inability to control the amount of material removed and the large amount of waste generated.

Wet Blasting

Wet blast cleaning involves use of a suspended fine abrasive. The abrasive/water mixture is delivered by compressed air to the contaminated area. By using a very fine abrasive, the amount of materials removed can be carefully controlled.

7.1.2 Non-Abrasive Cleaning Methods

Non-abrasive cleaning methods work by forcing the contaminant off a surface with pressure. In general, the equipment surface is not removed using non-abrasive methods.

Low-Pressure Water

This method consists of a container which is filled with water. The user pumps air out of the container to create a vacuum. A slender nozzle and hose allow the user to spray in hard-to-reach places.

High-Pressure Water

This method consists of a high-pressure pump, an operator controlled directional nozzle, and a high-pressure hose. Operating pressure usually ranges from 340 to 680 atmospheres (atm) and flow rates usually range from 20 to 140 liters per minute.

Ultra-High-Pressure Water

This system produces a water jet that is pressured from 1,000 to 4,000 atmospheres. This ultra-high-pressure spray can remove tightly-adhered surface films. The water velocity ranges from 500 meters/second (m/s) (1,000 atm) to 900 m/s (4,000 atm). Additives can be used to enhance the cleaning action.

Rinsing

Contaminants are removed by rinsing through dilution, physical attraction, and solubilization.

Damp Cloth Removal

In some instances, due to sensitive, non-waterproof equipment or due to the unlikelihood of equipment being contaminated, it is not necessary to conduct an extensive decontamination procedure. For example, air sampling pumps hooked on a fence, placed on a drum, or wrapped in plastic bags are not likely to become heavily contaminated. A damp cloth should be used to wipe off contaminants which may have adhered to equipment through airborne contaminants or from surfaces upon which the equipment was set.

Disinfection/Sterilization

Disinfectants are a practical means of inactivating infectious agents. Unfortunately, standard sterilization methods are impractical for large equipment. This method of decontamination is typically performed off-site.

7.2 Field Sampling Equipment Decontamination Procedures

The decontamination line is setup so that the first station is used to clean the most contaminated item. It progresses to the last station where the least contaminated item is cleaned. The spread of contaminants is further reduced by separating each decontamination station by a minimum of three (3) feet. Ideally, the contamination should decrease as the equipment progresses from one station to another farther along in the line.

A site is typically divided up into the following boundaries: Hot Zone or Exclusion Zone (EZ), the Contamination Reduction Zone (CRZ), and the Support or Safe Zone (SZ). The decontamination line should be setup in the Contamination Reduction Corridor (CRC) which is in the CRZ. Figure 1 (Appendix B) shows a typical contaminant reduction zone layout. The CRC controls access into and out of the exclusion zone and confines decontamination activities to a limited area. The CRC boundaries should be conspicuously marked. The far end is the hotline, the boundary between the exclusion zone and the contamination reduction zone. The size of the decontamination corridor depends on the number of stations in the decontamination process, overall dimensions of the work zones, and amount of space available at the site. Whenever possible, it should be a straight line.

Anyone in the CRC should be wearing the level of protection designated for the decontamination crew. Another corridor may be required for the entry and exit of heavy equipment. Sampling and monitoring equipment and sampling supplies are all maintained outside of the CRC. Personnel don their equipment away from the CRC and enter the exclusion zone through a separate access control point at the hotline. One person (or more) dedicated to decontaminating equipment is recommended.

7.2.1 Decontamination Setup

Starting with the most contaminated station, the decontamination setup should be as follows:

Station 1: Segregate Equipment Drop

Place plastic sheeting on the ground (Figure 2, Appendix B). Size will depend on amount of equipment to be decontaminated. Provide containers lined with plastic if equipment is to be segregated. Segregation may be required if sensitive equipment or mildly contaminated equipment is used at the same time as equipment which is likely to be heavily contaminated.

Station 2: Physical Removal With A High-Pressure Washer (Optional)

As indicated in 7.1.2, a high-pressure wash may be required for compounds which are difficult to remove by washing with brushes. The elevated temperature of the water from the high-pressure washers is excellent at removing greasy/oily compounds. High pressure washers require water and electricity.

A decontamination pad may be required for the high-pressure wash area. An example of a wash pad may consist of an approximately 1 1/2 foot-deep basin lined with plastic sheeting and sloped to a sump at one corner. A layer of sand can be placed over the plastic and the basin is filled with gravel or shell. The sump is also lined with visqueen and a barrel is placed in the hole to prevent collapse. A sump pump is used to remove the water from the sump for transfer into a drum.

Typically heavy machinery is decontaminated at the end of the day unless site sampling requires that the machinery be decontaminated frequently. A separate decontamination pad may be required for heavy equipment.

Station 3: Physical Removal With Brushes And A Wash Basin

Prior to setting up Station 3, place plastic sheeting on the ground to cover areas under Station 3 through Station 10.
Fill a wash basin, a large bucket, or child's swimming pool with non-phosphate detergent and tap water. Several bottle and bristle brushes to physically remove contamination should be dedicated to this station . Approximately 10 - 50 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 4: Water Basin

Fill a wash basin, a large bucket, or child's swimming pool with tap water. Several bottle and bristle brushes should be dedicated to this station. Approximately 10-50 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 5: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to contain the water during the rinsing process. Approximately 10-20 gallons of water may be required initially depending upon the amount of equipment to decontaminate and the amount of gross contamination.

Station 6: Nitric Acid Sprayers

Fill a spray bottle with 10% nitric acid. An acid rinse may not be required if inorganics are not a contaminant of concern. The amount of acid will depend on the amount of equipment to be decontaminated. Provide a 5-gallon bucket or basin to collect acid during the rinsing process.

Station 7: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to collect water during the rinsate process.

Station 8: Organic Solvent Sprayers

Fill a spray bottle with an organic solvent. After each solvent rinse, the equipment should be rinsed with distilled/deionized water and air dried. Amount of solvent will depend on the amount of equipment to decontaminate. Provide a 5-gallon bucket or basin to collect the solvent during the rinsing process.

Solvent rinses may not be required unless organics are a contaminant of concern, and may be eliminated from the station sequence.

Station 9: Low-Pressure Sprayers

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to collect water during the rinsate process.

Station 10: Clean Equipment Drop

Lay a clean piece of plastic sheeting over the bottom plastic layer. This will allow easy removal of the plastic in the event that it becomes dirty. Provide aluminum foil, plastic, or other protective material to wrap clean equipment.

7.2.2 Decontamination Procedures

Station 1: Segregate Equipment Drop

Deposit equipment used on-site (i.e., tools, sampling devices and containers, monitoring instruments radios, clipboards, etc.) on the plastic drop cloth/sheet or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross contamination. Loose leaf sampling data sheets or maps can be placed in plastic zip lock bags if contamination is evident.

Station 2: Physical Removal With A High-Pressure Washer (Optional)

Use high pressure wash on grossly contaminated equipment. Do not use high- pressure wash on sensitive or non-waterproof equipment.

Station 3: Physical Removal With Brushes And A Wash Basin

Scrub equipment with soap and water using bottle and bristle brushes. Only sensitive equipment (i.e., radios, air monitoring and sampling equipment) which is waterproof should be washed. Equipment which is not waterproof should have plastic bags removed and wiped down with a damp cloth. Acids and organic rinses may also ruin sensitive equipment. Consult the manufacturers for recommended decontamination solutions.

Station 4: Equipment Rinse

Wash soap off of equipment with water by immersing the equipment in the water while brushing. Repeat as many times as necessary.

Station 5: Low-Pressure Rinse

Rinse sampling equipment with distilled/deionized water with a low-pressure sprayer.

Station 6: Nitric Acid Sprayers (required only if metals are a contaminant of concern)

Using a spray bottle rinse sampling equipment with nitric acid. Begin spraying (inside and outside) at one end of the equipment allowing the acid to drip to the other end into a 5-gallon bucket. A rinsate blank may be required at this station. Refer to Section 9.

Station 7: Low-Pressure Sprayers

Rinse sampling equipment with distilled/deionized water with a low-pressure sprayer.

Station 8: Organic Solvent Sprayers

Rinse sampling equipment with a solvent. Begin spraying (inside and outside) at one end of the equipment allowing the solvent to drip to the other end into a 5-gallon bucket. Allow the solvent to evaporate from the equipment before going to the next station. A QC rinsate sample may be required at this station.

Station 9: Low-Pressure Sprayers

Rinse sampling equipment with distilled/deionized water with a low-pressure washer.

Station 10 : Clean Equipment Drop

Lay clean equipment on plastic sheeting. Once air dried, wrap sampling equipment with aluminum foil, plastic, or other protective material.

7.2.3 Post Decontamination Procedures

1. Collect high-pressure pad and heavy equipment decontamination area liquid and waste and store in appropriate drum or container. A sump pump can aid in the collection process. Refer to the Department of Transportation (DOT) requirements for appropriate containers based on the contaminant of concern.

2. Collect high-pressure pad and heavy equipment decontamination area solid waste and store in appropriate drum or container. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.

3. Empty soap and water liquid wastes from basins and buckets and store in appropriate

drum or container. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.

4. Empty acid rinse waste and place in appropriate container or neutralize with a base and place in appropriate drum. pH paper or an equivalent pH test is required for neutralization. Consult DOT requirements for appropriate drum for acid rinse waste.

5. Empty solvent rinse sprayer and solvent waste into an appropriate container. Consult DOT requirements for appropriate drum for solvent rinse waste.

6. Using low-pressure sprayers, rinse basins, and brushes. Place liquid generated from this process into the wash water rinse container.

7. Empty low-pressure sprayer water onto the ground.

8. Place all solid waste materials generated from the decontamination area (i.e., gloves and plastic sheeting, etc.) in an approved DOT drum. Refer to the DOT requirements for appropriate containers based on the contaminant of concern.

9. Write appropriate labels for waste and make arrangements for disposal. Consult DOT regulations for the appropriate label for each drum generated from the decontamination process.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITYASSURANCE/ QUALITY CONTROL

A rinsate blank is one specific type of quality control sample associated with the field decontamination process. This sample will provide information on the effectiveness of the decontamination process employed in the field.

Rinsate blanks are samples obtained by running analyte free water over decontaminated sampling equipment to test for residual contamination. The blank water is collected in sample containers for handling, shipment, and analysis. These samples are treated identical to samples collected that day. A rinsate blank is used to assess cross contamination brought about by improper decontamination procedures. Where dedicated sampling equipment is not utilized, collect one rinsate blank per day per type of sampling device samples to meet QA2 and QA3 objectives.

If sampling equipment requires the use of plastic tubing it should be disposed of as contaminated and replaced with clean tubing before additional sampling occurs.

10.0 DATA VALIDATION

Results of quality control samples will be evaluated for contamination. This information will be utilized to qualify the environmental sample results in accordance with the project's data quality objectives.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow OSHA, U.S. EPA, corporate, and other applicable health and safety procedures.

Decontamination can pose hazards under certain circumstances. Hazardous substances may be incompatible with decontamination materials. For example, the decontamination solution may react with contaminants to produce heat, explosion, or toxic products. Also, vapors from decontamination solutions may pose a direct health hazard to workers by inhalation, contact, fire, or explosion.

The decontamination solutions must be determined to be acceptable before use. Decontamination materials may degrade protective clothing or equipment; some solvents can permeate protective clothing. If decontamination materials do pose a health hazard, measures should be taken to protect personnel or substitutions should be made to eliminate the hazard. The choice of respiratory protection based on contaminants of concern from the site may not be appropriate for solvents used in the decontamination process.

Safety considerations should be addressed when using abrasive and non-abrasive decontamination equipment. Maximum air pressure produced by abrasive equipment could cause physical injury. Displaced material requires control mechanisms.

Material generated from decontamination activities requires proper handling, storage, and disposal. Personal Protective Equipment may be required for these activities.

Material safety data sheets are required for all decontamination solvents or solutions as required by the Hazard Communication Standard (i.e., acetone, alcohol, and trisodiumphosphate).

In some jurisdictions, phosphate containing detergents (i.e., TSP) are banned.

12.0 REFERENCES

Field Sampling Procedures Manual, New Jersey Department of Environmental Protection, February, 1988.

A Compendium of Superfund Field Operations Methods, EPA 540/p-87/001.

Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual, USEPA Region IV, April 1, 1986.

Guidelines for the Selection of Chemical Protective Clothing, Volume 1, Third Edition, American Conference of Governmental Industrial Hygienists, Inc., February, 1987.

Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, NIOSH/OSHA/USCG/EPA, October, 1985.

APPENDIX A

Table

Table 1. Soluble Contaminants and Recommended Solvent Rinse

TABLE 1
Soluble Contaminants and Recommended Solvent Rinse

SOLVENT[1]	EXAMPLES OF SOLVENTS	SOLUBLE CONTAMINANTS
Water	Deionized water Tap water	Low-chain hydrocarbons Inorganic compounds Salts Some organic acids and other polar compounds
Dilute Acids	Nitric acid Acetic acid Boric acid	Basic (caustic) compounds (e.g., amines and hydrazines)
Dilute Bases	Sodium bicarbonate (e.g., soap detergent)	Acidic compounds Phenol Thiols Some nitro and sulfonic compounds
Organic Solvents [2]	Alcohols Ethers Ketones Aromatics Straight chain alkalines (e.g., hexane) Common petroleum products (e.g., fuel, oil, kerosene)	Nonpolar compounds (e.g., some organic compounds)
Organic Solvent[2]	Hexane	PCBs

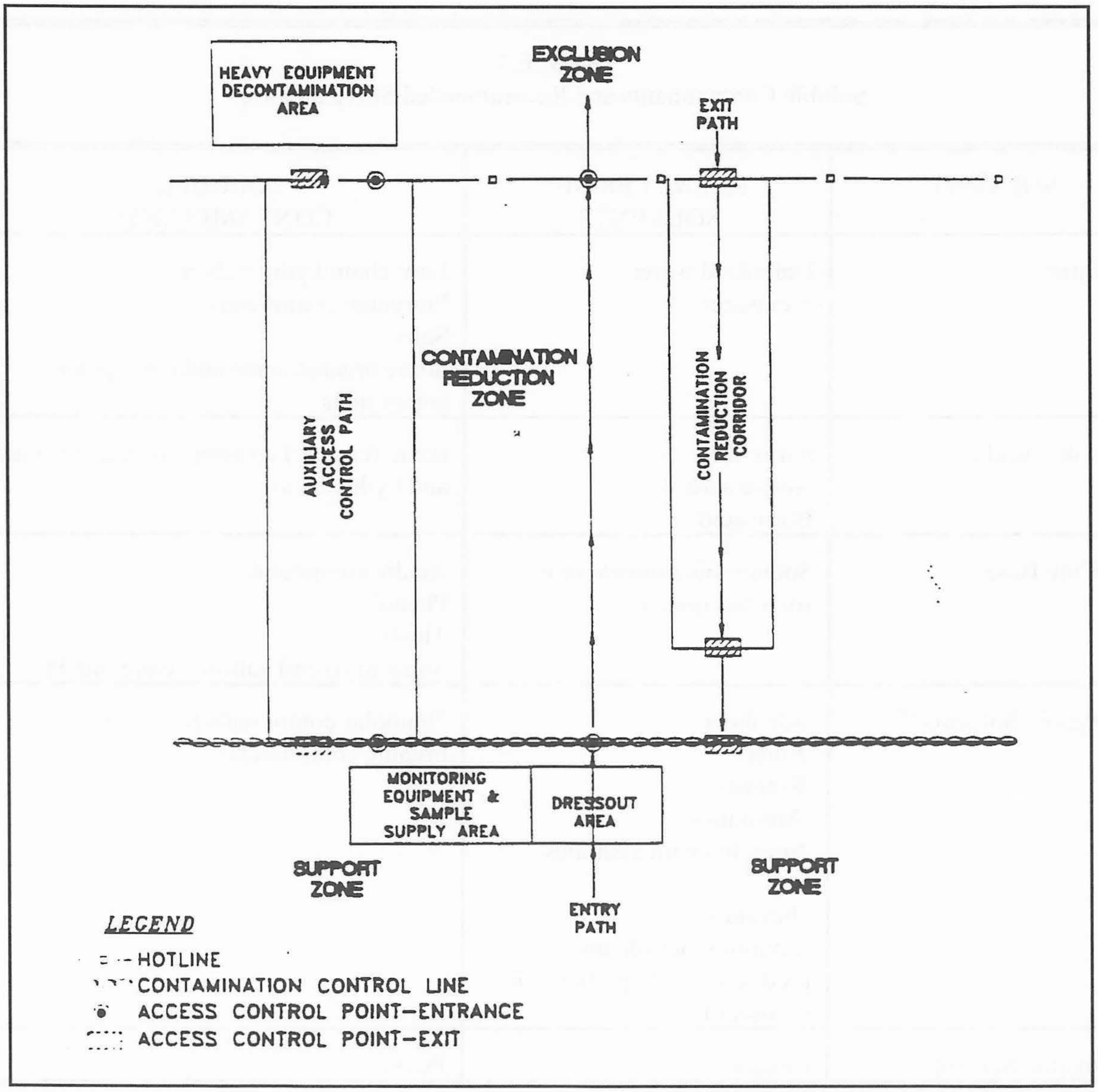
[1] - Material safety data sheets are required for all decontamination solvents or solutions as required by the Hazard Communication Standard

[2] - WARNING: Some organic solvents can permeate and/or degrade the protective clothing

APPENDIX B

Figures

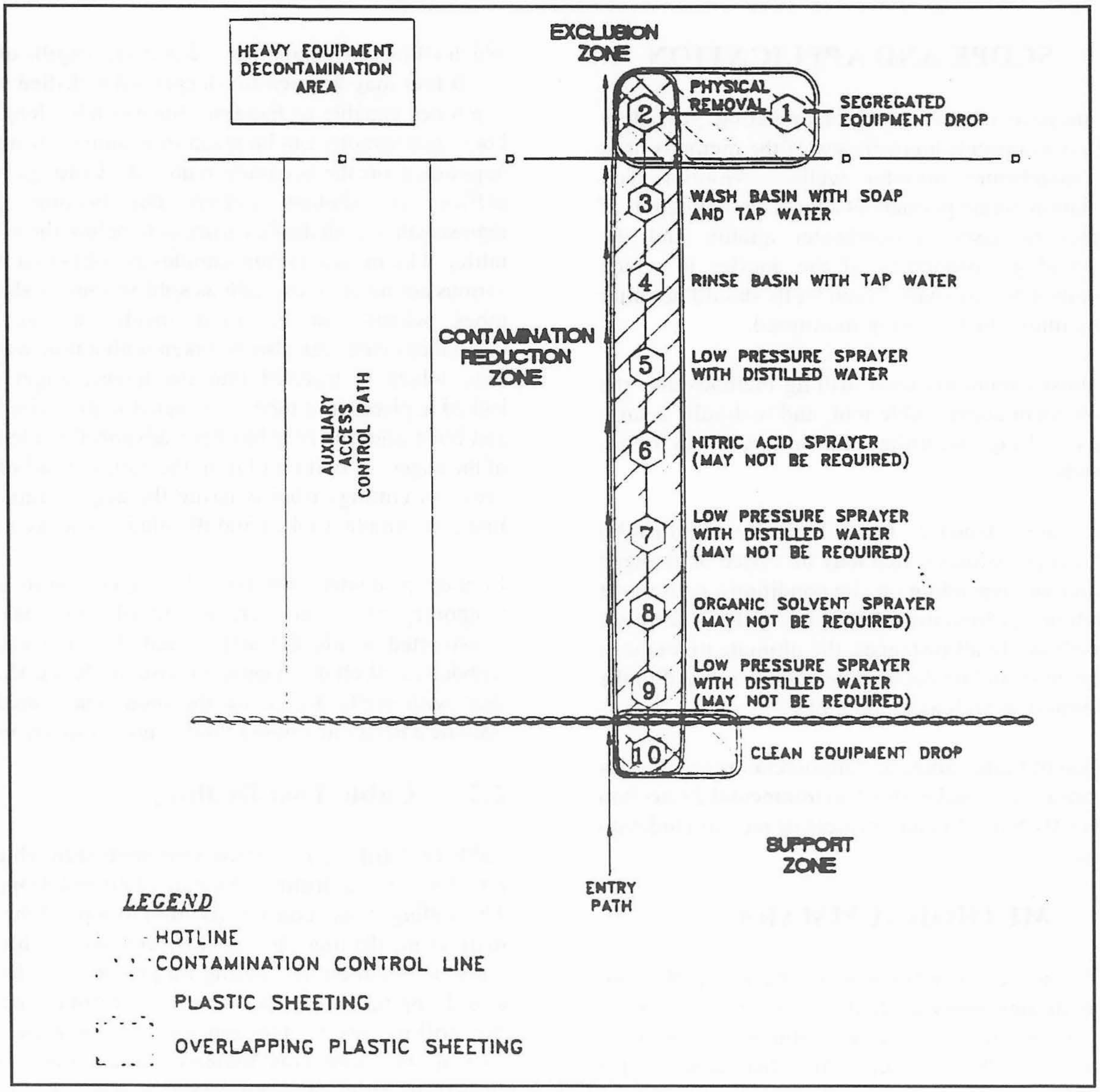
Figure 1. Contamination Reduction Zone Layout



APPENDIX B (Cont'd.)

Figures

Figure 2. Decontamination Layout



MONITOR WELL INSTALLATION

SOP#: 2048
DATE: 03/18/96
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1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to provide an overview of the methods used for groundwater monitor wells. Monitor well installation create permanent access for collection of samples to assess groundwater quality and the hydrogeologic properties of the aquifer in which contaminants may exist. Such wells should not alter the medium which is being monitored.

The most commonly used drilling methods are: the hollow-stem auger, cable tool, and hydraulic rotary. Rotary drilling can utilize mud rotary or air rotary methods.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, depending on site conditions, equipment limitations, or limitations imposed by the procedures themselves. In all instances, the ultimate procedures employed should be documented and described in the final report as well as in logbooks.

Mention of trade names or commercial products does not constitute United States Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

There is no ideal monitor well installation method for all conditions therefore, hydrogeologic conditions at the site as well as project objectives must be considered before deciding which drilling method is appropriate.

2.1 Hollow-Stem Augering

Outside diameters of hollow-stem augers generally range from 6 1/4 inches to 22 inches with corresponding inner diameters ranging from 2 1/4 inches to 13 inches. Auger lengths are usually 5 feet which allows easy handling. However, lengths of 10 or 20 feet may be used for deeper holes drilled with machines capable of handling the extended lengths. Formation samples can be taken in a number of ways, depending on the accuracy required. Cuttings may suffice for shallow depths but become less representative with depth, particularly below the water table. The most accurate samples are obtained with various coring devices, such as split spoons or shelby tubes which can be used inside the augers. Continuous cores can also be taken with a thin-walled tube which is inserted into the lowest auger and locked in place. The tube is retracted with a wire line and hoist after the hole has been advanced the length of the auger. A bottom plug in the cutting head or bit prevents cuttings from entering the augers until the first core sample is taken and the plug is knocked out.

In unconsolidated material, the augers serve as a temporary casing and gravel-packed wells can be constructed inside the augers and then the augers withdrawn. Well development is usually less difficult than with wells drilled by the mud rotary method because a bentonite drilling fluid is not normally used.

2.2 Cable Tool Drilling

Cable tool drilling is a percussion method in which a bit, attached to a drilling string, is lifted and dropped. The drilling string, consists (bottom to top) of the bit, drill stem, drilling jars, socket, and wire cable. A walking beam on the drilling rig provides the lifting and dropping motion to the wire cable and hence to the drilling string. The repeated action breaks or loosens the formation material which mixes with formation water or water added to the hole by the operator to form a slurry. The slurry facilitates removal of the cuttings which are periodically removed from the hole with a bailer. In unconsolidated formations, steel casing must be driven or pushed into the ground as the drilling progresses in order to prevent hole collapse. A hardened steel drive shoe on the bottom end of the casing prevents damage during driving. A well may then be constructed inside the steel casing and the casing pulled back. In consolidated formations, the casing may be driven through the weathered zone, and seated in solid rock. The hole below the casing may remain open or may be fitted with a smaller diameter inner casing and screen, depending on the sampling requirements. Depending on formation material, extensive well development may often not be necessary.

2.3 Rotary Drilling

2.3.1 Mud Rotary Method

In the mud rotary method the drill bit is rotated rapidly to cut the formation material and advance the borehole. The drill bit is attached to hollow drilling rods which transfer power from the rig to the bit. In conventional rotary drilling, cuttings are removed by pumping drilling fluid (water, or water mixed with bentonite or other additives) down through the drill rods and bit, and up the annulus between the borehole and the drill rods. The drilling fluid flows into a mud pit where the cuttings settle out and then is pumped back down the drill rods. The drilling fluid also cools the bit and prevents the borehole from collapsing in unconsolidated formations.

Sampling may be done from the cuttings but samples are generally mixed and the amount of fine material may not be accurately represented. Coring may be done through the drill rods and bit if a coring bit (with a center opening big enough to allow passage of the coring tube) is used. When drilling unconsolidated formations, a temporary surface or shallow casing may have to be installed in order to prevent cross-contamination, hole collapse, or wall erosion by the drilling fluid. Casing (riser pipe), screen, and gravel pack are usually installed in the open hole or through the surface casing. Once the well is constructed, extensive well development may be necessary in order to remove drilling fluid from the formation.

2.3.2 Air Rotary Method

The air rotary method uses air as the drilling fluid. Air is forced down the drill rods by an air compressor, escapes out of the bit and returns to the surface in the annular space between the hole wall and the drill string. Cuttings are moved out of the hole by the ascending air and collect around the rig. Cuttings are mixed and may not always be representative of the depth currently being drilled. In the conventional air rotary method, the drill string operates in a manner similar to that described for the mud rotary system. In a "hammer" or "down-the-hole" air rotary method, the bit is pneumatically driven rapidly against the rock in short strokes while the drilling string slowly rotates. The use of air rotary methods are generally limited to consolidated and semi-consolidated formations. Casing is often used in semi-consolidated formations and through the weathered portion of consolidated formations to prevent hole collapse. In environmental work, the air supply must be filtered to prevent introduction of contamination into the borehole.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Often, a primary objective of the drilling program is to obtain representative lithologic or environmental samples. The most common techniques for retrieving samples are:

In unconsolidated formations:

C Split spoon sampling, carried out continuously or at discrete intervals during drilling, as summarized in ASTM Method D-1586-84, Split Barrel Sampling
C Shelby tube sampling when an undisturbed sample is required from clayey or silty soils, especially for geotechnical evaluation or chemical analysis
C Cutting collection when a general lithologic description and approximate depths are sufficient

In consolidated formations:

C Rock coring at continuous or discrete intervals
C Cutting collection when a general lithologic description and approximate depths are sufficient

When collecting environmental samples, the amount of sample to be collected and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling and storage for air and waste samples are discussed in the specific SOPs for the technique selected.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Advantages and disadvantages of the various drilling methods are summarized below.

4.1 Auger Drilling

The advantages of auger drilling are:

C Relatively fast and inexpensive

C Because augers act as temporary casing, drilling fluids are not used resulting in reduced well development

The disadvantages of auger drilling are:

C Very slow or impossible to use in coarse materials such as cobble or boulders

C Cannot be used in consolidated formations and is generally limited to depths of approximately 100 feet in order to be efficient

4.2 Cable Tool Drilling

The advantages of cable tool drilling are:

C Relatively inexpensive with minimum labor requirements

C The water table and water bearing zones are easily identified

C Driven casing stabilizes borehole and minimizes potential for cross-contamination

C Especially successful in drilling caving formations or formations containing boulders

C Accurate formation samples can usually be obtained from cuttings

The disadvantages of cable tool drilling are:

C Extremely slow rate of drilling

C Necessity to drive casing may limit depth in large diameter holes.

4.3 Rotary Drilling

4.3.1 Mud Rotary Drilling

The advantages of mud rotary drilling are:

C Fast, more than 100 feet of borehole advancement per day is common

C Provides an open borehole, necessary for some types of geophysical logging and other tests

The disadvantages of mud rotary drilling are:

C Potential for cross-contamination of water-bearing zones

C Drill cuttings may be mixed and not accurately represent lithologies at a given drilling depth

C Drilling mud may alter the groundwater chemistry

C Water levels can only be determined by constructing wells

C Drilling mud may change local permeability of the formation and may not be entirely removed during well development

C Disposal of large volumes of drilling fluid and cuttings may be necessary if they are contaminated

4.3.2 Air Rotary Drilling

The advantages of air rotary drilling are:

C Fast, more than 100 feet of borehole advancement a day is possible

C Preliminary estimates of well yields and water levels are often possible

C No drilling fluid to plug the borehole

The disadvantages of air rotary drilling are:

C Generally cannot be used in unconsolidated formations

C In contaminated zones, the use of high-pressure air may pose a significant hazard to the drill crew because of transport of contaminated material up the hole

C Introduction of air to the groundwater could reduce concentration of volatile organic compounds

5.0 EQUIPMENT

The following equipment is necessary for the site geologist:

C Metal clipboard box case (container for well logs)
C Ruler
C Depth sounder
C Water level indicator
C All required health and safety gear
C Sample collection jars
C Trowels
C Description aids (Munsell color chart, grain size charts, etc.)
C Geolis® Logbooks (Appendix A)
C Field Logbook

Equipment and tools to install the well are normally provided by the drilling contractor.

6.0 REAGENTS

Reagents are not required for preservation of soil samples. Samples should, however, be cooled to 4° C and protected from sunlight in order to minimize any potential reaction due to the light sensitivity of the sample. Decontamination of drilling equipment should follow the Sampling Equipment Decontamination SOP and the site-specific work plan.

7.0 PROCEDURES

7.1 Preparation

All drilling and well installation programs must be planned and supervised by a professional geologist/hydrogeologist.

The planning, selection and implementation of any monitor well installation program should include the following:

C Review of existing data on site geology and hydrogeology including publications, air photos, water quality data, and existing maps. These may be obtained from local, state or federal agencies

C Assesment of the site to determine potential access problems for drill rig, locate water supply sources, establish equipment storage area, and observe outcrops

C Perform utilities check, note location of underground utilities and of overhead electrical wires

C Preparation of a Site Safety Plan

C Select drilling, sampling and well development methods

C Determination of well construction specifications (i.e., casing and screen materials, casing and screen diameter, screen length and screen interval, filter pack and screen slot size)

C Determination of the need for containing drill cuttings and fluids and their method of disposal

C Preparation of work plan including all of the above

C Preparation of and execute the drilling contract

7.2 Field Preparation

Prior to mobilization, the drill rig and all associated equipment should be thoroughly decontaminated by a steam/pressure washer to remove all oil, grease, mud, etc. Before drilling each boring, all the "down-the-hole" drill equipment should be steam cleaned and rinsed with potable water to minimize cross-contamination. Special attention should be given to the threaded section of the casings, and to the drill rods. All drilling equipment should be steam-cleaned at completion of the project to ensure that no contamination is transported to or from the sampling site.

7.3 Well Construction

The well casing material should not interact with the groundwater. Well casings for environmental projects are usually constructed of polyvinyl chloride (PVC), Teflon^{TM}, fiberglass, or stainless steel. Details of the construction methods are given in Sections 7.3.1 and 7.3.2.

7.3.1 Bedrock Wells

Wells completed in bedrock will be drilled using the air or mud rotary method. Crystalline rock wells are usually drilled most efficiently with the air rotary method while consolidated sedimentary formations are drilled using either the air rotary or mud rotary method. The compressed air supply will be filtered prior to introduction into the borehole to remove oil or other contaminants. Bedrock wells may be completed as an open-hole, providing that borehole cave-in is not a possibility.

Bedrock wells will be advanced with air or mud rotary methods until a minimum of 5 feet of competent rock has been drilled. Minimum borehole diameter will be 8 inches. The drill string will then be pulled from the borehole and 6-inch I.D. Schedule 80 or 40 PVC casing inserted. Portland cement/bentonite grout will be pumped into the hole and up the annular space outside the casing. After the grout has set (minimum of 24 hours), the cement will be drilled out and the borehole advanced to the desired depth. Figure 1 (Appendix B) shows typical construction details for an open-hole bedrock well.

The preferred method of well completion for the bedrock wells will be open-hole. However, if the open borehole is subject to cave-in, the well(s) will be completed as screened and cased sand-packed wells. For details of completion see Section 7.3.2.

7.3.2 Overburden Well Construction

Any of the drilling methods discussed in this SOP can be used to drill or set a well in the overburden. The hollow-stem method is the preferred choice for shallow (<100 ft.) overburden wells because the well can be constructed inside of the augers. Details of the construction are provided below and are shown in Figure 2 (Appendix B).

1. The screen slot size will be determined by the site hydrologist, based upon sand-pack size. The length of screen used will be site-dependent. Casing sections will be flush-threaded. Screw-threaded bottom plugs will be used. To prevent introduction of contaminants into the well, no glue-connected fittings will be used. Each piece of PVC pipe, screen, and the bottom plug will be steam-cleaned before lowering into the borehole. The site hydrogeologist is responsible for the supervision of all steam cleaning procedures.

2. The annular space between the well screen and the borehole wall will be filled with a uniform gravel/sand pack to serve as a filter media. For wells deeper than approximately 50 feet, or when recommended by the site geologist, the sand pack will be emplaced using a tremie pipe. A sand slurry composed of sand and potable water will be pumped through the tremie pipe into the annulus throughout the entire screened interval, and over the top of the screen. Allowance must be made for settlement of the sand pack.

3. The depth of the top of the sand will be determined using the tremie pipe, thus verifying the thickness of the sand pack. Additional sand shall be added to bring the top of the sand pack to approximately 2 to 3 feet above the top of the well screen. Under no circumstances should the sand pack extend into any aquifer other than the one to be monitored. In most cases, the well design can be modified to allow for a sufficient sand pack without threat of crossflow between producing zones through the sand pack.

4. In materials that will not maintain an open hole using hollow-stem augers, the temporary or outer casing will be withdrawn gradually during placement of sand pack/grout. For example, after filling two feet with sand pack, the outer casing should be withdrawn 2 feet. This step of placing more gravel and withdrawing the outer casing should be repeated until the level of the sand pack is approximately 3 feet above the top of the well screen. This ensures that there is no locking of the permanent (inner) casing in the outer casing.

5. A bentonite seal of a minimum 2-foot vertical thickness will be placed in the annular space above the sand pack to separate the sand pack from the cement surface seal. The bentonite will be placed through a tremie pipe or poured directly into the annular space, depending upon the depth and site conditions. The bentonite will be pourable pellets. The hydrogeologist will record the start and stop times of the bentonite seal emplacement, the interval of the seal, the amount of bentonite that was used, and problems that arise. The type of bentonite and the supplier will also be recorded.

   A cap placed over the top of the well casing before pouring the bentonite pellets will prevent pellets from entering the well casing.

6. If a slurry of bentonite is used as annular seal, it is prepared by mixing powdered or granular bentonite with potable water. The slurry must be of sufficiently high specific gravity and viscosity to prevent its displacement by the grout to be emplaced above it. As a precaution (regardless of depth) and depending on fluid viscosity, a few handfuls of bentonite pellets may be added to solidify the bentonite slurry surface.

7. Cement and/or bentonite grout is placed from the top of the bentonite seal to the ground surface.

   Only Type I or II cement without accelerator additives may be used. An approved source of potable water must be used for mixing grouting materials. The following mixes are acceptable:

   C Neat cement, a maximum of 6 gallons of water per 94 pound bag of cement

   C Granular bentonite, 1.5 pounds of bentonite per 1 gallon of water

   C Cement-bentonite, 5 pounds of pure bentonite per 94 pound bag of cement with 7-8 gallons of water

   C Cement-bentonite, 6 to 8 pounds of pure bentonite per 94 pound bag of cement with 8-10 gallons of water, if water mixed

   C Non-expandable cement, mixed at 7.5 gallons of water to one half (1/2) teaspoon of Aluminum Hydroxide, 94 pounds of neat cement (Type I) and 4 pounds of bentonite

   C Non-expandable cement, mixed at 7 gallons of water to one half (1/2) teaspoon of Aluminum Hydroxide, 94 pounds of neat cement (Type I and Type II)

8. Grout is pumped through a tremie pipe (normally a 1.25-inch PVC or steel pipe) to the bottom of the annulus until undiluted grout flows from the annulus at the ground surface

9. In materials that will not maintain an open hole, the temporary steel casing should be withdrawn in a manner that prevents the level of grout from dropping below the bottom of the casing.

10. Additional grout may be added to compensate for the removal of the temporary casing and the tremie pipe to ensure that the top of the grout is at or above ground surface. After the grout has set (about 24 hours), any depression due to settlement is filled with a grout mix similar to that described above.

11. The protective casing should now be set. Casing may be a 5 foot minimum length of black iron or galvanized pipe extending about 1.5 to 3 feet above the ground surface, and set in concrete or cement grout. The protective casing diameter should be 4 inches greater than the well casing. A 0.5-inch drain hole may be installed near ground level. A flush-mount protective casing may also be used in areas of high traffic or where access to other areas would be limited by a well stick-up.

12. A protective steel cap, secured to the protective casing by a padlock, should be installed.

13. Steel guard posts should be installed around the protective casing in areas where vehicle traffic may be a problem. Posts should have a minimum diameter of 3 inches and be a

minimum of 4 feet high.

14. All monitor wells should be labelled and dated with paint or steel tags.

7.4 Well Development

Well development is the process by which the aquifer's hydraulic conductivity is restored by removing drilling fluids, and fine-grained formation material from newly installed wells. Two methods of well development that are commonly used are surging and bailing, and overpumping. A well is considered developed when the pH and conductivity of the groundwater stabilizes and the measured turbidity is <50 nephelometric turbidity units (NTUs).

Surging and bailing will be performed as follows:

1. Measure the total depth (TD) of the well and depth to water (DTW).
2. Using an appropriately sized surge block, surge 5-foot sections of well screen, using 10-20 up/down cycles per section. Periodically remove the surge block and bail accumulated sediment from the well, as required.
3. For open-hole wells, a 6-inch surge block will be used inside the cased portion of the well. Sediments will be bailed periodically, as required. Overpumping may be used in combination with surging and bailing for development of bedrock wells. The method(s) used will be based on field conditions encountered, and will be determined by the site hydrogeologist. However, sediment will initially be removed from the wells by bailing in order to minimize the volume of development water generated.

The pump used must be rated to achieve the desired yield at a given depth. The pump system should include the following:

C A check valve to prevent water from running back into the well when the pump is shut off
C Flexible discharge hose
C Safety cable or rope to remove the pump from the well
C Flow meter monitoring system (measuring bucket or inline flow meter)
C Generator
C Amp meter, to measure electrical current (load)

The amp meter is used to monitor pump performance. If the pump becomes clogged, the current will increase due to stress on the pump. If the water level drops below the intake ports, the current will drop due to decreased resistance on the pump.

8.0 CALCULATIONS

To maintain an open borehole during rotary drilling, the drilling fluid must exert a pressure greater than the formation pore pressure. Typical pore pressures for unconfined and confined aquifers are 0.433 define (psi/ft) and 0.465 psi/ft, respectively.

The relationship for determining the hydrostatic pressure of the drilling fluid is:

Hydrostatic Pressure (psi) = Fluid Density (lb/gal) x Height of Fluid Column (ft) x 0.052

The minimum grout volume necessary to grout a well can be calculated using:

Grout Vol (ft^3) = Vol of Borehole (ft^3) - Vol of Casing (ft^3) = $L\,(r_B^2 - r_C^2)$

where:

L = length of borehole to be grouted (ft)
r_B = radius of boring (ft)
r_C = radius of casing (ft)

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance activities that apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on standard well completion forms, field data sheets or within field/site logbooks. Descriptive logs, pump tests, and well completion date are entered on Geolis® forms. The Geolis® forms are used to ensure data is collected uniformly by all Site Geologists and provide

input to a standardized computer well file. Appendix A contains examples of Geolis® forms used to record descriptions of geologic samples.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

Drilling rigs and equipment present a variety of safety hazards. REAC personnel working around drilling rigs should know the position of the emergency "kill" switch. Wirelines and ropes should be inspected and frayed or damaged sections discarded. Swivels and blocks should turn freely. Gages should be operational and controls clearly marked. All underground utilities should be clearly marked, and drillers should be aware of any overhead hazards such as power lines. Avoid drilling in these areas. Ear protection should be worn when working around drilling equipment for extended periods of time, particularly air rotary equipment. Failure to follow safety procedure or wear the proper personal protection gear on the part of either the drilling crew or REAC personnel may result in dismissal from the job.

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety practices.

12.0 REFERENCES

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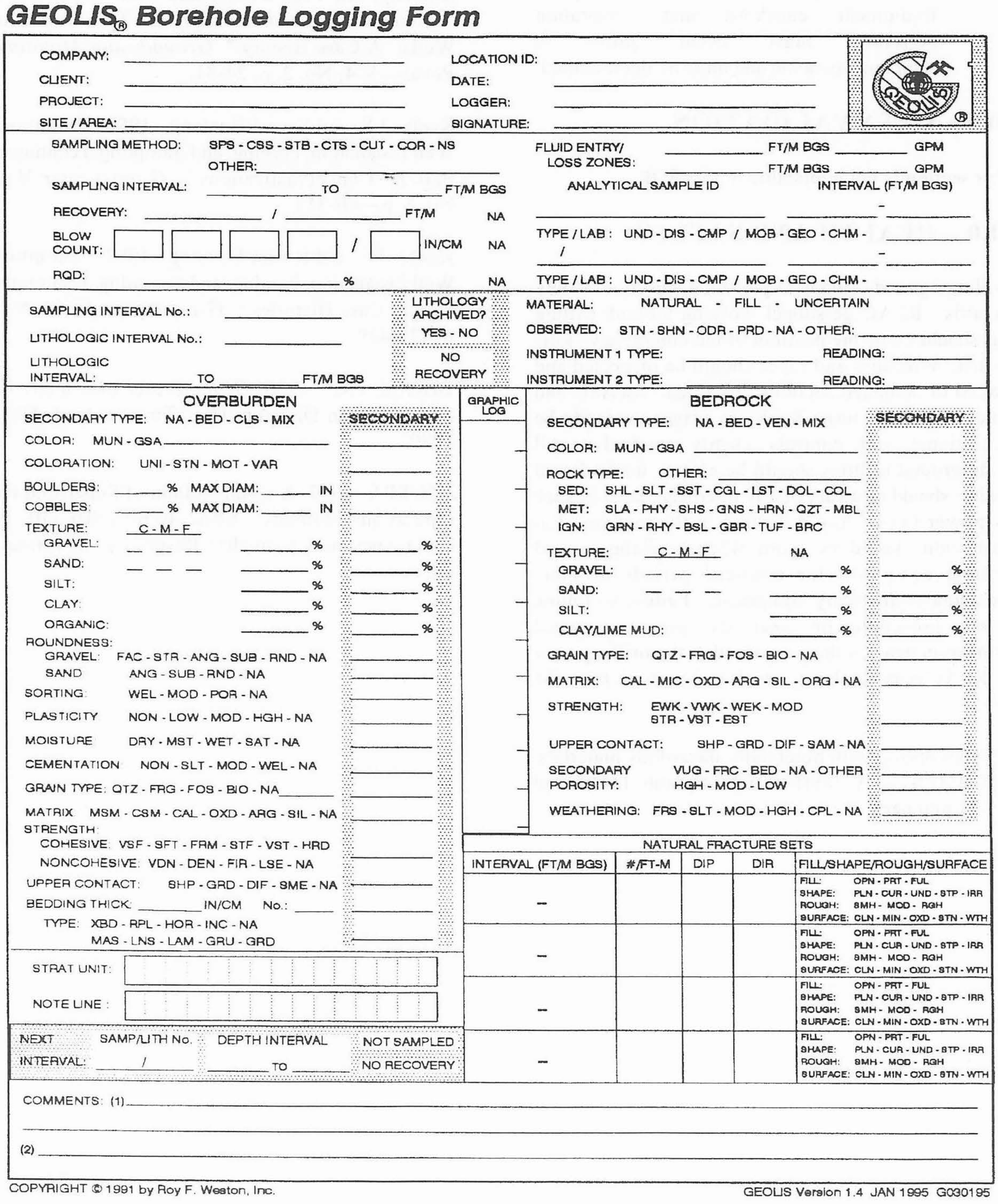
APPENDIX A

Geolis Forms

Form 1. Geolis® Borehole Logging Form



GEOLIS® Borehole Logging Form

COMPANY: ______
CLIENT: ______
PROJECT: ______
SITE / AREA: ______

LOCATION ID: ______
DATE: ______
LOGGER: ______
SIGNATURE: ______

SAMPLING METHOD: SPS - CSS - STB - CTS - CUT - COR - NS
OTHER: ______
SAMPLING INTERVAL: ______ TO ______ FT/M BGS
RECOVERY: ______ / ______ FT/M NA
BLOW COUNT: ☐ ☐ ☐ ☐ / ☐ IN/CM NA
RQD: ______ % NA

FLUID ENTRY/ LOSS ZONES: ______ FT/M BGS ______ GPM
______ FT/M BGS ______ GPM
ANALYTICAL SAMPLE ID ______ INTERVAL (FT/M BGS) ______ - ______
TYPE / LAB : UND - DIS - CMP / MOB - GEO - CHM - ______
/ ______ ______ - ______
TYPE / LAB : UND - DIS - CMP / MOB - GEO - CHM - ______

SAMPLING INTERVAL No.: ______
LITHOLOGIC INTERVAL No.: ______
LITHOLOGIC INTERVAL: ______ TO ______ FT/M BGS

LITHOLOGY ARCHIVED? YES - NO
NO RECOVERY

MATERIAL: NATURAL - FILL - UNCERTAIN
OBSERVED: STN - SHN - ODR - PRD - NA - OTHER: ______
INSTRUMENT 1 TYPE: ______ READING: ______
INSTRUMENT 2 TYPE: ______ READING: ______

OVERBURDEN — SECONDARY

SECONDARY TYPE: NA - BED - CLS - MIX
COLOR: MUN - GSA ______ ______
COLORATION: UNI - STN - MOT - VAR ______
BOULDERS: ______ % MAX DIAM: ______ IN ______
COBBLES: ______ % MAX DIAM: ______ IN ______
TEXTURE: C - M - F
GRAVEL: __ __ __ ______ % ______ %
SAND: __ __ __ ______ % ______ %
SILT: ______ % ______ %
CLAY: ______ % ______ %
ORGANIC: ______ % ______ %
ROUNDNESS:
GRAVEL: FAC - STR - ANG - SUB - RND - NA ______
SAND ANG - SUB - RND - NA ______
SORTING: WEL - MOD - POR - NA ______
PLASTICITY NON - LOW - MOD - HGH - NA ______
MOISTURE DRY - MST - WET - SAT - NA ______
CEMENTATION NON - SLT - MOD - WEL - NA ______
GRAIN TYPE: QTZ - FRG - FOS - BIO - NA ______ ______
MATRIX MSM - CSM - CAL - OXD - ARG - SIL - NA ______
STRENGTH:
COHESIVE: VSF - SFT - FRM - STF - VST - HRD
NONCOHESIVE: VDN - DEN - FIR - LSE - NA ______
UPPER CONTACT: SHP - GRD - DIF - SME - NA ______
BEDDING THICK: ______ IN/CM No.: ______ ______
TYPE: XBD - RPL - HOR - INC - NA
MAS - LNS - LAM - GRU - GRD ______

STRAT UNIT: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
NOTE LINE : ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

NEXT INTERVAL: SAMP/LITH No. ______ / ______ DEPTH INTERVAL ______ TO ______ NOT SAMPLED NO RECOVERY

GRAPHIC LOG

BEDROCK — SECONDARY

SECONDARY TYPE: NA - BED - VEN - MIX
COLOR: MUN - GSA ______ ______
ROCK TYPE: OTHER: ______
SED: SHL - SLT - SST - CGL - LST - DOL - COL
MET: SLA - PHY - SHS - GNS - HRN - QZT - MBL
IGN: GRN - RHY - BSL - GBR - TUF - BRC ______
TEXTURE: C - M - F NA
GRAVEL: __ __ __ ______ % ______ %
SAND: __ __ __ ______ % ______ %
SILT: ______ % ______ %
CLAY/LIME MUD: ______ % ______ %
GRAIN TYPE: QTZ - FRG - FOS - BIO - NA ______
MATRIX: CAL - MIC - OXD - ARG - SIL - ORG - NA ______
STRENGTH: EWK - VWK - WEK - MOD
STR - VST - EST ______
UPPER CONTACT: SHP - GRD - DIF - SAM - NA ______
SECONDARY POROSITY: VUG - FRC - BED - NA - OTHER ______
HGH - MOD - LOW ______
WEATHERING: FRS - SLT - MOD - HGH - CPL - NA ______

NATURAL FRACTURE SETS

INTERVAL (FT/M BGS)	#/FT-M	DIP	DIR	FILL/SHAPE/ROUGH/SURFACE
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH

COMMENTS: (1) ______

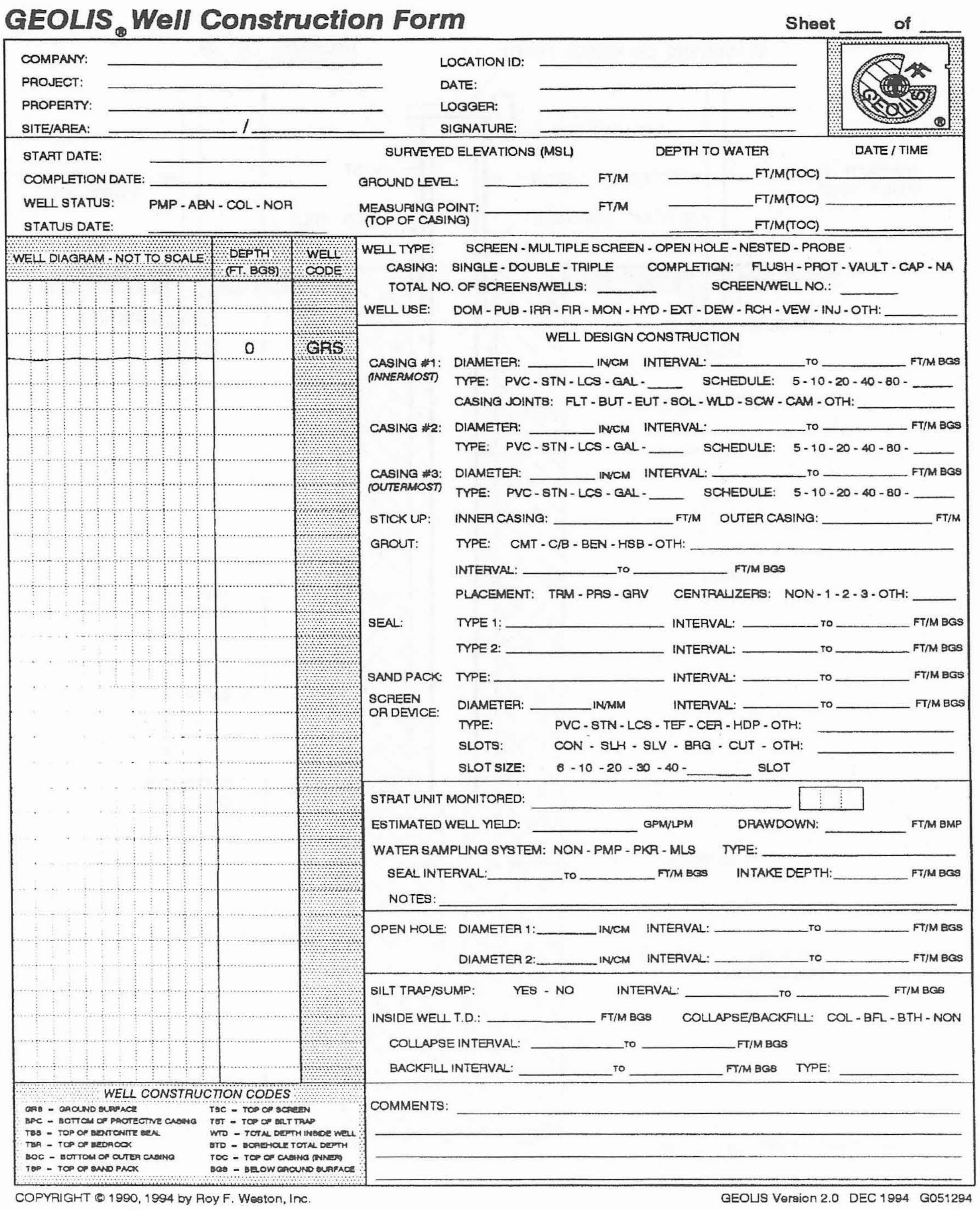
(2) ______

GEOLIS Version 1.4 JAN 1995 G030195

APPENDIX A (Cont'd)

Geolis Forms

Form 2. Geolis® Well Construction Form



GEOLIS® Well Construction Form Sheet ____ of ____

COMPANY: ____________________
PROJECT: ____________________
PROPERTY: ____________________
SITE/AREA: __________ / __________
LOCATION ID: ____________________
DATE: ____________________
LOGGER: ____________________
SIGNATURE: ____________________

START DATE: ____________________
COMPLETION DATE: ____________________
WELL STATUS: PMP - ABN - COL - NOR
STATUS DATE: ____________________

SURVEYED ELEVATIONS (MSL)
GROUND LEVEL: __________ FT/M
MEASURING POINT: __________ FT/M
(TOP OF CASING)

DEPTH TO WATER DATE / TIME
__________ FT/M(TOC) __________
__________ FT/M(TOC) __________
__________ FT/M(TOC) __________

WELL DIAGRAM - NOT TO SCALE	DEPTH (FT. BGS)	WELL CODE
	0	GRS

WELL TYPE: SCREEN - MULTIPLE SCREEN - OPEN HOLE - NESTED - PROBE
CASING: SINGLE - DOUBLE - TRIPLE COMPLETION: FLUSH - PROT - VAULT - CAP - NA
TOTAL NO. OF SCREENS/WELLS: ________ SCREEN/WELL NO.: ________
WELL USE: DOM - PUB - IRR - FIR - MON - HYD - EXT - DEW - RCH - VEW - INJ - OTH: __________

WELL DESIGN CONSTRUCTION

CASING #1: DIAMETER: ________ IN/CM INTERVAL: __________ TO __________ FT/M BGS
(INNERMOST) TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____
CASING JOINTS: FLT - BUT - EUT - SOL - WLD - SCW - CAM - OTH: __________
CASING #2: DIAMETER: ________ IN/CM INTERVAL: __________ TO __________ FT/M BGS
TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____
CASING #3: DIAMETER: ________ IN/CM INTERVAL: __________ TO __________ FT/M BGS
(OUTERMOST) TYPE: PVC - STN - LCS - GAL - _____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - _____
STICK UP: INNER CASING: __________ FT/M OUTER CASING: __________ FT/M
GROUT: TYPE: CMT - C/B - BEN - HSB - OTH: __________
INTERVAL: __________ TO __________ FT/M BGS
PLACEMENT: TRM - PRS - GRV CENTRALIZERS: NON - 1 - 2 - 3 - OTH: _____
SEAL: TYPE 1: __________ INTERVAL: __________ TO __________ FT/M BGS
TYPE 2: __________ INTERVAL: __________ TO __________ FT/M BGS
SAND PACK: TYPE: __________ INTERVAL: __________ TO __________ FT/M BGS
SCREEN OR DEVICE: DIAMETER: ________ IN/MM INTERVAL: __________ TO __________ FT/M BGS
TYPE: PVC - STN - LCS - TEF - CER - HDP - OTH: __________
SLOTS: CON - SLH - SLV - BRG - CUT - OTH: __________
SLOT SIZE: 6 - 10 - 20 - 30 - 40 - ________ SLOT

STRAT UNIT MONITORED: ____________________ ☐☐☐
ESTIMATED WELL YIELD: __________ GPM/LPM DRAWDOWN: __________ FT/M BMP
WATER SAMPLING SYSTEM: NON - PMP - PKR - MLS TYPE: __________
SEAL INTERVAL: __________ TO __________ FT/M BGS INTAKE DEPTH: __________ FT/M BGS
NOTES: ____________________

OPEN HOLE: DIAMETER 1: ________ IN/CM INTERVAL: __________ TO __________ FT/M BGS
DIAMETER 2: ________ IN/CM INTERVAL: __________ TO __________ FT/M BGS

SILT TRAP/SUMP: YES - NO INTERVAL: __________ TO __________ FT/M BGS
INSIDE WELL T.D.: __________ FT/M BGS COLLAPSE/BACKFILL: COL - BFL - BTH - NON
COLLAPSE INTERVAL: __________ TO __________ FT/M BGS
BACKFILL INTERVAL: __________ TO __________ FT/M BGS TYPE: __________

WELL CONSTRUCTION CODES

GRS - GROUND SURFACE	TSC - TOP OF SCREEN
BPC - BOTTOM OF PROTECTIVE CASING	TST - TOP OF SILT TRAP
TBS - TOP OF BENTONITE SEAL	WTD - TOTAL DEPTH INSIDE WELL
TBR - TOP OF BEDROCK	BTD - BOREHOLE TOTAL DEPTH
BOC - BOTTOM OF OUTER CASING	TOC - TOP OF CASING (INNER)
TSP - TOP OF SAND PACK	BGS - BELOW GROUND SURFACE

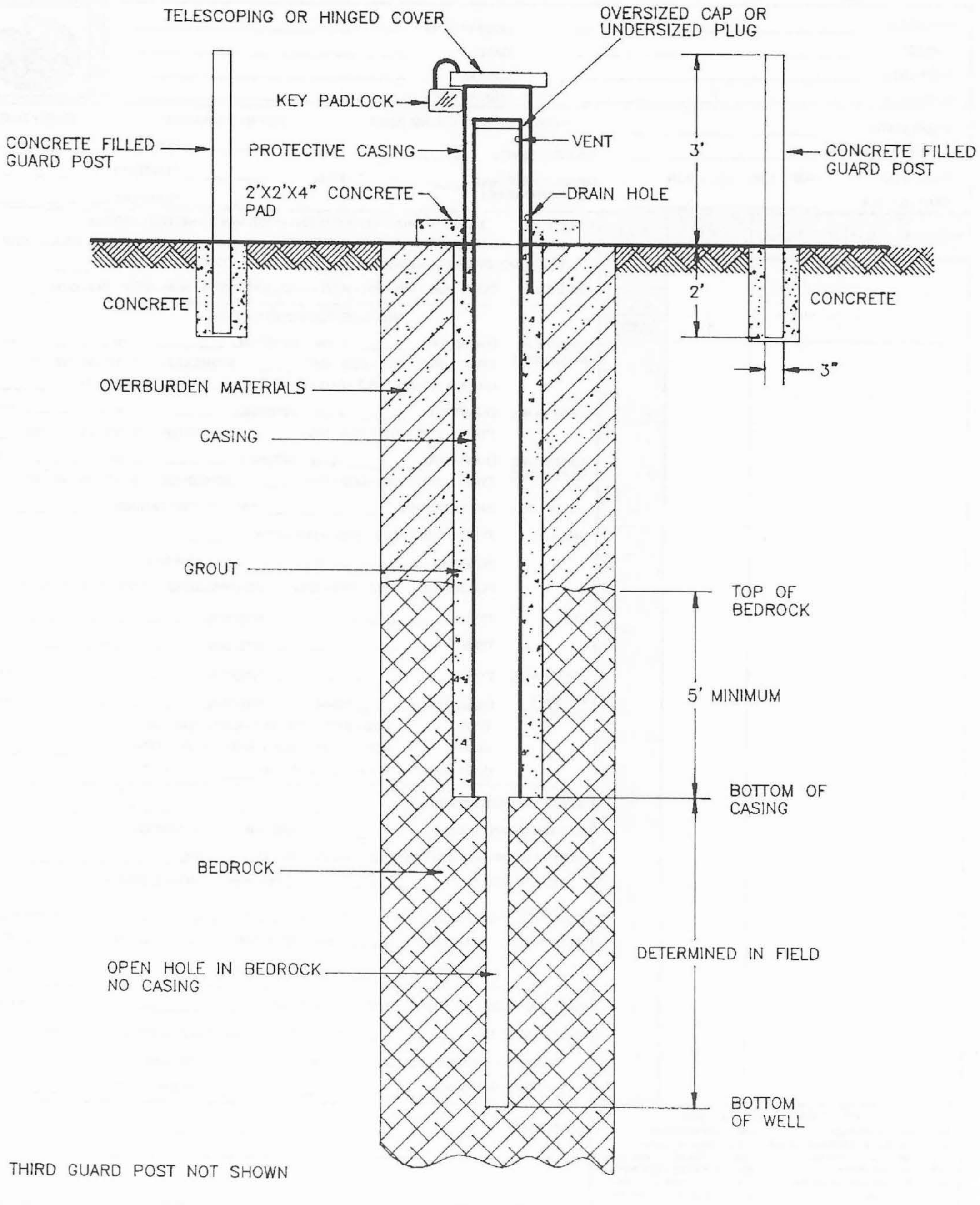
COMMENTS: ____________________

GEOLIS Version 2.0 DEC 1994 G051294

APPENDIX B

Figures

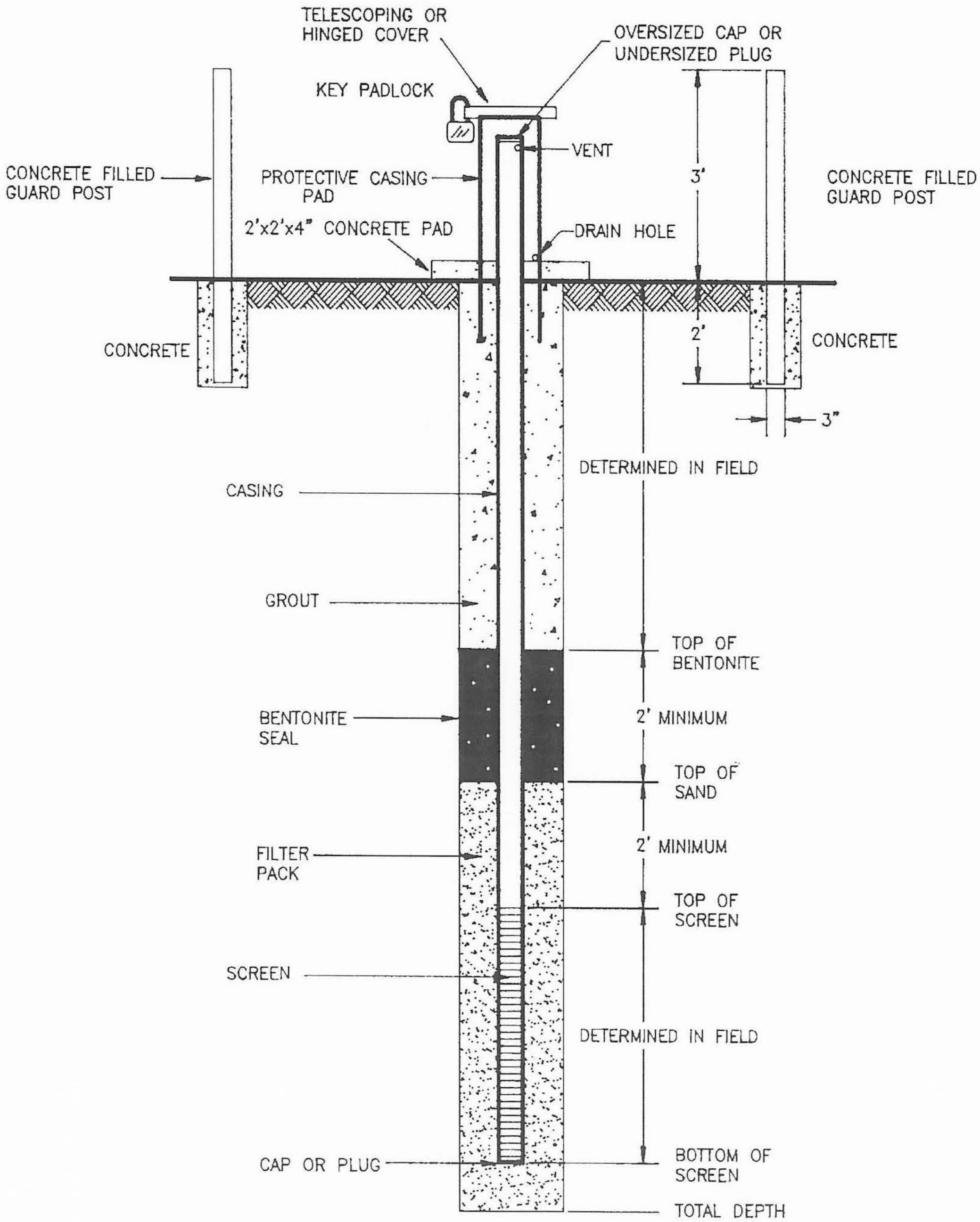
FIGURE 1. Typical Bedrock Well Construction



APPENDIX B (Cont'd)

Figures

FIGURE 2. Typical Overburden Well Construction



SOVEREIGN CONSULTING INC

Environmental services executed safely and consistently...

SHEPLEY HILL LANDFILL SUPPLEMENTAL INVESTIGATION WORKPLAN ADDENDUM

REVISON 1 TO THE FINAL WORKPLAN DATED JANUARY 2010

DATA ANALYSIS PLAN

Prepared for:

US Army Corp of Engineers
New England District
Concord, Massachusetts

Prepared by:

Sovereign Consulting Inc.
905B South Main Street,
Suite 202
Mansfield, Massachusetts 02048

May 2010

In accordance with the contract approval, the Army Contractor has prepared a Workplan Addendum to the existing Shepley's Hill Landfill Supplemental Investigation Workplan, Volumes 1 and 2 and prepared by AMEC dated January 2010. This Workplan Addendum details additional investigation work not covered by the AMEC Work Plans prior to implementing the field work portion of the contract. The intent of this Workplan Addendum is to build upon the AMEC work plans and specifically detail Standard Operating Procedures (SOPs), Field Sampling Plan (FSP), Data Acquisition Plan, and Quality Assurance Project Plan.

This Data Analysis Plan describes how the data collected during the investigation efforts will be used and analyzed to fill the data gaps identified in Volume 1 and 2 of the *Supplemental Investigation Workplan* (AMEC) and further the understanding of site conditions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AMEC	AMEC Earth and Environmental, Inc.
As	Arsenic
bgs	below ground surface
BOD	biological oxygen demand
Ca	Calcium
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl	Chloride
COD	chemical oxygen demand
CSM	conceptual site model
DO	dissolved oxygen
DQO	data quality objective
EPA	Environmental Protection Agency
Fe	Iron
FS	Feasibility Study
ID	identification
MassDEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
Mg	Magnesium
mg/L	milligram per liter
µg/L	microgram per liter
umhos/cm	micro Mhos per centimeter
Mn	Manganese
mV	millivolt
Na	Sodium
NAS	National Academy of Science
NPL	National Priorities List
O&M	Operation and Maintenance
ORP	oxidation-reduction potential
pH	Standard potential of Hydrogen ion concentration
PVC	polyvinyl chloride
RI	remedial investigation
ROD	Record of Decision
SGI	Supplemental Groundwater Investigation
SHL	Shepley's Hill Landfill
Sovereign	Sovereign Consulting Inc
TBD	To Be Determined
TDS	total dissolved solids
TKN	Total Kjeldahl Nitrogen
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USACE-NAE	U.S. Army Corps of Engineers – New England District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

This Data Analysis Plan (DAP), along with the Field Sampling Plan (FSP), the Quality Assurance Project Plan (QAPP) and the Site Safety and Health Plan (SSHP), are components of the *Supplemental Investigation Workplan Addendum.* This DAP focuses effort on data to be collected specifically related to proposed investigations listed in items 1, 2, 3, and 5 below. If data is required during preparation of items 4, 6, 7, 8, and 9 collected during the investigation that is not proposed our DAP will be updated with relevant data. This Data Analysis Plan describes how the data collected during the investigation efforts of items 1, 2, 3, and 5 will be used and analyzed to fill the data gaps identified in Volume 1 and 2 of the *Supplemental Investigation Workplan* (AMEC) and further the understanding of site conditions. More complete presentation of these analyses will be conducted and reported in future documents.

Volume 1 of the *Supplemental Investigation Workplan* concluded that the following constitute the key data gaps for the Shepley's Hill Landfill:

1. Extent of arsenic plume north and northwest of landfill;
2. North plume capture at landfill boundary;
3. North plume monitored natural attenuation within the Impacted Area;
4. Landfill gas impacts in the area of the North Plume;
5. East plume delineation and capture in the vicinity of Plow Shop Pond;
6. Arsenic source strength and predicted duration;
7. Implementability of an air sparging system;
8. Implementability of floc removal in Red Cove of Plow Shop Pond;
9. Implementability of onsite waste management for landfill consolidation.

Closure of the data gaps as described will provide data necessary to complete delineation of contaminants, update human and ecological risk assessments, and evaluate previously identified and potentially new remedial alternatives.

In order to address additional data needs identified in Volume 1 and 2 of the *Supplemental Investigation Workplan*, a series of field investigations has been proposed within this *Supplemental Investigation Workplan Addendum*. These proposed activities, as well as the rationale for conducting these activities, are presented in detail in the FSP. The information gathered from the field activities will be used in conjunction with existing data where possible to:

- Validate and modify, if necessary, the existing Conceptual Site Model (CSM);
- Validate and modify, if necessary, the numerical groundwater flow model;
- Evaluate the effectiveness of the existing groundwater extraction system to fully capture the North Plume at the landfill toe; and
- Evaluate possible remedial scenarios to address contaminant migration into Red Cove.

The revised CSM and groundwater flow model will subsequently be used to support the risk assessment as required and as appropriate to determine the need for additional remedial actions.

1.0 INTRODUCTION

This Data Analysis Plan (DAP), along with the Field Sampling Plan (FSP), the Quality Assurance Project Plan (QAPP) and the Site Safety and Health Plan (SSHP), are components of the *Supplemental Investigation Workplan Addendum.* This DAP describes how the data will be used and analyzed to fill the data gaps identified in Volume 1 and 2 of the *Supplemental Investigation Workplan* (AMEC) and further of the understanding site conditions. A more complete presentation of these analyses will be conducted and reported as discussed in the following sections.

1.1 Objectives

In order to address additional data needs identified in Volume 1 and 2 of the *Supplemental Investigation Workplan (AMEC)*, a series of field investigations has been proposed. These proposed activities as well as the rationale for conducting these activities are presented in detail in the FSP, and summarized on Table 1-1. The resulting information gathered during completion of the field activities will be used in conjunction with existing data where possible to:

- Evaluate and modify, if necessary, the existing Conceptual Site Model (CSM);
- Validate and modify, if necessary, the numerical groundwater flow model;
- Evaluate the effectiveness of the existing groundwater extraction system to capture the North Plume at the landfill toe; and
- Evaluate possible remedial scenarios to address contaminant migration into Red Cove.

The revised CSM and groundwater flow model will subsequently be used to support an update to the risk assessment (if necessary) and to determine the need for additional remedial actions.

1.2 Document Organization

A summary of the initial data gaps analysis in relation to the major components of the existing CSM was presented in Volume 1 of the *Supplemental Investigation Workplan (AMEC).* Section 2.0 of this DAP presents a discussion as to how the data gathered during the field activities will be used to evaluate and modify the CSM, as well as present some preliminary results. Methods to assess and modify the existing numerical groundwater flow model are summarized in Section 4.0.

2.0 CONCEPTUAL SITE MODEL

While the existing CSM provides a good technical basis for ongoing characterization activities at the site, Volume 1 of the *Supplemental Investigation Workplan* identified several areas where additional data could be used to support the validity of, or refine if necessary, the existing CSM. In particular, the following additional data was identified as necessary to confirm the validity of the CSM: distribution of arsenic in groundwater north and northwest of the arsenic treatment plan (ATP) in the vicinity of Nonacoicus Brook, between the ATP and Plow Shop Pond, and within the area between the center of the landfill and Red Cove. Information will be collected during the Supplemental Investigation. A description of the process for evaluating these data as well as preliminary results is presented below.

2.1 Hydrogeologic Assessment

2.1.1 Bedrock Topography

In the prevailing hydrogeologic conceptual model for glacial-fill valleys, unconsolidated overburden (naturally occurring sands and gravels and, in this case, emplaced landfill waste) constitutes the primary aquifer. These aquifer materials have been deposited within a glacially-eroded (and now partially buried) topography of crystalline bedrock of which Shepley's Hill is a remnant upland. By virtue of a significantly lower bulk permeability and porosity relative to overburden, bedrock is assumed to constitute a significant aquitard, effectively limiting active groundwater circulation to within the overlying overburden aquifer.

As discussed in Volume 1 (AMEC), bedrock is assumed to have a strong influence on groundwater flow patterns – and consequently arsenic plume locations - within the study area. One hypothesis is that the arsenic plume is following the buried bedrock valley beneath the study area. The valley is oriented generally north beneath the landfill, and is interpreted to turn more westerly, parallel to the general trend of Nonacoicus Brook. Proposed wells, together with results from a geophysical study, will permit testing this hypothesis. Information from the geophysical survey (seismic refraction) will be combined with depth-to-bedrock information from proposed borings to refine the topography of the bedrock surface as presented on Figure 1.

2.1.2 Groundwater Flow

Based on the current conceptual model, horizontal groundwater flow within the unconsolidated surficial aquifer is expected to be a significant groundwater transport process, while vertical gradients and flow should be limited to recharge and discharge areas. Further analysis of horizontal and vertical hydraulic gradients will be performed, to the extent possible, as part of the Supplemental Investigation. This will include water levels and analytical data from all new wells and borings. To the extent permitted by the data, the working hypotheses presented above will be revised as necessary based on those data.

2.2 Arsenic Data Assessment

2.2.1 North Plume

A Supplemental Groundwater Investigation (Harding ESE, 2002) indicates arsenic detections along the eastern extent are neither contiguous with the main plume lobe nor strongly correlated with ORP. Because prevailing hydraulic gradients are westward in the Nonacoicus Brook valley fill aquifer, further investigation east of SHX-01-06X and Nonacoicus Brook has not been a key issue. However, since Institutional Controls (ICs) on residential use of groundwater are under consideration in the FFS, further investigation is proposed to better define the area where ICs would be needed.

Farther north, the following initial data gaps are apparent:

- The western plume limit just north and downgradient of West Main Street is west of DEP-08-03, which had 1,700 ppb dissolved arsenic (6/08). While this plume edge is constrained by earlier (2001) profile results from SHX-01-10X, -13X, and -11X located slightly upgradient, the screens at SHP-07-01C and -01D sampled in 2007 are shallower than DEP-08-03 and may be above the plume. Consequently, the western plume in the area of West Main Street is unconstrained in the area east of DEP-08-05 (which extended to bedrock) and northwest of SHX-01-11X.
- The northern plume limit is interpreted to be under Nonacoicus Brook immediately north of DEP-08-03 and -08, which had 1700 and 240 ppb dissolved arsenic respectively (both 6/08). There is no monitoring well situated directly north of these locations where drilling access is limited by the wetland.
- To the northwest the plume appears to be constrained by DEP-08-07, but a data gap may exist to the west between DEP-08-05 and DEP-08-07.

Borings are proposed in each of the above areas (Figure 1). Locations shown on the north side of Nonacoicus Brook are tentative and will be refined based on field access. Groundwater will be profiled for arsenic using field testing methods with confirmatory laboratory analysis for arsenic and other water quality parameters at 10-foot intervals, from the groundwater table to the bedrock surface.

For the northern plume areas, if profile results suggest the 100 ppb plume limit has not been adequately identified, a new boring would be advanced to collect this data. When drilling results suggest the plume limit has been identified, temporary well screens would be constructed at appropriate intervals and sampled for metals and water quality characteristics. The temporary wells will be installed at a separate time, following receipt of confirmatory laboratory arsenic data.

The profile and laboratory analytical results will be used to update plume depictions (plan and section views), and if appropriate, the CSM. Ultimately, the data will be used to identify sentry monitoring wells, and may include new and existing wells, particularly in the northern plume area.

2.2.2 North Plume Capture at Boundary

Objectives for the current remedy in place include operating the treatment system to contain the arsenic plume in the vicinity of the base boundary near the north end of the landfill and demonstrating that the north trending arsenic plume is fully captured. The latest revised groundwater model and other lines of evidence as presented in the 2008 Annual Report suggest that impacted groundwater at the toe of the landfill is fully contained, subject to some uncertainty as to the extent of impact east of SHM-96-5B (ECC, 2009). A boring is proposed in the area of SHL-21 as shown on Figure 2, extending to bedrock with groundwater sampling every 10 feet during drilling, and analysis for arsenic and field parameters. If profile results suggest the plume limit has not been identified, a new boring would be advanced (offset east away from the plume) to collect this data. When drilling results suggest the plume limit has been identified, temporary well screens would be constructed at appropriate intervals and sampled for metals and water quality characteristics. Using field data and the groundwater model, an assessment will be made as whether the existing extraction system is adequate, or whether additional remedial efforts (e.g., additional extraction wells) may be required to fully prevent offsite migration of arsenic in groundwater.

To assist in data interpretation, the groundwater profile and laboratory analytical results will be used to update plume depictions (plan and section views). The analytical results will be compared to historic data from nearby upgradient, downgradient and crossgradient wells. Finally, the analytical results will be evaluated for consistency with the groundwater model. Based on a comprehensive weight-of-evidence evaluation, the CSM will be updated if appropriate.

2.2.3 East Plume Delineation and Capture

Objectives for the current remedy in place include eliminating the continuing discharge of high-arsenic groundwater from SHL to Plow Shop Pond (AOC 72) sediments. Discussions among stakeholders have identified the need for additional information on the distribution of arsenic in groundwater on the eastern margins of the landfill in the vicinity of Red Cove and near the center of the landfill, southwest of Red Cove. Five new groundwater monitoring wells were initially recommended by USEPA for the area between SHL and AOC 72 to collect data on arsenic concentrations in this area (USEPA 2008). Based on subsequent discussions among stakeholders, and review of results from an updated groundwater model, one new monitoring well is proposed at this time, to be located within the landfill approximately 350 feet southwest of Red Cove (Figure 2). Information derived from installation and sampling of this well will be used initially to evaluate the need for additional wells in this area, and ultimately, in combination with groundwater modeling, to evaluate remedies such as hydraulic controls (extraction or injection) or in situ treatment in the discharge area.

A boring will be extended to bedrock with groundwater sampling every 10 feet during drilling, and analysis for arsenic and field parameters and will ultimately be completed as a two-inch diameter temporary monitoring well using rotosonic drilling techniques. The boring will be advanced 5 to 10 feet into bedrock for bedrock confirmation purposes. The temporary well will be constructed and screened at the appropriate interval and sampled for metals and water quality characteristics. The removal and repair of the landfill cap will conducted using the methods outlined within the Field Sampling Plan.

Data generated from the proposed activities will be incorporated into the site data base, and used to update the groundwater model, as appropriate. Data developed during installation and sampling of wells will provide further insight into groundwater flow in the area upgradient of Red Cove. It will assist in identifying the dividing line between groundwater that flows north and that which flows east into Plow Shop Pond. Also, data developed during drilling will be used to refine the CSM with respect to the presence and depth of buried wastes, and the quantity of waste present below the water table. Based on the new chemistry data and using the updated groundwater model, an evaluation of hydraulic controls or extent of in-situ remedy will be conducted in the Final FFS.

3.0 NUMERICAL GROUNDWATER FLOW MODEL

The existing numerical groundwater flow model (developed using the USGS MODFLOW program (MacDonald & Harbaugh, 1988), and running groundwater Vistas pre- and post-processor for the Shepley's Hill area has been utilized over many years to guide site investigations, interpret the arsenic plume trajectory, and predict the effectiveness of the contingency pump and treat remedy currently in operation. To date this model has been calibrated primarily to water level data.

As necessary, revision and validation of the groundwater model will proceed in a step-wise fashion. The first step will be to incorporate all pertinent data collected as part of the proposed field investigation including depth to bedrock from borings and geophysical surveys, and hydraulic head data.

The second step will be to compare model-predicted hydraulic heads, discharges, and flow patterns to field data. Hydraulic head data will be obtained from all new wells installed as part of the investigation. Flow patterns, particularly in the three areas addressed by the investigation, will be interpreted from the arsenic plume orientation, as determined by analytical data from existing and new proposed monitoring wells, and consideration of geochemical conditions.

By iterative trial-and-error adjustment of aquifer permeabilities and model boundary conditions, the model will be recalibrated as necessary. Evaluation of the adequacy of calibration will be performed by computing key statistics on the residuals (differences between observed and predicted values) including the mean error (simple average of all residuals), mean absolute error, and root mean squared error, as well as the spatial distribution of residual values. The primary objective will be to minimize individual residual values, the key statistics, and spatial bias (large residuals clustered in a specific area).

Model variants will be prepared for a range of current and hypothetical future conditions so that impacts of the current contingency remedy, and any proposed modifications, on aquifer levels, flow patterns, and discharges to surface water can be evaluated. As long-term changes are of concern, all models will be run under steady-state conditions. Particle track simulations utilizing MODPATH (Pollock, 1989) will be used to illustrate flow patterns. The results of the flow modeling, in terms of flow patterns, groundwater velocities, and discharge rates, will be integrated with analytical data to define arsenic fluxes.

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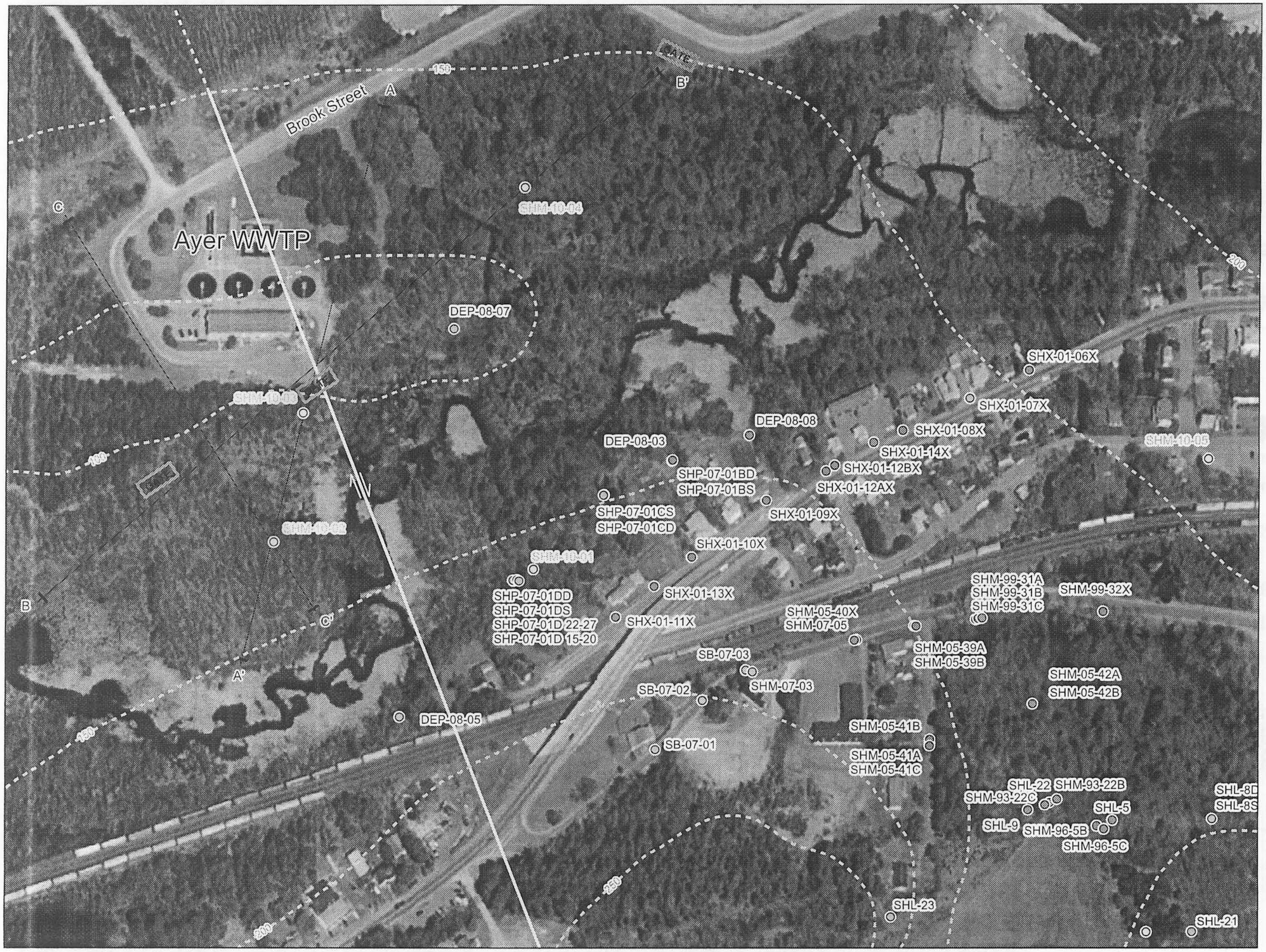
Pollock, D.W. 1989. Documentation of Computer Programs to Compute and Display Pathlines Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. USGS Open File Report 89-391.

USEPA. 2008. Final Report; Arsenic Fate, Transport, and Stability Study; Groundwater, Surface Water, Soil and Sediment Investigation; Fort Devens Superfund Site, Devens, MA, September 2008.

FIGURES

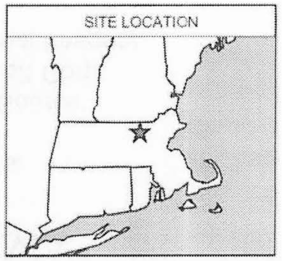


Proposed Investigations Near the Impacted Area

Devens
Ayer, Massachusetts

LEGEND

○	Dissolved Arsenic < MCL
●	Dissolved Arsenic > MCL
○	Proposed Boring / Well Location
- - -	Interpreted Bedrock Elevation (AMSL)
	Fault Line
┼──┼	Proposed Geophysical Survey Line
GATE	Fence Gate



NOTES & SOURCES

Aerial Imagery: 1:5,000 Color Digital Ortho Images, Microsoft Bing Maps, 2008.

0 200
Feet

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905B S. Main Street Unit 202 Mansfield, MA 02048
Tel: 508-339-3200 Fax: 508-339-3248
www.sovcon.com

FIGURE
1

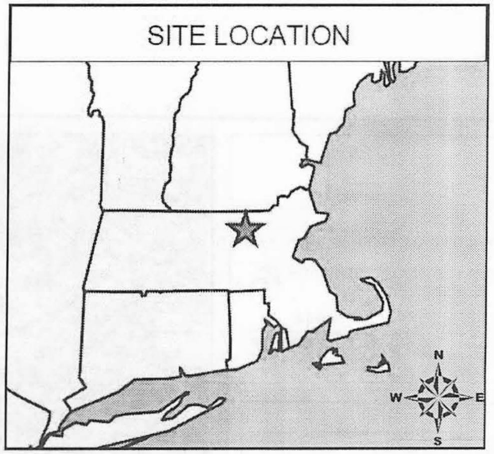

Figure 2 - Proposed Well Locations
Shepley Hill Landfill - Fort Devens
Ayer, MA

Notes:

Base Map Source:
2009 Microsoft Corp.
Bing Maps Aerial Imagery

Legend

- ● Existing Wells and Borings
- ○ Proposed Boring/Well Locations

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Tel: 508-339-3200 Fax: 508-339-3248
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TABLES

Table 1-1
Proposed Rationale for Selection of Sampling Locations
Supplemental Investigation Workplan Addendum
Shepley's Hill Landfill

AREA OF INTEREST	TECHNICAL AND DATA QUALITY OBJECTIVE(S)	TECHNICAL APPROACH	DATA EVALUATION	OUTCOME
1. Red Cove area.	• Extend monitoring network west beyond the area immediately adjacent to Red Cove. • Provide data on bedrock elevation. • Assess hydraulic gradients and flow patterns. • Determine arsenic concentrations (DL ≤ 10ug/l) and ORP values in groundwater in the probable source area of arsenic discharging to Red Cove. • Provide input for groundwater model	• Profiling arsenic concentrations in groundwater to bedrock. • Core sampling and detailed analysis of stratigraphy. • Collect samples for geotechnical analysis. • One temporary monitoring well constructed to allow for sampling and water level monitoring. • Collect water levels from new and existing wells.	• Update relevant interpretive maps and cross-sections. • Compare GW flow direction to predictions made with recalibrated groundwater model.	• Provide data to validate or refine prediction made with the groundwater model with respect to flow patterns and potential sources of Arsenic.
2. Area due east of the extraction wells.	• Explicitly define the eastern extent of the main northward trending lobe of the Arsenic plume. • Determine arsenic concentrations (DL ≤ 10ug/l) in the area at the margin of the extraction well influence. • Define SHL arsenic plume boundary (defined as arsenic ≈ 100ppb and negative ORP). • Provide input for groundwater model	• Profiling arsenic concentrations in groundwater to bedrock. • One temporary monitoring well constructed to allow for sampling and water level monitoring.	• Comparison to predicted capture zone for the extraction wells at current operational rates.	• Improved plume delineation to support performance assessment of Contingency Remedy with respect to containment of the primary Arsenic source.
3. Ayer residential area along W. Main St.	• Provide a bounding monitoring well to constrain the eastward extent of the north trending SHL arsenic plume lobe. • Determine arsenic concentrations (DL ≤ 10ug/l) and ORP values in groundwater in the region currently under-characterized. • Define SHL arsenic plume boundary (defined as arsenic ≈ 100ppb and negative ORP). • Provide input for groundwater model. • Acquire sufficient and appropriate plume information to develop institutional controls for groundwater use.	• Profiling arsenic concentrations in groundwater to bedrock. • Two temporary monitoring well constructed to allow for sampling and water level monitoring. •	• Update relevant interpretive maps and cross-sections.	• Provide the basis for defining the extent of institutional controls required to manage risk to residents for exposure to impacted groundwater.
4. Nonacoicus Brook area	• Constrain the western plume extent by completing the 'necklace' of deep monitoring wells, established by DEP-08-03, DEP-08-05 and DEP-08-07, encircling the presumed discharge area. • Assess hydraulic gradients and flow patterns. • Determine arsenic concentrations (DL ≤ 10ug/l) and ORP values in groundwater. • Define SHL arsenic plume boundary (defined as arsenic ≈ 100ppb and negative ORP). • Provide input for groundwater model. • Determine if Nonacoicus Brook and associated wetland is a hydraulic barrier.	• Characterizebedrock elevations using geophysical techniques. • Profiling arsenic concentrations in groundwater to bedrock. • Six temporary monitoring wells constructed to allow for sampling and water level monitoring. •	• Integrate bedrock elevations from borings and geophysical studies with existing information to select optimum well locations. • Update groundwater flow model and evaluate changes to predicted flow patterns and discharge locations.	• Improved plume delineation to support assessment of potential for Arsenic to migrate westward toward the MacPherson water supply well.

Locations for proposed boring\wells and geophysical transects are shown on Figures 1 and 2.