U.S. Army Corps of Engineers
Louisville District

Final Work Plan
Remedial Investigation/Feasibility Study
TCE Groundwater Plume
Former Raco Army Airfield and Missile Site
Chippewa County, Michigan
FUDS Property No. E05MI0026

U.S. Army Corps of Engineers
Louisville District
Contract No. W912BV-10-D-2000
Delivery Order No. CY01

November 2014

Work Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.

November 2014

Final Work Plan
Remedial Investigation/Feasibility Study
TCE Groundwater Plume
Former Raco Army Airfield and Missile Site
Chippewa County, Michigan
FUDS Property No. E05MI0026

Date Issued – November 2014

Prepared for
U.S. Army Corps of Engineers – Louisville District
600 Martin Luther King Jr. Place
Louisville, Kentucky 40202-2232

Prepared under
Contract No. W912BV-10-D-2000
Delivery Order CY01

THIS PAGE INTENTIONALLY LEFT BLANK

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Notice is hereby given that an Independent Technical Review (ITR) has been conducted that is appropriate to the level of risk and complexity inherent in the project for the Work Plan for the Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05M10026. During the ITR, compliance with established policy, principles, and procedures was verified. This included review of procedures to be used to create a product that meets the customer's needs, consistent with law and existing U.S. Army Corps of Engineers (USACE) policy.

Larry Copeland Project Manager	11/05/14 Date
Katherine Sheedy ITR Team Member	11/5/14 Date
Kim Morris Quality Assurance Reviewer	11/10/14 Date

Significant concerns and the explanation of the resolution are as follows:

None.

As noted above, all concerns resulting from the independent technical review of the document have been considered.

Paul Lewers ITR Team Leader, GEO Consultants, LLC	11/9/14 Date

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

LIST OF FIGURES vii
LIST OF TABLES vii
LIST OF APPENDICES viii

ACRONYMS AND ABBREVIATIONS ix

1. INTRODUCTION 1
1.1 PURPOSE AND OBJECTIVES 1
1.2 WORK PLAN ORGANIZATION 1

2. SITE DESCRIPTION AND PHYSICAL SETTING 3
2.1 SITE LOCATION, HISTORY AND LAND USE 3
2.2 SITE PHYSICAL CHARACTERISTICS 4
2.2.1 Site Topography 4
2.2.2 Site Geology 4
2.2.3 Site Hydrogeology 4
2.2.4 Climate 5

3. PREVIOUS INVESTIGATIONS AND REMEDIAL INVESTIGATION APPROACH 7
3.1 ENVIRODYNE ENGINEERS, INC. (ENVIRODYNE) – 1986-1987 7
3.2 IT CORP – 1990-1991 7
3.3 SVERDRUP ENVIRONMENTAL, INC. – 1996-1997 8
3.4 USACE – 2002 8
3.5 EARTH TECH – 2003-2004 8
3.5.1 2003 Activities 8
3.5.2 2004 Activities 8
3.6 GEO – 2007 9
3.7 GEO – 2009 9
3.7.1 Vertical Aquifer Profile Activities – September 2009 10
3.7.2 Sampling of Groundwater Monitoring Wells – October 2009 10
3.8 INTEGRATED SITE ASSESSMENT AND REMEDIAL INVESTIGATION APPROACH 11
3.8.1 Source for Groundwater Contamination at the Raco Site 12
3.8.2 Groundwater Contaminant Distribution and Potential Receptors 12
3.8.3 Remedial Investigation Approach 13

4. TASK DESCRIPTIONS 17
4.1 PROJECT MANAGEMENT 17
4.1.1 Coordination of Field Work with USFS/Hiawatha National Forest, CELRL, and MDEQ 17
4.1.2 Management of Personnel, Equipment, and Contracted Services 17
4.1.3 Management of Investigation-Derived Waste 17
4.1.4 Site Restoration 18
4.1.5 Subcontractors 18
4.1.6 Project Plans 19
4.1.7 Consideration and Implementation of Green and Sustainable Remediation (GSR) Practices 20
4.2 COMMUNITY RELATIONS 20
4.3 RI FIELD ACTIVIES/DATA MANAGEMENT/REPORTING 20
4.3.1 RI Field Activities 20
4.3.2 Data Management 20
4.3.3 RI Report 21

4.4 BASELINE RISK ASSESSMENT METHODS 21
4.4.1 Introduction 21
4.4.2 Data Evaluation 22
4.4.3 Exposure Assessment 23
4.4.4 Toxicity Assessment 25
4.4.5 Risk Characterization 26
4.4.6 Uncertainty Analysis 28
4.4.7 Ecological Site Reconnaissance 28
4.4.8 Baseline Risk Assessment Summary and Conclusions 29
4.5 FEASIBILITY STUDY 29
5. REFERENCES 33

LIST OF FIGURES

Figure 1. Site location
Figure 2. Site features
Figure 3. Former Missile Battery Area 1972 aerial photograph
Figure 4. Land use and ownership in the vicinity of the Raco Site
Figure 5. Regional topography and surface waters
Figure 6. Potentiometric map, former Missile Battery Area (October 2009)
Figure 7. Soil sampling locations from previous investigations
Figure 8. Groundwater sampling locations from previous investigations
Figure 9. Trichloroethene versus depth profiles from prior Vertical Aquifer Profile (VAP) investigation (GEO 2010) and proposed initial VAP locations
Figure 10. Historical trichloroethene levels in existing monitoring wells
Figure 11. Plan-view, initial Vertical Soil Borings for Vertical Aquifer Profile groundwater sampling
Figure 12. Preliminary conceptual site exposure model

LIST OF TABLES

Table 1. Coordinates and construction information for monitoring wells and Vertical Aquifer Profile (VAP) soil boreholes (VSBs) installed during previous investigations at the Raco Site
Table 2. Depth to water (feet below top of casing) and groundwater elevations (feet above mean sea level) in monitoring wells at the Raco Site
Table 3. Climate data for Raco, Michigan
Table 4. Monitoring wells at the former Raco Missile Battery Area sampled from 1987 to 2009
Table 5. Trichloroethene concentrations (µg/L) measured in monitoring wells located at the former Raco Missile Battery Area
Table 6. Trichloroethene concentrations (µg/L) measured during the previous Vertical Aquifer Profile (VAP) investigation (GEO 2010).
Table 7. Monitoring well sampling summary and rationale for the Raco Site TCE Plume Remedial Investigation
Table 8. Project team members and subcontractors
Table 9. Raco Site TCE Plume Remedial Investigation/Feasibility Tasks and Follow-On Activities
Table 10. Exposure parameters for potential receptors exposed to groundwater from the Raco Site

LIST OF APPENDICES

Appendix A. Field Sampling Plan

Appendix B. Quality Assurance Project Plan

Appendix C. Field Forms, Checklists, and Laboratory Accreditation Certificates

1. Daily Quality Control Report
2. Health and Safety Checklist
3. Instrument Calibration Checklist
4. Surveying Checklist
5. Borehole and Core Logging Checklist
6. Field Documentation Checklist
7. Sample Collection Checklist
8. Packing, Storing, and Shipment of Samples Checklist
9. Investigation-Derived Waste Management Checklist
10. Mobilization/Demobilization Checklist
11. ECCS Chain of Custody
12. CT Laboratories Chain of Custody
13. Water Level Measurements
14. Well Development Log Form
15. HTRW Drilling Log (MRK-55)
16. Quanta Daily Calibration
17. Permanent Monitoring Well Construction Log
18. Waste Item Container Log
19. Lab Certifications
20. Field Change Request
21. Decontamination Checklist
22. through 27. GEO Technical Procedures
28. Daily Safety Tailgate Meeting Form

Appendix D. Monitoring Well Construction Diagrams

Appendix E. Project Schedule

Appendix F. Geographic Information Systems Files and Data (Final revision only)

Appendix G. Technical Memorandum, Green and Sustainable Remediation

ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
BLRA	Baseline Risk Assessment
CELRL	U.S. Army Corps of Engineers, Louisville District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethene
COC	contaminant of concern
COPC	chemical of potential concern
CSF	cancer slope factor
CSIA	compound specific isotope analysis
CSM	conceptual site exposure model
cm	centimeters
DAD	dermal absorbed dose
DCE	dichloroethene
DO	dissolved oxygen
DoD	Department of Defense
DQO	data quality objective
Earth Tech	Earth Tech, Inc.
ECCS	Environmental Chemistry Consulting Services, Inc.
ER	Engineer Regulation
FS	Feasibility Study
FSP	Field Sampling Plan
FUDS	Formerly Used Defense Sites
GC/MS	gas chromatograph/mass spectrometer
GEO	GEO Consultants, LLC
GIS	Geographic Information Systems
GSR	Green and Sustainable Remediation
HI	hazard index
HQ	hazard quotient
IDW	Investigation-Derived Waste
ILCR	incremental lifetime cancer risk
ITR	Independent Technical Review
kg	kilograms
L	liter
MBA	Missile Battery Area
MBT	molecular biological tool
MCL	maximum contaminant level
MDC	maximum detected concentration
MDEQ	Michigan Department of Environmental Quality
mg	milligrams
MNA	Monitored Natural Attenuation
MW	Monitoring Well
ORP	oxidation reduction potential
PPE	personal protective equipment
PWS	Performance Work Statement
QAPP	Quality Assurance Project Plan
QSM	Quality Systems Manual

Raco Site	the former Raco Army Airfield and Missile Site
RfD	reference dose
RG	remedial goal
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
sec	second
Smithers	Smithers Scientific Services, Inc.
Sverdrup	Sverdrup Environmental, Inc.
TCE	trichloroethene
trans-1,2-DCE	trans-1,2-dichloroethene
UCL_{95}	95% Upper Confidence Limit
UFP	Uniform Federal Policy
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VAP	Vertical Aquifer Profile
VSB	VAP soil boring or borehole
VOC	volatile organic compound
WP	Work Plan
µg	micrograms
µg/kg	micrograms per kilogram
µg/L	micrograms per liter

1. INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

This Remedial Investigation (RI)/Feasibility Study (FS) Work Plan (WP) describes activities to be conducted at the former Raco Army Airfield and Missile Site (Raco Site) located in Chippewa County, Michigan. The overall purpose of the RI/FS is to characterize the nature and extent of risks posed by the trichloroethene (TCE) groundwater plume within the former Missile Battery Area (MBA) of the Raco Site and to evaluate remedial options. The specific objectives are (1) to horizontally and vertically delineate the boundary of the TCE groundwater plume to a concentration of 5 micrograms per liter (µg/L), (2) to perform an initial evaluation of the temporal stability of the TCE groundwater plume and the potential for natural attenuation, (3) to conduct a Baseline Risk Assessment (BLRA) to quantify risks from exposure to TCE-impacted groundwater, (4) to identify and evaluate potential remedial alternatives that may be implemented if there are unacceptable risks, and (5) to collect a sufficient quantity of hydrogeologic information and engineering data during the RI field work that will allow an evaluation of remedial alternatives in the FS, if performed.

The RI/FS will be performed by GEO Consultants, LLC (GEO) for the U.S. Army Corps of Engineers (USACE), Louisville District (CELRL) under the Department of Defense (DoD) Formerly Used Defense Sites (FUDS) Program. GEO is performing the RI/FS for CELRL under Contract Number W912BV-10-D-2000, Delivery Order CY01. The RI/FS will be completed in accordance with the requirements of the National Contingency Plan, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act. In addition, all work performed will follow the guidance and policy outlined in the following documents (1) *DoD Manual, Defense Environmental Restoration Program (DERP) Management* (DoDM 4715.20, DoD 2012) and (2) *Environmental Quality: Formerly Used Defense Sites Program Policy* [Engineer Regulation (ER) 200-3-1, USACE 2004]. The lead regulatory agency is the Michigan Department of Environmental Quality (MDEQ).

1.2 WORK PLAN ORGANIZATION

This WP contains an overview of the technical approach to be used in the RI/FS and is organized as follows:

- Section 1 – Introduction. This section presents the purpose and objectives of the RI/FS, and the organization of the WP.
- Section 2 – Site Description and Physical Setting. Site history, location, general description, and land use at the Raco Site are presented in this section. Current knowledge of physical characteristics is summarized, including topography, geology, hydrogeology, and climate.
- Section 3 – Previous Investigations and RI Approach. This section contains a summary of previous investigations, as well as the current understanding of potential sources, contaminant distribution, and migration pathways at the Raco Site. This section includes identification of data needs and a discussion of how these will be addressed by the RI field activities.
- Section 4 – Task Descriptions. This section presents a description of the major tasks to be completed as part of the RI/FS. These include project management, community relations, RI field activities, risk assessment, and the FS.
- Section 5 – References. A list of references used to support information presented in this document is provided.

Additional details regarding the RI field activities are presented in the following documents, included as appendices to this WP:

- Appendix A – contains the Field Sampling Plan (FSP) which describes procedures to be used during the RI field activities.
- Appendix B – contains the Quality Assurance Project Plan (QAPP) which describes the Quality Assurance and Quality Control procedures to be used during the RI field activities, sample analysis and data evaluation. The QAPP has been prepared in accordance with the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP, USEPA 2005).
- Appendix C – contains field forms and checklists that will be used during the RI field work. It also includes the accreditation certifications for CT Laboratories, the primary laboratory, and Environmental Chemistry Consulting Services, Inc (ECCS), the mobile laboratory to be used in this project.
- Appendix D – contains monitoring well construction diagrams.
- Appendix E – contains the project schedule current at the time of submittal.
- Appendix F – (on digital media) contains the Geographic Information Systems (GIS) files and data used to develop this WP.
- Appendix G – contains a Technical Memorandum documenting the progress to date in incorporating green and sustainable remediation practices in this RI/FS project.

2. SITE DESCRIPTION AND PHYSICAL SETTING

2.1 SITE LOCATION, HISTORY AND LAND USE

The Raco Site is located 18 miles southwest of Sault Sainte Marie, Michigan, in the Hiawatha National Forest (Figure 1). The property is geographically located at 46° 20' 54" North, 84° 48' 19" West in Sections 20-22, 27-29, and 32-33, Township 46 North, Range 4 West of the Michigan Principal Meridian. The DoD used the site as an airfield for 21 years and as a missile base for approximately 13 years, ending in 1972. The site consisted of three 5000 foot runways oriented in a triangular configuration, the Fuel Depot Area east of the airfield, and the MBA located southeast of the airfield (Figure 2). The MBA included 28 Bomarc missile silos and associated support facilities (Figure 3). The focus of the RI/FS is in the northeastern portion of the former MBA in the vicinity and east of the former wastewater lagoon where previous investigations have identified a TCE plume (Figure 3).

The Raco Site property consisted of 1825.94 acres acquired between 1942 and 1945 via various transfer permits, licenses, leaseholds, easements, and fee purchases (see FUDS boundary in Figure 2). Part of this acreage, a 600-acre parcel, was transferred from the Fort Brady Target Range (now FUDS Property E05MI0005). Therefore, the 600-acre parcel is included with the Raco Army Airfield and Missile Site (FUDS Property E05MI0026) and excluded from E05MI0005 as duplicate acreage. The Raco Army Airfield was constructed between 1942 and 1943 east of the Fort Brady Target Range/FUDS Property E05MI0005. Around 1960, the MBA was constructed southeast of the airfield (Figure 2 and Figure 3). Between 1962 and 1964, the Air Force released all property interests to the U.S. Forest Service (USFS) except for the 152.54-acre missile area and an additional 5-acre area. On 30 June 1973 and 24 March 1976, respectively, these 152.54-acre and 5-acre areas were released to the USFS. Since that time, the property has remained under USFS jurisdiction.

Since 1973, the USFS has entered into several permit agreements with outside interests. They are summarized below (Woodruff and Pearce 1989).

- 1973 – a sawmill was operated by a local Indian Tribe resulting in accumulation of a large pile (approximately 5000 cubic yards) of sawdust, wood waste, and other debris.
- 1978 – sale and removal of seven of the base buildings, the water tower, and 28 missile silo shelters.
- 1981 and 1984 – dumping of broken concrete and waste construction materials into the silos. This debris resulted from road repair operations on Route M-28 and was used to reduce the hazard potential of public travel near open missile silos.
- Present – airfield runways and other portions of the site are currently used during the winter months for automobile tire testing by Smithers Scientific Services, Inc. (Smithers). The buildings and water supply wells located on the northeast portion of the former MBA as well as the circular tracks were added by Smithers (Figure 2).

The Raco Site, specifically the airfield runways and the former MBA, is leased by Smithers and used for industrial purposes. However the surrounding area is managed by the USFS for the following uses: (1) to provide wildlife habitat for various avian species, (2) to provide conifer timber products to the regional economy, and (3) to provide dispersed and developed recreation (USDA 2006). Because of its location within the National Forest System, the Raco Site is likely to remain publicly owned and part of the Hiawatha National Forest in the future. Recreation residences, which consist of cabins owned by private individuals who may occupy the residences on a non-permanent basis, are present within the Hiawatha National Forest in the areas east/southeast of the former MBA (Sections 27 and 32 of Township 46 North, Range 4 West), in the presumed direction of groundwater flow from the site (see Section 2.2.3). However none are located

within the Raco Site. It is unlikely that such recreation residences will be constructed in the future because the USFS is no longer granting new permits for cabins/recreation residences in the Hiawatha National Forest (USDA 2006). It should be noted that there are privately owned tracts of land within the Hiawatha National Forest, two of which are located approximately one mile east and 1.5 miles southeast of the Raco Site (Figure 4). According to the Chippewa County on-line parcel records database, the tracts to the east consist of residential parcels while the tracts to the southeast consist of residential and commercial forest properties.

GEO (2010) conducted a well survey within a one mile radius of the Raco Site to locate and identify private and public/domestic water supply wells using online water well databases. The only wells identified during this survey were the water supply wells owned by Smithers located north/northeast of the former MBA (Figure 2). According to the water well database for the State of Michigan, there are no water supply wells in the privately owned tract of land east of the Raco Site; however there are a cluster of residential wells in the tract of land southeast of the site (well locations in Figure 4).

2.2 SITE PHYSICAL CHARACTERISTICS

2.2.1 Site Topography

The topography of the Raco Site is relatively flat with an elevation ranging from 900 feet to 920 feet above mean sea level (amsl). However, the surface elevation drops steadily to the southeast as shown in Figure 5. Within one mile from the Raco Site in this direction, the ground surface is at an elevation of 850 feet; within an additional 0.5 miles surface streams draining to the southeast as well as associated wetlands are encountered (also shown in Figure 5). These surface drainage features suggest that this is a potential discharge region for groundwater originating at the Raco Site.

2.2.2 Site Geology

The glacial deposits and landform features of Chippewa County are predominantly of the Wisconsin ice age. During late Wisconsin time, Lake Algonquin, an early stage in the succession of the Upper Great Lakes, covered nearly all of Chippewa County (Vanlier and Deutsch 1958). Glacial deposits in Chippewa County are composed of till, outwash, lacustrine sediments, and dunes. Most of the moraines in Chippewa County were originally deposited in glacial Lake Algonquin.

The Raco Site appears to lie close to what was located along the northwestern boundary of the glacial Lake Algonquin 10,000 to 11,000 years ago. The sediments underlying the Raco Site have been described in boring logs associated with previous investigations (generally less than 100 feet deep) as homogeneous fine to very fine sands with traces of silt and gravel. However, drilling logs associated with the Smithers water supply wells north/northeast of the former MBA (Figure 2) with depths as great as nearly 200 feet indicate the increasing presence of sandy-silty clay lithologies at depths within the range of 70-140 feet below ground surface (bgs). The latter suggests that finer grained sediments may also be present at these depths at the former MBA of the Raco Site. This observation in most of the water supply drilling logs is consistent with what appears to be a transition to the lacustrine sediments that were deposited in glacial Lake Algonquin to the east of the Raco Site; in this area there is a thinning and disappearance of the surficial sands within 4-8 miles and a growing importance of clay-dominant lithologies.

2.2.3 Site Hydrogeology

Twenty-seven monitoring wells have been installed across the Raco Site as part of previous investigations (summarized in Section 3). Monitoring well construction data are presented in Table 1, and well construction diagrams are included in Appendix D of this WP. Twenty of the monitoring wells are located within the former Raco MBA (Figure 3) while the rest of the wells are located in the airfield and at

the Fuel Depot (west of the airfield). The depth of wells range from about 35 to 130 feet and 10-foot screens are typical for all wells (Table 1). Table 2 presents historical water level measurements in monitoring wells at the Raco Site. The water table is encountered at a depth of approximately 35 to 55 feet bgs, and at an elevation of approximately 850 – 860 feet amsl. Potentiometric maps were constructed during each of the past investigations at the Raco Site, and all such maps are very consistent since 1986 even as the number and distribution of monitoring wells has increased over time. These maps illustrate that groundwater flow is in an easterly to south-easterly direction with a lateral gradient of approximately 0.002 ft/ft. Figure 6 shows the potentiometric map constructed from water levels measured in October 2009 and reported in GEO (2010). A regional groundwater contour map prepared by the state of Michigan as part of the Groundwater Inventory Mapping Project (2005) show southeasterly flow towards the wetlands and surface waters east of the Raco Site (Figure 5); this regional map suggests that the general easterly direction seen in Figure 6 may shift, trending more southeasterly with distance from the Raco Site.

2.2.4 Climate

Average monthly temperatures, average precipitation, and record temperatures for Raco, Michigan (Weather Channel 2013) are summarized in Table 3. Average annual precipitation is 32.9 inches, with highest precipitation occurring in the fall months (August through October).

THIS PAGE INTENTIONALLY LEFT BLANK

3. PREVIOUS INVESTIGATIONS AND REMEDIAL INVESTIGATION APPROACH

There have been a series of previous investigations at the Raco Site that have contributed soil and groundwater characterization data applicable to the TCE groundwater plume. As noted previously, twenty-seven monitoring wells (Table 1) have been installed at the Raco Site, twenty of which are located at the former Raco MBA (Figure 3). Historic water level measurements are presented in Table 2, while a summary of monitoring well sampling events at the former Raco MBA is shown in Table 4. This section presents brief summaries of previous investigation results relevant to the TCE groundwater plume, followed by a discussion of data needs that will be addressed by the RI field activities. It should be noted that the previous investigations at the Raco Site included the analysis of a suite of inorganic and organic constituents however only TCE exceeded screening criteria and only in groundwater. Thus, the focus of the RI/FS is on TCE and its dechlorination products, and only TCE analysis results are discussed in the summary of previous investigations.

3.1 ENVIRODYNE ENGINEERS, INC. (ENVIRODYNE) – 1986-1987

Envirodyne (1987) conducted a Contamination Evaluation Study between December 1986 and April 1987 at the request of USACE, following the Defense Environmental Restoration Account directive. This study included a records review, site inspection, surface soil sampling, and installation of four groundwater monitoring wells (RG-01, RG-02, RG-03 at the former MBA and RG-04 at the former Fuel Depot). Only RG-03 is located near the TCE plume (Figure 3). TCE was detected in the groundwater sample collected from RG-03 at 3.0 µg/L and was not detected in the other wells (see Table 5 for historical TCE analysis results in monitoring wells at the former Raco MBA).

3.2 IT CORP – 1990-1991

IT Corp. conducted an investigation in 1990 (Stage 1) and 1991 (Stage 2). The Stage 1 tasks included:

- The installation of eight monitoring wells (MW-05 through MW-12). Of these monitoring wells, MW-05 through MW-08 are located within the former Raco MBA, and MW-07 and MW-08 are located near the TCE plume (Figure 3).
- Groundwater sampling at 12 monitoring wells in September/November 1990 (see Table 4). Seven of the monitoring wells sampled are within the former Raco MBA, three of which were within or near the TCE plume: RG-03, MW-07, and MW-08. TCE was only detected in MW-08 at a concentration of 3J µg/L (Table 5, September 1990 sampling date).
- Slug testing of two monitoring wells (MW-07 and MW-08) located within or near the TCE plume.
- Advancement of soil borings to a depth of 45 feet bgs, and analysis of soil samples in the wastewater treatment lagoon area (Figure 7).
- Collection of 16 geotechnical samples for grain size distribution analysis (results consistently indicated poorly graded sand, or poorly graded sand with trace of silt).

The Stage 2 tasks completed include:

- The installation of three monitoring wells (MW-13 through MW-15). MW-14 and MW-15 are located in the former Raco MBA while only MW-14 is located within or near the TCE plume (Figure 3).

- Groundwater sampling in July 1991 at five monitoring wells in the former Raco MBA (RG-01, RG-03, MW-08, MW-14, and MW-15). TCE was only detected in MW-08 at a concentration of 3J µg/L, the same concentration measured in September 1990 (Table 5).
- Slug testing of one well within or near the TCE plume (MW-14).
- Advancement, sampling, and analysis of soil borings within the wastewater treatment lagoon.

3.3 SVERDRUP ENVIRONMENTAL, INC. – 1996-1997

Sverdrup Environmental, Inc. (Sverdrup) conducted an investigation at the site in 1996 and 1997. This investigation included installation of soil borings and sampling of existing monitoring wells. Previously installed monitoring wells were redeveloped and sampled in 1997 (Sverdrup, as cited in Earth Tech 2005); only one monitoring well at the former Raco MBA (MW-05) was sampled and TCE was not detected (Table 5).

3.4 USACE – 2002

In May 2002, USACE (2003) sampled 15 monitoring wells at the Raco Site, nine of which were located at the former Raco MBA (RG-01 through RG-03, MW-05 through MW-08, MW 14, MW-15). Samples were collected using dedicated hand bailers after stabilization of pH, temperature, and specific conductance. TCE was only detected in MW-08 at a concentration of 11 µg/L; this value is higher than the previous detection of 3J µg/L in 1990-1991 (Table 5).

3.5 EARTH TECH – 2003-2004

Earth Tech (2005) conducted a Site Investigation in phases from September 2003 to November 2004. The 2004 Earth Tech investigation was designed to evaluate the extent of TCE contamination in the former Raco MBA. This investigation included the installation of soil borings, redevelopment of existing wells, the installation and development of new wells, and groundwater sampling. The following information and data were compiled from Earth Tech (2005).

3.5.1 2003 Activities

- Two additional monitoring wells were installed at the former Raco MBA (MW-17 and MW-18). The newly installed wells and existing monitoring wells at the former Raco MBA were sampled in October 2003 (see Table 4 for sampled wells). TCE was only detected in two wells: in MW-08 at a concentration of 14 µg/L, and in MW-18 at a concentration of 1.6 µg/L (Table 5).

3.5.2 2004 Activities

- Groundwater samples were collected in May 2004 from many of the same wells sampled during the October 2003 event (see Table 4 for sampled wells). TCE was detected in MW-08 and MW-18, at 19 µg/L and 0.56 µg/L, respectively (Table 5).
- Five soil borings (the former Composite Building, sludge drying bed, and wastewater treatment plant lagoon, see Figure 7) were advanced to a depth of 80 feet bgs in the former Raco MBA. The areas were deemed most likely to be a source of TCE contamination in the groundwater. They were also investigated to determine the optimum placement for additional wells. Soil samples were collected at 10, 20, and 40 feet bgs. Groundwater samples were collected at 70 and 80 feet bgs. The soil samples indicated no evidence of a source area for the TCE. The groundwater collected from the soil borings, however, contained TCE concentrations ranging from 0.8 to 18 µg/L.

- Based on the results of the soil boring investigations, four new monitoring wells (MW-19, MW-20, MW-21, and MW-22) were installed to depths of approximately 90 feet bgs.
- MW-07, MW-08, MW-14, MW-18, MW-19, MW-20, MW-21, and MW-22 were sampled in November 2004. TCE was detected in MW-08 (19 µg/L), MW-18 (0.8 µg/L), MW-19 (4.4 µg/L), and MW-20 (0.52 µg/L).

3.6 GEO – 2007

GEO conducted an investigation at the Raco Site from June 2007 to August 2007. Tasks included sampling of monitoring wells in and around the former Raco MBA (see Table 4 for sampled wells). The results of this investigation were documented in GEO (2008) and are summarized below.

The highest TCE concentrations in June and August 2007 were measured in groundwater samples from MW-19 (32 and 33 µg/L, respectively); these concentrations are almost ten times higher than the concentration measured in November 2004 (4 µg/L) when this well was sampled after it was installed in October 2004. The second highest TCE concentrations were measured in MW-08 (19 and 12 µg/L); these concentrations are comparable and slightly lower than the previous TCE concentrations in this well (last sampled in November 2004, see Table 5). The remaining TCE detections were below 1 µg/L in RG-02, MW-18, and MW-20; the results in these wells are comparable to the results in previous samples collected from these wells (Table 5).

Of the monitoring wells that were present at the former Raco MBA by 2007, TCE was detected above 5 µg/L in MW-08 and MW-19 during multiple sampling events; these wells are believed to be down gradient of the former wastewater treatment lagoon. TCE was detected in MW-08 eight times during the prior 11 sampling events from September 1990 through August 2007, at concentrations ranging from 3 to 33 µg/L (see Table 5). TCE had been detected in MW-19 in each of the three sampling events since its installation: November 2004 (4.4 µg/L), June 2007 (32 µg/L), and August 2007 (33 µg/L).

3.7 GEO – 2009

GEO (2010) conducted RI/FS activities at the former Raco MBA from September 2009 to October 2009. Tasks included the following.

- Advancement of 10 Vertical Aquifer Profile (VAP) soil boreholes (VSBs, Figure 8) through rotosonic drilling to collect groundwater samples from discrete depths with a groundwater sampler. Groundwater samples were analyzed in an on-site mobile laboratory to assist in the vertical and horizontal delineation of TCE detected in previous groundwater investigations.
- The installation of five monitoring wells (MW-23 through MW-27) based on the results of onsite mobile laboratory volatile organic compound (VOC) analysis of groundwater samples collected during VAP sampling.
- One round of groundwater sampling from 12 monitoring wells and four water supply wells located on the property (Figure 2). Samples were analyzed for VOCs by fixed-base analytical laboratories.
- A well survey to locate domestic water supply wells within a one mile radius of the former Raco MBA (this was discussed in Section 2.1).

The following summarizes the results of the VAP investigation (Section 3.7.1) and monitoring well sampling (Section 3.7.2) conducted as part of this study.

3.7.1 Vertical Aquifer Profile Activities – September 2009

Ten VAP boreholes ranging in depth from 58 to 157 feet bgs were drilled within and east of the former Raco MBA (Figure 8). VSB-01 (not shown in the figure) was drilled approximately 450 feet west of VSB-07 in an area without suspected contamination sources; no VAP groundwater samples were collected from this borehole. Boring logs indicated soil at the VAP borehole locations consisted predominantly of fine grained sands with trace silt. The focus of the VAP investigation was to identify the source area of TCE impact and, if possible, define the boundaries of TCE-impacted groundwater. After reaching the zone of saturation, every 10 feet of VAP borehole drilling advancement was followed by groundwater sampling through the 2-foot push-ahead groundwater sampler. The VAP groundwater sampling provided TCE concentration versus depth data at each boring location (Table 6). The former wastewater treatment lagoon (identified in Figure 3 and Figure 8) is considered a potential TCE source area with TCE concentrations exceeding 5 µg/L in groundwater samples from VAP boreholes located down-gradient of the lagoon (VSB-02, VSB-03, VSB-04, VSB-06, VSB-08 and VSB-10). VSB-07 was drilled in the vicinity of a former heating oil tank (identified as "UST C-04" in previous reports) that was excavated in 1987; this was ruled out as a TCE source area based on the very low concentrations of TCE detected in the VAP groundwater samples collected from this location (maximum TCE of 0.17 µg/L). VSB-09 was drilled immediately upgradient while VSB-05 was drilled immediately north of the former wastewater lagoon (Figure 8). The maximum TCE concentration detected in VSB-09 was 2 µg/L (Table 6). TCE was not detected in any of the VAP samples from VSB-05 analyzed by the on-site laboratory (reporting limit of 1 µg/L) although a confirmation sample analyzed by the fixed-base off-site laboratory contained 0.28 µg/L (Table 6).

Analytical results for VAP groundwater samples obtained by the onsite mobile laboratory were used to guide the successive VAP borehole locations and the conversion of five boreholes to monitoring wells. The highest detected TCE concentrations in the VAP groundwater samples were collected from VSB-08 (67 µg/L/65 µg/L, 77 feet bgs), VSB-03 (60 µg/L/77 µg/L, 97 feet bgs) and VSB-10 (61 µg/L/55 µg/L, 127 feet bgs). Note that the second TCE value listed for each VAP sample is the concentration measured in the off-site fixed-base laboratory. VSB-08, VSB-03, and VSB-10 are located at increasing distances from the former wastewater lagoon; the highest peak on their profiles follow a remarkably linear downward trajectory as shown in Figure 9. Furthermore, there is no apparent attenuation in TCE concentration within the 400-foot distance spanning the three VAP borehole locations. The thickness of the TCE profile is also relatively constant at approximately 40 feet (Figure 9). Based on the VAP results, VSB-08, VSB-03, and VSB-10 were converted to MW-26, MW-23, and MW-27. VSB-04 (maximum TCE of 12 µg/L in the VAP groundwater samples) and VSB-06 (no TCE detected) were converted to MW-24 and MW-25 respectively.

In summary, the VAP investigation confirmed eastward migration of the TCE plume, following a groundwater flow direction inferred from potentiometric results (Figure 6) and downward migration through the sandy aquifer (Figure 9).

3.7.2 Sampling of Groundwater Monitoring Wells – October 2009

Following the VAP investigation, selected VAP boreholes were converted into monitoring wells in September 2009. The screened intervals of the monitoring wells were selected to match the respective depth ranges where groundwater samples obtained from each VAP had the highest observed TCE concentrations. Sixteen wells were sampled in October 2009 at the former Raco MBA. Four of the wells were potable groundwater wells used by Smithers (located in the Smithers Buildings area shown in Figure 2). The results of the 12 monitoring wells sampled are shown in Table 5. All wells were purged and sampled with dedicated bladder pumps using modified low-flow techniques. TCE concentrations in five of the monitoring wells installed during the VAP investigation (MW-23 through MW-27) as well as in existing wells MW-08 and MW-19 exceeded the TCE maximum contaminant level (MCL) of 5 µg/L (see data in Table 5). The TCE

concentrations detected in MW-08 and MW-19 (7.6 and 22 µg/L, respectively) were lower than the concentrations measured in 2007. The highest TCE concentrations were measured in MW-26 and MW-23 (51 and 48 µg/L, respectively); these values are lower but comparable to the maximum TCE concentrations measured in the corresponding VAP boreholes (VSB-08, 67 µg/L and VSB-03, 60 µg/L). However, the TCE concentration in MW-27 measured in October 2009 (16 µg/L) is significantly lower than the value measured in the corresponding VAP borehole (VSB-10, 61 µg/L). VOCs were not found in the Smithers water supply wells.

The 2009 investigation at the Raco Site combined with previous investigation results has defined the northern, southern, western, and vertical extents of the TCE plume to a concentration of 5 µg/L (Figure 10). Groundwater data from MW-07, VSB-05, VSB-07, and VSB-09 are used to bound the western part of the plume (see locations in Figure 8, data for MW-07 in Table 5 and data from VAP boreholes in Table 6). Based on the TCE concentrations identified in VSB-10 (61 µg/L) and in the monitoring well installed in VSB-10 [MW-27 (16 µg/L)], the eastern portion of the TCE plume has not been fully defined.

In addition to TCE concentration data, most of the previous investigations included the analysis of groundwater samples for common TCE anaerobic degradation daughter products (1,2-cis-DCE, 1,2-trans-DCE, and vinyl chloride). With the exception of a single detection of vinyl chloride below the quantitation limit for groundwater from MW-08 (USACE 2002), the results for these three constituents were non-detects. The lack of detectable amounts of the degradation products suggests that such a TCE reaction pathway may not be important.

Another means for exploring whether the geochemical aquifer environment can support anaerobic degradation of TCE is to evaluate field water quality parameters that were collected as part of the groundwater sampling process. Temperature, pH, specific conductance, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity are the parameters that are monitored during well purging. Parameters such as pH, DO, and ORP are useful for evaluating whether the geochemical conditions are sufficiently reducing (DO and ORP) or the pH falls within the range that supports the viability of key types of bacteria within the aquifer. Several of the prior investigations only involved collection of temperature, pH, and specific conductance results (Envirodyne 1987; IT 1991) whereas Earth Tech (2005) and GEO (2008, 2010) provide a full suite of the water quality parameters. With some exceptions that might reflect measurement deficiencies, there was reasonable consistency among the results obtained by the different investigations. In general, the observed DO concentrations and ORP results suggest a relatively oxidizing environment that may not support a reductive dechlorination pathway for TCE. It should be noted that all the prior geochemical data were collected from the existing monitoring wells, and that geochemical conditions may change further east of the current extent of the monitoring network.

There are other geochemical parameters that can be used to evaluate the viability of anaerobic TCE degradation at the Raco Site. The concentration of ferrous iron (Fe^{2+}) and redox couples such as nitrate/nitrite and sulfate/sulfide can be helpful however analysis for these parameters was not performed in any of the previous investigations.

3.8 INTEGRATED SITE ASSESSMENT AND REMEDIAL INVESTIGATION APPROACH

The following is an integrated assessment of site conditions based on previous investigations at the Raco MBA and the RI approach to address data needs. A Conceptual Site Model is presented in the QAPP (Worksheet #10, Appendix B).

3.8.1 Source for Groundwater Contamination at the Raco Site

Figure 7 illustrates the locations of soil borings from which soil samples were collected and analyzed from the vicinity of the TCE plume at the former MBA. Envirodyne (1987) suggested that low level TCE contamination in well RG-3 (3J µg/L) may have originated in association with the wastewater treatment lagoon at the former MBA. However, the soil sample collected from 0 – 2 feet bgs from within the wastewater lagoon (reportedly dry at the time and has been dry during all subsequent investigations) did not contain any detectable levels of TCE (see RS-2 in Figure 7). TCE was not detected in any other soil samples (0 – 2 feet bgs) collected by Envirodyne from other locations in the vicinity of the TCE plume (RS-2 to RS-8 in Figure 7). Both IT (1991) and Earth Tech (2005) installed several boreholes (maximum depth of 45 feet bgs) in the vicinity of the wastewater treatment lagoon and at other locations within the former MBA (e.g., the former Assembly Maintenance building, former sludge drying beds, near the former USTs). Of the soil borings illustrated in Figure 7, TCE was detected only in one soil sample from boring SB-08 at a depth of 20 feet and at a very low concentration [0.55 micrograms per kilogram (µg/kg)]. A non-aqueous phase liquid source was not found during any of the previous investigations. An estimate of the total TCE mass in the current extent of the groundwater plume (5 pounds or less[1]) suggests that the original TCE release to groundwater was a relatively small amount and/or as a dissolved phase. In summary, there is no direct evidence of an active TCE source area at the former Raco MBA.

Although a definitive contaminant source area at the former Raco MBA has not been defined, groundwater contamination results (see Table 5) indicate that the source(s) probably lie within the general area between the former Assembly Maintenance Building and the wastewater treatment lagoon (Figure 7). It is possible that the original source(s) are now exhausted of TCE through gradual dissolution by infiltrating precipitation over the past 40 to 50 years. If so, then leaching of TCE from sources in the vadose zone may no longer occur and the plume will gradually evolve from an initial growth phase through stabilization and eventually begin to diminish in size. Currently it is unknown what evolutionary phase applies to the TCE plume at the site.

Given the amount of existing soil data at the former MBA (Figure 7), no further soil sampling for chemical analysis in the presumed source area is planned for this RI/FS. However, grain-size distribution and organic carbon are soil properties that influence TCE fate and transport. These soil properties, if measured for the Raco Site, can be used to evaluate TCE migration and attenuation as well as assist in the evaluation of potential remediation technologies for the FS.

3.8.2 Groundwater Contaminant Distribution and Potential Receptors

Figure 8 illustrates the locations where groundwater data from monitoring wells and soil boreholes were collected from the former MBA in the vicinity of the TCE plume. These wells and borehole locations represent data collected as early as 1987 to as recently as 2009. The TCE detections in the monitoring wells are shown in Figure 10. The analytical data included metals, semi-volatile organic compounds, pesticides, and VOCs, with the only contaminant exceeding the screening criteria within the plume being TCE. Based on the TCE concentrations in groundwater samples collected at these locations from prior site investigations (Table 5), a 5 µg/L isocontour that bounds the lateral extent of the plume has been placed on Figure 10. The isocontour is a solid line where the footprint of the plume is adequately defined and dashed in those areas where additional monitoring data are required. All monitoring wells and borehole locations within the boundary contained at least one groundwater sample with TCE levels greater than 5 µg/L. Additional characterization efforts are needed to delineate the eastern end of the TCE plume to a concentration of 5

[1] Estimated from the current plume dimensions (225 feet wide, 400 feet long, and 40 feet thick; see Section 3.8.2), porosity of 30%, and TCE concentration of 77 µg/L, the maximum measured concentration in groundwater samples from the site (see data in Tables 5 and 6).

μg/L. The currently defined extent of the plume is approximately 400 feet long, 225 feet wide, with a height of 40 feet based on the TCE depth profile from the VAP investigation (Figure 9).

In Section 2.1, it was noted that publicly owned land within the Hiawatha National Forest east and southeast of the Raco Site (along the groundwater flow direction, see Section 2.2.3) is unlikely to be transferred to private ownership. Furthermore, there are no recreational residences in these areas and it is unlikely that new cabins will be built because the USFS no longer issues new special use permits for such recreational residences within the Hiawatha National Forest (USDA 2006). Thus, the only potential residential receptors are current and future residents in the privately owned properties located 1 mile east and 1.5 miles southwest of the Raco Site (Figure 4). Based on data collected to date, the Raco MBA plume appears to be oriented in a direction toward these potential receptors. However, that preliminary interpretation only can be evaluated when the plume is fully delineated and temporal data are available for assessing the state of the plume (i.e. growing, shrinking, or stable). Thus, obtaining both kinds of information is essential in order to assess the extent and stability of the plume and to fully characterize risks associated with it.

3.8.3 Remedial Investigation Approach

It is apparent from Figure 10 that the most poorly defined limit of the TCE plume (both laterally and vertically) currently occurs in the eastern half of the plume where only three locations with groundwater data exist (VSB-04/MW-24, VSB-06/MW-25, and VSB-10/MW-27). Given the successful application of the VAP groundwater sampler during the 2009 investigation (Section 3.7), the same overall approach of using VAP boreholes advanced through rotosonic drilling, collecting groundwater samples from the boreholes with a push-ahead groundwater sampling method, and analysis of groundwater samples by an on-site mobile laboratory will be applied to the RI field work to further delineate the TCE plume. The strategy for positioning VAP boreholes based on the configuration of the TCE plume inferred from historical data (Figure 11) is described in the FSP (Appendix A). Up to a total of 2400 lineal feet of borehole drilling is currently planned for the RI/FS. Using an estimated average depth of 200 feet, this drilling capacity corresponds to 12 boreholes. Similar to the approach used in the 2009 investigation, monitoring wells (up to 6) will be installed in selected VAP boreholes to expand the monitoring network at the Raco Site. The RI field work will consist of the following phases:

- A Verification Sampling Event[2] where existing monitoring wells will be sampled in Spring 2014.
- Drilling of VAP boreholes for groundwater sampling to vertically and laterally delineate the eastern end of the TCE plume, followed by installation of up to six monitoring wells in selected VAP boreholes (scheduled for Summer 2014).
- Two rounds of groundwater sampling round at least six months apart (Fall 2014 and Spring 2015).

The use of the VAP approach to delineate the TCE plume at the Raco Site is generally consistent with the Triad approach of using a dynamic work strategy (USEPA 2008a). The dynamic work strategy is being applied to the positioning of the new VAP boreholes. The location of the first borehole will be dependent on historical data as well as results to be collected during the Verification Sampling Event currently planned for Spring 2014. Verification sampling will occur approximately five months before the VAP investigation currently planned for late Summer 2014. The Verification Sampling Event was included in the RI because the last groundwater sampling at the Raco Site was conducted in 2009 and only one set of samples had been collected from the monitoring wells installed at that time (MW-23 through MW-27). Resampling of these monitoring wells (and several additional selected wells) during the Verification Sampling Event will assist in determining if the plume configuration may have changed since 2009. Furthermore, the TCE

[2] The Verification Sampling Event is being used to supplement previous data and to verify the plume axis/configuration inferred from previous investigation data.

concentration results will add another element of temporal TCE contamination information to the groundwater database for plume monitoring wells. Sample analysis will take place in an off-site fixed-base laboratory. The initial VAP borehole locations shown in Figure 11 are based on the plume axis inferred from the VAP data collected in 2009 and existing monitoring well data (see FSP for more details on the VAP drilling strategy). The locations of the initial VAP boreholes may be altered if the results of the Verification Sampling Event suggest that the plume configuration/plume axis may have changed since 2009.

In accordance with the dynamic work strategy recommended by the TRIAD approach, the siting of VAP boreholes subsequent to the initial locations will be based on groundwater analysis for TCE and its chlorinated degradation products [cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-DCE, vinyl chloride] by an on-site mobile laboratory. The mobile laboratory is equipped with a gas chromatograph/mass spectrometer (GC/MS) that was selected over true real-time measurement technologies (i.e., the Membrane Interface Probe equipped with a Flame Ionization or Photoionization Detector). The GC/MS approach was chosen because the target delineation concentration (5 μg/L) is lower than the detection limits of the real-time measurement technologies (1 mg/L). The borehole drilling strategy and decision process for delineating the TCE plume to a concentration of 5 μg/L is described in detail in the FSP (Appendix A). The dynamic work strategy is also being implemented in the siting of new monitoring wells; the locations selected for well installation will be based on the VAP groundwater data as described in the FSP (Appendix A).

In addition to plume delineation, data to be gathered as part of this RI will provide evidence related to the evolution of the TCE plume over time (growth, stability, or recession in the down gradient direction). There is very little existing site data that can be used to infer temporal trends in the TCE plume. Data from MW-08 (1990 – 2009) and MW-19 (2004 – 2009) (see Table 5) indicate shifts in TCE concentration over time in these two wells, but it is impossible to determine the cause(s) of the changes with this limited data set. The ability to capture similar data from monitoring wells associated with the plume may help to better understand how it is evolving and provide important insights on how this information impacts potential remediation alternatives. As such, in addition to the Verification Sampling Event, the RI field tasks include two rounds of groundwater sampling (Fall 2014 and Spring 2015) from existing and new monitoring wells to be installed during this investigation. Integration of analytical results of groundwater samples obtained from newly installed monitoring wells during the RI field tasks with historical data from previous site investigations will be used to evaluate TCE plume stability at the Raco Site.

Besides defining the boundary of the contaminant plume and plume stability, it is essential to refine the current understanding of aquifer hydraulic properties to improve estimates of groundwater flow velocity. Several slug tests have been conducted at the former Raco MBA, although most were conducted on monitoring wells where the water table intersects the well screens and may not have yielded reliable slug test results. Five slug tests are planned for the RI field work.

In addition to the slug tests nested piezometers may be installed at the Raco Site if there is adequate drilling capacity remaining (before the 2400-foot limit is reached) after the plume has been delineated during the VAP investigation. The nested piezometers would provide an estimate of vertical groundwater gradient, which may be a useful parameter for the design of future remedial technologies. The vertical gradient is not considered an essential piece of information for developing a conceptual model for plume migration at the Raco Site because the VAP investigation from 2009 (GEO 2010) has already confirmed downward transport of the TCE plume (e.g., Figure 9).

Existing analyses within the TCE plume do not reveal the presence of typical anaerobic degradation products such as cis-1,2- DCE and vinyl chloride. However, a more detailed evaluation of Monitored Natural Attenuation (MNA) at the Raco Site is required because the TCE concentrations are relatively low

(<100 µg/L) and degradation may be occurring but with degradation products below detection limits. Also, given the relatively low concentrations, MNA may be a viable alternative using only physical attenuation mechanisms. RI field activities include measurements of the standard set of parameters used for MNA screening. In addition, the RI field sampling will include innovative analytical methods to explore evidence of TCE degradation or the potential for stimulating degradation that may apply to future remediation approaches. These innovative methods include: compound specific isotopic analysis (CSIA) and molecular biological tools (MBTs). In CSIA, TCE is extracted from groundwater samples and subjected to $\delta^{13}C$ analysis; down gradient changes in the isotopic ratio for TCE may indicate if TCE attenuation processes involving abiotic or biological degradation are active in the plume. The limits of detection for chlorinated ethenes varies with the sample injection/preparation methods, but $\delta^{13}C$ values can be measured by CSIA in groundwater samples with TCE concentrations as low as 1µg/L using the purge and trap process (USEPA 2008b). Furthermore, the level of reproducibility for the $\delta^{13}C$ analysis for TCE is ±0.5 per mil (‰). The CSIA approach to characterizing TCE attenuation processes can be used to detect both abiotic and biological degradation. Combining the CSIA results with other geochemical indicators obtained during this investigation (e.g., oxidative or reductive conditions in the aquifer) will help clarify the type(s) of natural attenuation processes that may be occurring. The lack of significant carbon isotopic fractionation of TCE along the flow path of the plume will be suggestive of contaminant attenuation by advection-dispersive processes.

MBTs are a recently developed tool for detecting and quantifying specific organisms and/or genes that are known to be involved in microbially-mediated TCE degradation processes in both reducing and oxidizing environments (NAVFAC 2011). The specific MBT to be used is the "CENSUS" analysis performed by Microbial Insights. Information provided by these analyses will be used to evaluate the potential for MNA. If the RI indicates unacceptable risk at the Raco Site and a FS is required, the presence or absence of the requisite organisms for reductive dechlorination is also a crucial piece of information that will be useful for the FS in that it will determine whether biostimulation is feasible or whether bioaugmentation would be needed should in-situ biological treatment be considered as a remedy for the site.

In summary, the RI field work include the following activities (details can be found in the FSP [Appendix A] and the UFP-QAPP [Appendix B]):

- A Verification Sampling Event of selected existing monitoring wells to determine the potential for plume movement since prior sampling events (2009), and to evaluate whether the VAP drilling strategy (described in the FSP) needs to be modified. Data will also be used for future trend analysis. Groundwater samples will be collected from eight existing wells within and on the margin of the TCE Plume at the Raco Site (see Table 7). Water levels will be measured to develop a potentiometric surface map. Field water quality parameters will be measured in groundwater and used to document compositional stability before samples for VOC analysis are collected. Groundwater samples will be sent to an off-site fixed-based laboratory for analysis of TCE and dechlorination products (cis-1,2-DCE, trans-1,2-DCE and vinyl chloride). An Abbreviated WP for the Verification Sampling Event (USACE 2014a) was prepared separately from this WP in order to expedite the review process and enable sampling in Spring 2014.
- VAP and monitoring well installation (Summer 2014)
    - VAP borehole drilling and groundwater sampling using sonic drilling methods and a push-ahead groundwater sampling tool for TCE plume delineation. VAP boreholes will be advanced every 10 feet by rotosonic drilling; a 2-foot push-ahead sampler will be advanced for VAP groundwater sampling. Groundwater samples will be collected and analyzed for TCE and dechlorination products at an on-site mobile laboratory. The VAP boreholes will be located east of the existing monitoring wells in the previously un-delineated portions of the

TCE plume (Figure 11; also refer to the FSP in Appendix A of this WP for the VAP drilling strategy). VAP boreholes will be drilled and groundwater samples for on-site analysis will be collected until the TCE plume is delineated to 5 µg/L (refer to FSP and QAPP for the field decision process to be used in plume delineation). Continuous soil cores will be collected from the VAP boreholes and logged. In addition soil samples will be collected and analyzed for grain size distribution and total organic carbon by off-site fixed-base laboratories.

- Installation and development of up to six monitoring wells in selected VAP boreholes; well construction details (e.g., the depth of the 10-foot well screens) will be based on VAP results obtained from the boreholes. The new monitoring wells will be developed and surveyed.
- If there is excess rotosonic drilling capacity after the plume has been delineated (i.e. if less than a total of 2400 lineal feet of drilling has occurred), nested piezometers may be installed to provide vertical groundwater gradient information that may be useful in the FS.
- An ecological reconnaissance will also be conducted to evaluate the presence of ecological resources at the site.

- Two rounds of groundwater sampling (approximately six months apart) in a combination of existing and newly installed monitoring wells. Field water quality parameters and water levels will be measured during each event. Groundwater samples during both events will be sent to an off-site laboratory for analysis of TCE and dechlorination products. During both events, a subset of monitoring wells will be sampled for analysis of the standard MNA parameters by field methods and in an off-site laboratory. In addition to sampling for TCE, dechlorination products and MNA parameters, the following additional activities are planned.
  - During the Fall 2014 sampling event, slug tests will be performed in five monitoring wells to measure hydraulic conductivity.
  - During the Spring 2015 sampling event, a subset of monitoring wells will be sampled for CSIA and CENSUS analysis.

Table 7 provides a summary of the samples to be collected during each sampling event while additional details are described in the FSP (Appendix A) and QAPP (Appendix B). Data quality objectives (DQOs) for the RI/FS are provided in the QAPP (Appendix B, Worksheet #11). Monitoring wells for slug testing and will be selected in the field. It should be noted that the list of wells in Table 7 is smaller than the total number of wells at the Raco Site (Table 1). The wells selected for inclusion in the RI field work are those closest to the TCE plume (Figure 11). Furthermore, wells which are on the periphery of the plume and have historically had non-detectable TCE or TCE below 5 µg/L are excluded from sampling during the RI field work. The monitoring wells identified for sampling as shown in Table 7 have been optimized to allow resources to be focused on gathering data from monitoring wells that are relevant to the TCE plume. Furthermore, the reduced number of monitoring wells will reduce the volume of Investigation-Derived Waste (IDW).

4. TASK DESCRIPTIONS

Descriptions of the RI/FS project tasks are presented below. This list of tasks was developed in accordance with U.S. Environmental Protection Agency (USEPA) guidance for conducting RI/FS under CERCLA (USEPA 1988) and the Performance Work Statement (PWS) (USACE 2013a) provided to GEO by CELRL. These tasks include project management (Section 4.1), community relations (Section 4.2), RI field activities/data management/reporting (Section 4.3), baseline risk assessment (Section 4.4), and the FS (Section 4.5).

4.1 PROJECT MANAGEMENT

As noted previously, the RI/FS will be performed by GEO under the technical direction of USACE/CELRL. MDEQ is the lead regulatory agency. The Raco Site and the surrounding area are owned by the USFS; all RI field activities are expected to be performed within land owned by USFS. Project team members, including subcontractors, are identified in Table 8. Major components of project management are described below. More details regarding project organization, roles, responsibilities, and communication pathways can be found in the QAPP (Worksheets #4, #5, #6, #7, Appendix B). The overall schedule for the RI/FS and follow-on tasks are presented in Table 9, while a more detailed schedule is provided in Appendix E.

4.1.1 Coordination of Field Work with USFS/Hiawatha National Forest, CELRL, and MDEQ

Prior to field activities, GEO will contact the USFS/Hiawatha National Forest to ensure that a mutually-agreed time frame for completion of the field work is established. GEO will not perform work on-site without a valid Right of Entry agreement between the USFS and CELRL.

Because the site is located in a rural area, GEO will coordinate with the USFS/Hiawatha National Forest regarding means of ingress prior to mobilizing to the site, in the event on-site communication is not available. Additionally, GEO will coordinate with the USFS/Hiawatha National Forest and CELRL to reschedule field activities in the event inclement weather poses mobilization/demobilization hazards. USFS will coordinate with Smithers as necessary regarding access to the site by GEO and its subcontractors (utility locator, drillers, mobile laboratory, surveyors) and the schedule for field activities.

Multiple scoping sessions involving CELRL, MDEQ, USFS, and GEO have been held during the planning phase of this RI/FS. The scoping sessions including primary decisions made during these sessions are summarized in the QAPP (Worksheet #9, Appendix B).

4.1.2 Management of Personnel, Equipment, and Contracted Services

All GEO employees, including subcontractors operating on behalf of GEO, will be held to the strictest procedure and safety policies while performing field activities, and will respect the property owned by others. Only equipment deemed necessary for the completion of the field activities will be brought on-site and will be maintained in good, and safe working condition during all times. Laboratory subcontractors will be responsible for performing testing and providing a product consistent with the details provided in the QAPP (Appendix B), and the PWS (USACE 2013a).

4.1.3 Management of Investigation-Derived Waste

IDW, consisting of soil cuttings from drilling operations, purge water from monitoring well development/sampling, disposable personal protective equipment (PPE), sample containers, and devices will be placed in appropriate containers, characterized, and removed from the site by a certified waste

disposal operator. During the previous investigations (GEO 2008, 2010), IDW was classified as an F-listed waste. This may have been an incorrect classification since there is currently no historical information regarding operations at the Raco Site to require an F-listing of the IDW. There is an ongoing search for historical records regarding operations at the Raco Site. If historical information that supports an F-listing is not found, the appropriateness of classifying the IDW from the RI as F-listed waste will be evaluated and possibly revised. Additional details regarding IDW handling and disposal is presented in the FSP (Appendix A).

4.1.4 Site Restoration

At the completion of all invasive field activities, the site conditions will be restored, to the maximum extent practicable, to their condition at the time of GEO's initiation of field work.

4.1.5 Subcontractors

4.1.5.1 Analytical and Soil Testing Laboratories

CT Laboratories, located at 1230 Lange Court, Baraboo, Wisconsin 53913, has been selected to perform the fixed-based laboratory analysis. Mr. Pat Letterer (800-228-3012) is the primary contact at CT Laboratories.

ECCS, located at 2525 Advance Road, Madison, Wisconsin 53718, has been selected to perform the mobile laboratory analysis. Mr. Nick Nigro (608-221-8700) is the primary contact for the mobile laboratory services at ECCS.

Both CT Laboratories and ECCS have current, National Environmental Laboratory Accreditation Conference accreditation for all appropriate fields-of-testing, using methods prescribed in the PWS (USACE 2013a). Certificates of accreditation are included in Appendix C.

Other laboratories to be used for analysis of samples are listed below:

- CSIA: Microseeps, Inc., 220 William Pitt Way, Pittsburgh, Pennsylvania 15238 (412-826-5245, info@microseeps.com)
- CENSUS: Microbial Insights, Inc., 10515 Research Drive, Knoxville, Tennessee 37932 (865-573-8188, info@microbe.com)
- Soil grain size analysis: PTS Laboratories, 8100 Secura Way Santa Fe Springs, California 90670 (562- 347-2500)

4.1.5.2 Drilling Services

Cascade Drilling Services, located at 6215 Lehman Drive, Flint, Michigan, has been selected to complete drilling services. Don Bond (810-523-3957) will be the point of contact for Cascade Drilling Services. Cascade Drilling purchased Boart Longyear who performed the field work in 2009 (GEO 2010). Cascade Drilling Services purchased Boart Longyear's U.S. Environmental and Infrastructure Business in July 2013.

4.1.5.3 Surveying

Northwoods Land Surveying, Inc. located at 816 Ashmun Street, Sault Ste. Marie, Michigan, has been selected to perform the on-site surveying. The primary point of contact at Northwoods Land Surveying, Inc. is Mr. William Karr (906-632-1500).

4.1.5.4 Ecological Site Reconnaissance

EnviroScience, Inc. will perform an ecological site reconnaissance and document observations in a letter report. The ecological site reconnaissance report will include a description of site layout, topography and site drainage, document any signs of contamination, characterize existing aquatic, terrestrial and wetland habitat types, identify any potentially sensitive environments and/or threatened and endangered species and record any observations or signs of wildlife. EnviroScience, Inc. is located at 5070 Stow Road, Stow, Ohio. The primary point of contact is Brooke Harrison (330-688-0111).

4.1.6 Project Plans

4.1.6.1 Quality Control Plan

The Quality Control Plan (GEO 2013a) addresses the statement of purpose of the investigation; identification and discussion of all organizational and technical interfaces; identification of the study and field teams, including assignment of all areas of responsibility; identification of project deliverables that will be submitted for an Independent Technical Review (ITR); identification of the ITR Team; description of the methods to be used for management of review comments; a declaration that all the records of the ITR will be made available to CELRL under request; and a description of the method used to identify the successive drafts of a particular deliverable.

4.1.6.2 Quality Assurance Surveillance Plan

The Quality Assurance Surveillance Plan (USACE 2013b) highlights key quality control activities or events that the Contracting Officer's Representative will use to determine when USACE inspections can be conducted to assess progress toward and/or completion of milestones.

4.1.6.3 Verification Sampling Event Work Plan

The Abbreviated WP for the Verification Sampling Event (USACE 2014a) describes the activities for the Verification Sampling Event. As noted in Section 3.8, selected monitoring wells at the Raco Site will be sampled during this event, which is currently scheduled to occur in Spring 2014. The data collected during this event will aid in the planning of subsequent field work to delineate the on-site TCE plume scheduled for Summer of 2014 and will also be used for future trend analysis. The Abbreviated WP for the Verification Sampling Event was designed to contain the minimum information required to complete the Verification Sampling prior to finalization of this WP.

4.1.6.4 Site-Specific Safety and Health Plan

The Site-Specific Safety and Health Plan (GEO 2013b) describes and addresses the full range of safety precautions to be implemented and observed during field investigation activities. It also addresses the required PPE and potential hazards.

4.1.6.5 Work Plan

This WP was developed to help efficiently manage the available resources, and to inform the stakeholders of the type (description) and timeframe (schedule) of the activities that will take place at the site. The WP discusses the personnel, equipment, and contracted services requirements of the project, as well as property restoration upon completion of the project's field activities.

The FSP (included as Appendix A of this WP) describes the sample collection procedures, field operations, and general description of the RI field sampling design. It was prepared following USACE

Engineer Manual 200-1-3, *Requirements for the Preparation of Sampling and Analysis Plans* (USACE 2001) and Section 2.3.2 of EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988). The sampling design in the FSP and the QAPP should be considered tentative and may change based on data collected during field activities.

The QAPP (included as Appendix B of this WP) describes the policy, organization, functional activities, DQOs, and measures necessary to achieve suitable data for use in selecting the appropriate remedy.

4.1.7 Consideration and Implementation of Green and Sustainable Remediation (GSR) Practices

The 2012 DERP Manual directs the use of GSR strategies for remedial actions when feasible. Examples of GSR strategies include:

- Efficient use of natural resources and energy;
- Reducing negative impacts on the environment;
- Minimizing or eliminating pollution at its source; and
- Reducing waste to the greatest extent possible.

The Technical Memorandum on GSR, which is included in Appendix G of this Work Plan, describes the identification and evaluation of GSR opportunities for this remedial investigation per the process outlined in USACE (2012a). The most beneficial GSR opportunities considered practical for implementation include the utilization of two sonic drilling rigs to reduce the total length of field work, minimizing drilling fluids, and minimizing soil waste. Additional details describing how each GSR opportunity will be implemented in the RI are provided in Appendix G.

4.2 COMMUNITY RELATIONS

A Community Relations Plan (USACE 2014b) has been prepared to identify and evaluate community concerns, develop a communications strategy to effectively reach the community, and identify the communications tools available to deliver key messages to stakeholders. Specific activities completed involving community relations include: (1) a community survey conducted in December 2013/January 2014 to determine the level of community involvement and concerns regarding the Raco TCE plume, (2) preparation of a fact sheet that was mailed to survey respondents in February 2014, and (3) establishing an Administrative Record/Information Repository at a selected location based on the survey results. Additional details regarding future tasks and efforts to maintain community involvement during the RI/FS at the Raco Site can be found in the Community Relations Plan.

4.3 RI FIELD ACTIVIES/DATA MANAGEMENT/REPORTING

4.3.1 RI Field Activities

The RI/FS Field Investigation will consist of the activities described in Section 3.8.3. Procedures for executing the field activities are presented in detail in the FSP (Appendix A). The QAPP (Appendix B) describes the Quality Control/Quality Assurance procedures to be used during the RI field investigation, sample analysis, and data evaluation.

4.3.2 Data Management

CT Laboratories (the primary off-site fixed-base laboratory) and ECCS (the mobile laboratory) are compliant with the most recently published versions of the DoD Quality Systems Manual (QSM). These laboratories hold current compliance with DoD QSM version 4.2 (DoD 2010), and will be compliant with

DoD QSM Version 5.0 (DoD 2013) by Summer/Fall of 2014. Additionally, both laboratories have current National Environmental Laboratory Accreditation Conference accreditation for all appropriate fields-of-testing, using methods prescribed in the PWS (USACE 2013a). A project-specific laboratory review of CT Laboratories was performed in accordance with DoD guidance (USACE 2012b); the review indicated that CT Laboratories can satisfy the project data quality requirements (see Worksheet #15 in Appendix B). Analytical data will be provided in electronic format, compatible with Automatic Data Review, or similar software. The data review services shall meet requirements in the QSM and project-specific e-QAPP criteria, as well as provide compatibility with data management software, preferably Environmental Data Management System.

Groundwater analytical data will be independently validated by a third-party data validator. The validation report will be included with the RI Report. Details regarding data validation can be found in Worksheet #36 of the QAPP (Appendix B).

4.3.3 RI Report

In addition to the required elements in USEPA guidance EPA/540/G-89/004, the RI report will contain the following as stated in the PWS (USACE 2013a): (1) discuss residential and/or public wells within one-half mile of the delineated contaminant plume in the groundwater, (2) discuss other environmental features of interest including but not limited to wetlands, sensitive receptor populations, and uncontrolled/non-remediated release sites (especially non-DoD) or activities contributing to ambient/anthropogenic background conditions, (3) include an evaluation of natural attenuation state and potential based on the data collected during the RI/FS field investigation, (4) include a two-dimensional lateral cross section, and three-dimensional figures of the groundwater contaminant plume with iso-concentration contours overlaid on the site map, (5) include a detailed conceptual site model, (6) include an assessment of the relative impacts to remedial action scope, cost, schedule, future site use, and risk of selecting industrial/commercial remedial goals (RGs) vs. residential (unrestricted) RGs. This evaluation will be used by USACE to select which RGs are carried forward for the FS. In general, USACE preference for FUDS is to remediate to unrestricted use when costs associated with periodic review and monitoring of a restricted-use remedy outweigh the costs of unrestricted use remediation. A list of potential Applicable or Relevant and Appropriate Requirements (ARARs) will be requested from MDEQ by USACE at the completion of the RI.

4.4 BASELINE RISK ASSESSMENT METHODS

4.4.1 Introduction

A BLRA will be performed as part of the RI to evaluate the potential for human health risks from exposure to groundwater. This assessment will present the risks for the “no-action” alternative. The methodology used in the BLRA will be based on USEPA guidance documents and will consist of the following steps detailed in the following sections:

- Section 4.4.2. Data evaluation of target analytes, including the screening process to identify chemicals of potential concern (COPCs) to be included in the risk assessment.
- Section 4.4.3. Exposure assessment, including identification of exposure pathways and potential intake estimates for each of the receptors and pathways.
- Section 4.4.4. Toxicity assessment, including the potential for adverse health effects of COPCs in exposed individuals.
- Section 4.4.5. Risk characterization, where human health COPCs are identified if risks exceed acceptable values for carcinogenic and non-carcinogenic risks.

- Section 4.4.6. Assessment of uncertainties associated with the BLRA.
- Section 4.4.7. Ecological Site Assessment
- Section 4.4.8. Baseline Risk Assessment Summary and Conclusions

4.4.2 Data Evaluation

The data evaluation will identify COPCs from the target analytes (TCE, cis-1,2-dichloroethene [cis-1,2-DCE], trans-1,2-dichloroethene [trans-1,2-DCE], and vinyl chloride) for groundwater being evaluated in the RI. The data evaluation to identify COPCs for groundwater will consist of a data quality assessment followed by risk-based screening.

4.4.2.1 Data Quality Assessment

The data set will be organized so that only one result will be used for each sample location per sampling event. For sample duplicates, the average of the detected values will be retained. Among original, re-analyzed, and diluted samples, the value deemed most valid by the chemist will be retained. Samples rejected by the validation process will not be included in the risk assessment. The data set will include samples collected beginning with the October 2009 sampling event (GEO 2010). The specific monitoring wells that will be included will be determined based on the results of the RI field work.

4.4.2.2 Risk-Based Screening

The objective of this evaluation is to identify COPCs that may pose a significant risk to human health. The risk-based screening values used in this process will be the minimum of the USEPA Regional Screening Levels (RSLs) (USEPA 2013) that are current at the time of the submittal of the Preliminary-Draft RI report. The maximum detected concentration (MDC) of each chemical in groundwater will be compared against the appropriate risk-based screening value. Chemicals detected below these concentrations will be eliminated from the COPC list. For carcinogens, the minimum of the USEPA RSL and the MDEQ Part 201 generic groundwater cleanup criteria will be used. For non-carcinogens, the minimum of the USEPA RSL and MDEQ Part 201 generic groundwater cleanup criteria will be multiplied by 0.1 to account for potential cumulative effects on target organs.

4.4.2.3 Summary of Chemicals of Potential Concern Screening Approach

The following assumptions will be used in the development of COPCs for the BLRA:

- The analytes being considered in the BLRA are TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride.
- Analytes not detected in groundwater will be eliminated from the COPC list.
- Target analytes detected at levels below their respective risk-based screening levels will be eliminated from the COPC list.

The COPC screening process and results will be summarized in tables which will include:

- Summary statistics, including frequency of detection, range of detected concentrations, arithmetic mean concentration, and 95% upper confidence limit (UCL_{95}) on the mean concentration the latest version of ProUCL (http://www.epa.gov/esd/tsc/software.htm) will be used to generate UCL_{95};
- All screening values; and
- Final COPC status.

It should be noted that non-detects in the dataset will be handled in accordance with the methods in ProUCL for censored datasets, i.e., non-detects will not be substituted with one-half the reporting limit.

4.4.3 Exposure Assessment

4.4.3.1 Current and Future Land Use

The Raco Site is currently owned by the USFS and used by Smithers during the winter months for automobile tire testing. No changes in the current industrial land usage are expected. In Section 2.1, it was noted that the Raco Site and surrounding publicly owned land within the National Forest System is highly unlikely to be transferred to private entities. The pathway to residential receptors from the TCE plume at the Raco Site would only be complete if the extent of the plume extends to privately-owned residential parcels approximately 1 mile east and 1.5 miles southeast downgradient of the TCE plume in both eastern and southeastern directions (Figure 4). The completeness of this pathway will be evaluated based on the results of RI field activities with respect to plume delineation and stability. Pathway completeness has been framed as one of the DQOs for the RI (see Worksheet #11 of the QAPP, Appendix B).

4.4.3.2 Potential Exposed Populations, Exposure Media, and Exposure Pathways

The current conceptual site exposure model (CSM, Figure 10) shows potentially exposed populations and exposure pathways. The receptors in the CSM include:

- An Industrial Worker (e.g., workers at the Smithers facility)
- Forest Area Worker
- Site Visitor (e.g., users of the Smithers facility or Hiawatha National Forest recreational visitors)
- Residential Receptors (adult and child)

The Industrial Worker, Forest Area Worker, and Site Visitor pathways are considered potentially complete because the existing water supply wells are not located within the known TCE plume. Risks from these potentially complete pathways will be evaluated. Analysis of the residential receptor pathway will be contingent on whether the RI results support a complete pathway from the TCE plume to the nearest residential parcels located more than one mile east and southeast of the Raco Site.

4.4.3.3 Exposure Point Concentrations

The Reasonable Maximum Exposure (RME) estimates the highest exposure reasonably expected to occur at each groundwater exposure unit. Each monitoring well will be considered as a groundwater exposure unit, and risks will be calculated for the monitoring wells/groundwater exposure units with the highest historical TCE detections at the Raco site. The exposure point concentration for each monitoring well/groundwater exposure unit will be set to the maximum TCE concentration measured in that well since 2009.

4.4.3.4 Exposure Parameters and Exposure Calculation Results

Standard intake equations from USEPA guidance (USEPA 1989, USEPA 2004) for ingestion, dermal contact, and inhalation of chemicals (shown below) will be used along with the exposure parameters (i.e. ingestion rate, dermal absorption factors) shown in Table 7.

Ingestion of Groundwater

Intakes for ingestion for groundwater COPCs will be estimated using equation (1):

$$Chemical\_Intake\left(\frac{mg}{kg-day}\right)=\frac{C_w \times IR_w \times EF \times ED \times ET}{BW \times AT} \quad (1)$$

Where:

C_w	=	chemical concentration in water (mg/L)
IR_w	=	ingestion rate of water (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
ET	=	exposure time (hours)
BW	=	body weight (kg)
AT	=	averaging (days) for carcinogens or non-carcinogens

Dermal Contact with Groundwater

The dermal absorbed dose (DAD) from chemicals in groundwater will be calculated using equation (2) from USEPA 2004.

$$Chemical\_DAD\left(\frac{mg}{kg-day}\right)=\frac{DA_{event} \times EV \times EF \times ED \times SA}{BW \times AT} \quad (2)$$

Where:

DAD	=	dermal absorbed dose (mg/kg-day)
DA_{event}	=	absorbed dose per event (mg/cm^2-event)
EV	=	event frequency (1 event/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
SA	=	surface area of skin exposed (cm^2)
BW	=	body weight (kg)
AT	=	averaging time (days) for carcinogens or non-carcinogens

DA_{event} (mg/cm^2-event) is calculated as follows for groundwater COPCs:

$$t_{event} \le t^*\_DA_{event} = 2FA \times K_p \times C_w \sqrt{\frac{6\tau_{event} \times t_{event}}{\pi}} \quad (3)$$

$$t_{event} > t^*\_DA_{event} = FA \times K_p \times C_w \left[\frac{t_{event}}{1+B} + 2\tau_{event}\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right] \quad (4)$$

Where:

DA_{event}	=	absorbed dose per event (mg/cm^2-event)
FA	=	fraction absorbed water (dimensionless)
K_p	=	dermal permeability coefficient of compound in water (cm/hr)
C_w	=	chemical concentration in water (mg/cm^3)
τ_{event}	=	lag time per event (hr/event)
t_{event}	=	event duration (hr/event)
t*	=	time to reach steady-state (fr) = 2.4 τ_{event}

B = dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless)

Inhalation of Volatiles from Groundwater Intake

Intakes for inhalation of volatiles from groundwater will be calculated using equation (5) USEPA 2009a):

$$EC\left(\frac{mg}{m^3}\right) = \left(\frac{C_a \times EF \times ED \times ET}{AT}\right) \tag{5}$$

Where:

EC = exposure concentration (mg/m^3)
C_a = chemical concentration in air (mg/m^3 [air])
ET = exposure time (hrs/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
AT = averaging time (days) for carcinogens or non-carcinogens

For inhalation of volatiles from groundwater, C_a is estimated as follows:

$$C_a\left(\frac{mg}{m^3}\right) = C_w\left(\frac{mg}{L}\right) \times 0.5\frac{L}{m^3} \tag{6}$$

The factor (0.5 L/m^3) for deriving an exposure/air concentration from the groundwater concentration is the same factor used in USEPA (1991) and in the development of the RSLs (USEPA 2013). As noted in USEPA (1991), this factor is based on a study of household uses of water (e.g. showering, laundering, dish washing) and the average concentration of the volatilized contaminant in air.

4.4.4 Toxicity Assessment

The toxicity assessment will evaluate the potential for COPCs to cause adverse health effects in exposed individuals. If possible, it will estimate the relationship between intake or dose of a COPC and the likelihood or severity of adverse health effects as a result of exposure. Toxic effects have been evaluated extensively by USEPA, as presented in USEPA's *Human Health Toxicity Values in Superfund Risk Assessments* (USEPA 2003), which provides for selection of toxicity values from the following three-tiered hierarchy:

1. Tier 1 – USEPA's Integrated Risk Information System (USEPA 2009b);

2. Tier 2 – USEPA Provisional Peer Reviewed Toxicity Values;

3. Tier 3 – Other toxicity values from additional USEPA and non-USEPA sources, including California Environmental Protection Agency, Agency for Toxic Substances and Disease Registry minimum risk levels, and USEPA's Health Effects Assessment Summary Tables (USEPA 1997).

4.4.5 Risk Characterization

The purpose of the risk characterization is to integrate the information obtained through the exposure and toxicity assessments to estimate potential risks and hazards. Potential carcinogenic effects are characterized by using projected intakes and chemical-specific, dose-response data [i.e., cancer slope factors (CSFs)] to estimate the probability that an individual will develop cancer over a lifetime. Potential non-carcinogenic effects will be characterized by comparing projected intakes of contaminants to toxicity values [i.e., reference dose (RfDs)]. The numerical risk and hazard estimates presented in the BLRA must be interpreted in the context of the uncertainties and assumptions associated with the risk assessment process and with the data upon which the risk estimates are based.

4.4.5.1 Risk Characterization for Carcinogens

For carcinogens, risk is expressed as the probability that an individual will develop cancer over a lifetime as a result of exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as the incremental lifetime cancer risk (ILCR), or the increased chance of cancer above the normal background rate of cancer. In the U.S., the background chance of contracting cancer is slightly greater than three in 10, or 3×10^{-1}. The calculated ILCRs will be compared to the target range in the National Contingency Plan of 1×10^{-4} to 1×10^{-6}, or 1-in-10,000 to 1-in-1,000,000 exposed persons developing an excess cancer.

The ILCR for each carcinogenic COPC will be calculated using one of the equations below (USEPA 1989, USEPA 2009a):

$$ILCR = I \times CSF \tag{7}$$

$$ILCR = IUR \times EC \tag{8}$$

Where:

I	=	chronic daily intake or DAD calculated in the exposure assessment (mg/kg-d)
EC	=	Exposure concentration (mg/m^3)
IUR	=	Inhalalation unit risk $(mg/m^3)^{-1}$
CSF	=	cancer slope factor $(mg/kg\text{-}d)^{-1}$

For a given exposure pathway from each investigation area, the total risk to a receptor exposed to several carcinogenic COPCs is the sum of the ILCRs for each carcinogen, as shown in Equation 9 below:

$$ILCR_{total} = \Sigma ILCR_i \tag{9}$$

Where:

$ILCR_{total}$	=	total probability of cancer incidence associated with all carcinogenic COPCs
$ILCR_i$	=	ILCR for the ith COPC

For TCE, the risk calculations will be completed in accordance with example calculations from USEPA in which the age-dependent adjustment factors are applied to the portion of the carcinogenic risk for kidney tumors (http://hero.epa.gov/index.cfm/reference/details/reference_id/758648). For Vinyl Chloride, the risks will be calculated in accordance with examples in Section 5.3.5.1 of the USEPA 2000 where risks for the resident adult exposed from birth is calculated by summing the risks from non-pro-rated

early life exposure (0 to 6 years) and the pro-rated risk from (0 to 30 years) using the (lower) carcinogenic toxicity factors for lifetime exposure during adulthood (http://www.epa.gov/ncea/iris/toxreviews/1001tr.pdf).

In addition to summing risks across all carcinogenic COPCs, risks will be summed across all exposure pathways for groundwater (e.g., ingestion, inhalation, and dermal contact). Per USEPA (1989) guidance, there will be two steps required to determine whether risks or hazard indices (HIs) for two or more pathways should be combined for a single exposed individual or group of individuals. The first will be to identify reasonable exposure pathway combinations. The second will be to examine whether it will be likely that the same individuals would consistently face the RME by more than one pathway. It is reasonable to assume that the same individual may be exposed to a given exposure medium at the RME level by multiple pathways.

4.4.5.2 Risk Characterization for Non-Carcinogens

In addition to developing cancer from exposure to contaminants, an individual may experience other toxic effects. The term "toxic effects" is used here to describe a wide variety of systemic effects ranging from minor irritations, such as eye irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risks associated with toxic (i.e., non-carcinogenic) chemicals will be evaluated by comparing an estimated exposure (i.e., intake or dose) from site media to an acceptable exposure expressed as a RfD. The RfD is the threshold level below which no toxic effects is expected to occur in a population, including sensitive subpopulations. The ratio of intake over the RfD is the hazard quotient (HQ) (USEPA 1989) and will be calculated as:

$$HQ = \frac{I}{RfD} \tag{10}$$

Where

I = daily intake or DAD of a COPC (mg/kg-d)
RfD = reference dose (mg/kg-d)

The HQs for each COPC/investigation area will be summed to obtain a HI for an investigation area, as shown below:

$$HI = \Sigma HQ_i \tag{11}$$

Where

HI = hazard index for all toxic effects
HQ_i = hazard quotient for the ith COPC

An HI greater than one has been defined as the level of concern for potential adverse non-carcinogenic health effects (USEPA 1989). This approach differs from the probabilistic approach used to evaluate carcinogens. An HQ of 0.01 does not imply a 1-in-100 chance of an adverse effect but indicates only that the estimated intake will be 100 times less than the threshold level at which adverse health effects may occur. In addition to summing hazards across all COPCs, hazards will be summed across all exposure pathways for a given environmental medium.

Note that HIs are determined by assuming dose additivity for those constituents acting by the same mechanism and inducing the same effects (USEPA 1989). Initially, all of the COPCs are assumed to have the same mechanism of toxicity. If the HI (across all COPCs) is below 1, then all target organ-specific HIs will also be below 1. If the HI exceeds 1, then HIs are calculated for each target organ. This approach

provides a more accurate estimation of the potential systemic toxicity associated with exposure to the constituent mixture.

4.4.5.3 Identification of Contaminants of Concern

Carcinogenic contaminants of concern (COCs) are defined for each media as those contaminants that have a total ILCR greater than 1×10^{-5} for a receptor in this BLRA. Non-carcinogenic COCs are defined for each media as those contaminants that produce an HI greater than 1 for a receptor in this BLRA. COCs with individual HQ values below 1 can result in a cumulative HI greater than 1 for a target organ or system. COCs will be evaluated for potential cumulative effects on a target organ or system. Summary tables will be modeled after RAGS Part D, Exhibit 4-1 (USEPA 2001).

4.4.5.4 Results

Risks and HQs at the Raco Site will be quantified for the Industrial Worker, Forest Area Worker, and Site Visitors. As noted previously, the residential receptors (adult and child) will be evaluated if the RI results support the hypothesis of a complete exposure pathway from the TCE plume to the residential parcels located more than 1 mile east and southeast of the Raco Site.

Detailed risk and hazard results for each receptor will be presented in the BLRA, and COCs will be identified on the tables that present the risk and hazard results. The ILCR for each receptor will be discussed relative to the target risk range in the National Contingency Plan. A discussion of the significance of all identified COCs will be included. A summary table displaying total risks and hazards across all COPCs for each receptor/medium/investigation area combination will also be shown in the BLRA. The results of the risk assessment will be summarized in the RI report in accordance with USEPA Risk Assessment Guidance, Subpart D (USEPA 2001).

4.4.6 Uncertainty Analysis

Uncertainties associated with each step of the risk assessment process will be discussed in the BLRA, where possible. Uncertainties include those associated with the data evaluation process, exposure assessment, toxicity assessment, and risk characterization. The uncertainty analysis will focus on site-specific factors that influence uncertainty such as land-use and data quality issues.

4.4.7 Ecological Site Reconnaissance

The process recommended by the U.S. Army for formulating site-specific management goals consists of two steps. The first step is the identification of important ecological places within the site, followed by the identification of valuable biological resources that are present within these important ecological places (U.S. Army 2005). Examples of important ecological places include critical habitat for Federal designated endangered or threatened species, wildlife refuge, etc. Since none of the listed important ecological places are anticipated to be present at the Raco Site, the management goal selected for the site is avoidance of widespread lethal impacts to plants and animals, in accordance with the process outlined in U.S. Army guidance (U.S. Army 2005).

Prior to conducting the ecological site reconnaissance, a desktop review of publically available resources will be performed to identify any known wetlands, streams and other significant ecological resources. Resource review will include U.S. Geological Survey (USGS) topographic maps, USGS National Hydrography Dataset, U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory maps and USFWS federally protected listed species. The presence or absence of Threatened and

Endangered species will be evaluated by reviewing the National Registry. This information will be used to assist gathering data during the ecological site reconnaissance.

Exposure of ecological receptors to contaminated groundwater at the Raco Site is considered unlikely given the depth of the water table (greater than 40 to 50 feet bgs). Furthermore, there are no important ecological resources anticipated within the Raco Site. This will be confirmed during the ecological site reconnaissance. It is therefore anticipated that no further investigations to characterize ecological risk are warranted.

4.4.8 Baseline Risk Assessment Summary and Conclusions

A summary and conclusions section will be included in the BLRA section of the RI report to summarize which receptors were evaluated in the Raco Site, and list the major steps that were taken to generate conclusions regarding human health risks and hazards associated with groundwater at the Raco Site. A brief summary of the risks and hazards will be presented, noting which chemicals have been determined to be COCs.

4.5 FEASIBILITY STUDY

If the RI indicates that there are unacceptable risks present at the site, an FS will be required. The FS process consists of development and screening of remedial action alternatives and a detailed analysis of a limited number of the most promising options to establish the basis for a remedy selection decision. The preliminary remedial action objective (RAO) for the Raco TCE Plume is to prevent ingestion of groundwater with TCE concentrations exceeding the MCL (5 μg/L), so that the initial remediation goal for TCE in groundwater is the MCL.

The three required alternatives to be considered are: (1) No Action, (2) Action to remediate the site to a condition that allows unlimited use and unrestricted exposure, and (3) Action to remediate the site to a protective condition that requires land use restrictions.

The preliminary list of potential processes for consideration in alternatives 2 and 3 include institutional controls, containment of contaminated groundwater, passive treatment of contaminated groundwater, and active treatment of contaminated groundwater. Source control and treatment or removal are not included because an active source for TCE contamination in groundwater at the Raco Site has not been identified during previous investigations (see Section 3.8). However, it is acknowledged that the need for source control will be determined by the RI results, judged specifically by the temporal state of the plume (i.e., expansion or increasing concentrations would suggest ongoing source contamination). The preliminary potential remedial action alternatives and associated technologies can be summarized as follows:

- No-action alternative – This is used as a baseline to compare against other alternatives.
- Institutional controls – Exposure to contaminated groundwater will be prevented by establishing administrative and legal controls [i.e., installation of water supply wells would be prohibited within the area where TCE groundwater concentrations exceed the MCL (5 μg/L)]. This alternative is a feasible option if the TCE plume is stable or shrinking. This option will require periodic monitoring to ensure that the institutional controls continue to be effective at preventing exposure to TCE-contaminated groundwater.
- Containment of contaminated groundwater
    - Permeable reactive barrier – A barrier consisting of reactive material (e.g., zero valent iron) capable of degrading dissolved-phase TCE is installed to intercept and treat contaminated

groundwater. This alternative may be eliminated during the screening phase due to the depth of the plume (> 100 feet bgs).

  - Pump and Treat Remediation – In this alternative, extraction wells will be installed to intercept the TCE plume and deliver contaminated groundwater into an above-ground treatment system. The treated groundwater can either be re-injected into the aquifer or discharged for disposal or further use.
  - Groundwater recirculation – In this alternative, circulating wells are installed to intercept the TCE plume; groundwater is extracted through one screened section of the circulating well and pumped through another screened section of the same well back into the aquifer. Groundwater is treated (e.g., through air stripping) within the well.
  - Air sparging – In this alternative, air sparge wells are installed to intercept the TCE plume and remove dissolved-phase contamination through air stripping.
- Passive treatment of contaminated groundwater
  - MNA – In this alternative, natural processes will be relied on to achieve the remediation goal throughout the TCE plume within a reasonable time frame compared to that achievable by other methods (USEPA 1999). This alternative will include long-term monitoring and contingency measures should the monitoring results indicate that the process is not proceeding in line with expectations.
  - Enhanced attenuation – This alternative involves the implementation of lower-energy remediation technologies to increase the natural attenuation capacity of the aquifer (ITRC 2008). Enhancements may include the addition of chemical amendments such as nutrients and electron donors to stimulate natural biodegradation and enhance reductive dechlorination, or the addition of beneficial microorganisms that are capable of degrading TCE. Bioenhancements require the presence of TCE-degrading organisms while bioaugmentation requires geochemical conditions suitable for sustaining the TCE-degrading microbes introduced into the aquifer.
- Active treatment of contaminated groundwater
  - In situ chemical oxidation – In this alternative, chemical oxidants (e.g., potassium permanganate, sodium persulfate, catalyzed hydrogen peroxide) that are known to effectively degrade TCE will be introduced into the aquifer through injection wells or direct-push probes. This technique more typically is applied to source areas, although it has also been applied to dissolved-phase plumes.
  - Groundwater recirculation – Circulating wells described previously can also be installed throughout the TCE plume to implement active treatment in addition to containment. The circulating wells can be used to introduce nutrients in a more active approach to enhanced reductive dechlorination.
  - Air sparging – Air sparging wells can be installed throughout the TCE plume to achieve active treatment in addition to containment.

The list of preliminary remedial alternatives presented above may be expanded to include other technologies. Current knowledge regarding the Raco Site combined with data to be gathered during the RI/FS field work will be used to screen the preliminary remedial alternatives based on the following factors:

- Short- and long-tern effectiveness and reductions achieved in toxicity, mobility, or volume
- Implementability including technical and administrative feasibility
- Grossly disproportionate cost.

The remedial alternatives that are retained after the screening process will undergo detailed individual assessment against nine evaluation criteria in accordance with USEPA (1998) guidance. These evaluation criteria include:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State/Support agency acceptance
- Community acceptance

The last two criteria will be formally assessed during the public comment period on the Proposed Plan.

Following the individual assessment against the nine criteria listed above, a comparative analysis of the alternatives will be conducted to evaluate the relative performance of the alternatives in relation to each specific evaluation criterion. The purpose of the comparative analysis is to better inform the remedy selection process. In addition to the evaluation criteria required by EPA/540/G-89/004 (USEPA 1988) guidance, the latest version of the SiteWise™ Tool will be used in the FS to quantify the environmental footprints of remedial alternatives in accordance with the PWS (USACE 2013a).

The screening as well as individual and comparative analysis of the remedial alternatives for the Raco TCE plume will be documented in the FS report. The major elements of the FS report include:

- Description of the alternatives and individual analysis (narrative and table)
- A narrative regarding the comparative analysis of the alternatives against the evaluation criteria
- Documentation of ARARs

The FS report will be prepared in accordance with EPA/540/G-89/004 (USEPA 1988). Based on the FS findings, a remedial alternative will be selected and presented to the stakeholders and the public in the Proposed Plan. If MNA is the selected remedy, the Proposed Plan will also include a long-term monitoring program and a contingency plan. After public input is obtained during the Proposed Plan phase, the selected remedial alternative including contingency plans will be documented in the Record of Decision. Design and implementation of the selected remedy will then occur during the Remedial Design/Remedial Action phase.

THIS PAGE INTENTIONALLY LEFT BLANK

5. REFERENCES

Chippewa County Summary undated. *Groundwater Mapping Project*. Various authors and contributors as referenced at http://gwmapinfo.rsgis.msu.edu/summary.php?thiscounty1=Chippewa.

DoD (Department of Defense) 2010. *DoD Quality Systems Manual (QSM) for Environmental Laboratories, Version 4.2.* October.

DoD (Department of Defense) 2012. *DoD Manual, Defense Environmental Restoration Program (DERP) Management (DoDM 4715.20)*. March.

DoD (Department of Defense) 2013. *DoD Quality Systems Manual (QSM) for Environmental Laboratories, Version 5.0.* July.

Earth Tech (Earth Tech, Inc.) 2003. *Draft Field Sampling Plan Revision 1, Raco Army Airfield and Bomarc Missile Site.* July.

Earth Tech (Earth Tech, Inc.) 2005. *Draft Site Investigation and Associated Activities Report.* April.

Envirodyne (Envirodyne Engineers) 1987. *Contamination Evaluation for the former Bomarc Missile Site, Raco Michigan, Final Report*.

GEO (GEO Consultants, LLC) 2008. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Environmental Site Investigation (Phase III), Hiawatha National Forest, Raco, Michigan*.

GEO (GEO Consultants, LLC 2010. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Remedial Investigation/Feasibility Study Activities, Hiawatha National Forest, Raco, Michigan.*

GEO (GEO Consultants, LLC) 2013a. *Quality Control Plan, Remedial Investigation/Feasibility, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* November.

GEO (GEO Consultants, LLC) 2013b. *Site-Specific Safety and Health Plan, Remedial Investigation/Feasibility, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* December.

IT Corp. (Information Technology Corporation) 1991. *Remedial Investigation, Former Air Force Airfield and Bomarc Missile Site, Chippewa County, Michigan*.

ITRC (Interstate Technology and Regulatory Council) 2008. *Enhanced Attenuation: Chlorinated Organics.* April.

NAVFAC (Naval Facilities Engineering Command) 2011. *Guidance Protocol: Application of Nucleic Acid-Based Tools for Monitoring Monitored Natural Attenuation (MNA), Biostimulation and Bioaugmentation at Chlorinated Solvents Sites. Naval Facilities Engineering Command. Engineering Service Center, Port Hueneme, CA.* February.

Reed, R.C. and Daniels, J. (compilers) 1987. *Bedrock geology of northern Michigan: Geological Survey Division, Michigan Dept. of Natural Resources*.

U.S. Army 2005. *Technical Document for Ecological Risk Assessment: Process for Developing Management Goals. U.S. Army Biological Technical Assistance Group.* August.

USACE (U.S. Army Corps of Engineers) 2001. Engineer Manual. EM 200-1-3. *Requirements for the Preparation of Sampling and Analysis Plans*, February.

USACE (U.S. Army Corps of Engineers) 2003. *Groundwater Monitoring Report, Former Raco AAF and Bomarc Missile Site, Hiawatha National Forest, Raco, Michigan,* January.

USACE (U.S. Army Corps of Engineers) 2004. Engineer Regulation ER 200-3-1, *Environmental Quality: Formerly Used Defense Sites (FUDS) Program Policy*, ER 200-3-1, May 10, 2004.

USACE (U.S. Army Corps of Engineers) 2009. *USACE Interim Guidance 10-01 – Decision Framework for incorporation of Green and Sustainable Practices into Environmental Remediation Projects*. http://www.environmental.usace.army.mil/pdf/IG%2010-01%2003_05_10%20doc.pdf

USACE (U.S. Army Corps of Engineers, Environmental and Munitions Center of Expertise) 2012a. *Final Study Report. Evaluation of Consideration and Incorporation of Green and Sustainable Remediation (GSR) Practices in Army Environmental Remediation*. August. https://www.fedcenter.gov/_kd/Items/actions.cfm?action=Show&item_id=22322&destination=ShowItem

USACE (U.S. Army Corps of Engineers, Environmental Quality) 2012b. Project Specific Review of Analytical Chemistry Laboratories. EM 200-1-1. Redline dated xx September 2012.

USACE (U.S. Army Corps of Engineers) 2013a. *Performance Work Statement for Raco TCE Groundwater Plume*. Revised August.

USACE (U.S. Army Corps of Engineers) 2013b. *Quality Assurance Surveillance Plan*, *Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* November.

USACE (U.S. Army Corps of Engineers) 2014a. *Draft-Final Abbreviated Work Plan Verification Sampling Event*, *Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E)5MI0026.* January.

USACE (U.S. Army Corps of Engineers) 2014b. *Preliminary-Draft Community Relations Plan*, *Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* February.

USDA (U.S. Department of Agriculture) 2006. *Hiawatha National Forest, 2006 Forest Plan.*

USEPA (U.S. Environmental Protection Agency) 1987. *Exposure Factors Handbook*. August.

USEPA (U.S. Environmental Protection Agency) 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA EPA/540/G-89/004.* Office of Radiation programs, Washington, DC.

USEPA (U.S. Environmental Protection Agency) 1989. *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual (Part A), USEPA/540/1-89-002,* Washington, D.C.

USEPA (U.S. Environmental Protection Agency) 1997. *Health Effects Assessment Summary Tables (HEAST)*, Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA (U.S. Environmental Protection Agency) 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites, Directive No. 9200.4-17P.* Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA (U.S. Environmental Protection Agency) 2000. *Toxicological Review of Vinyl Chloride. In Support of Summary Information on the Integrated Risk Information System (IRIS). EPA/635R-00/004.* May.

USEPA (U.S. Environmental Protection Agency) 2001. USEPA publication 9285.7-47. *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluations Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments).*

USEPA (U.S. Environmental Protection Agency) 2003. *Human Health Toxicity Values in Superfund Risk Assessments.*

USEPA (U.S. Environmental Protection Agency) 2004. *USEPA-540-R-99-005. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final*. July.

USEPA (U.S. Environmental Protection Agency) 2005. USEPA-505-B-04-900A. *Workbook for Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collections and Use Programs. Part 1: UFP-QAPP Manual.* Final, Version 1, March.

USEPA (U.S. Environmental Protection Agency) 2008a. *Demonstrations of Method Applicability under a Triad Approach for Site Assessment and Cleanup – Technology Bulletin,* August.

USEPA (U.S. Environmental Protection Agency) 2008b. *A Guide for Assessing Biodegradation and Source Identification of Organic Ground Water Contaminants using Compound Specific Isotope Analysis (CSIA).* EPA 600/R-08/148, December.

USEPA (U.S. Environmental Protection Agency) 2009a. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment, Final),* USEPA-540-R-070-002, OSWER 9285.7-82. Washington, D.C.

USEPA (U.S. Environmental Protection Agency) 2009b. *Integrated Risk Information System (IRIS) Database*, Office of Research and Development, Washington, D.C. Available online: http://cfpub.USEPA.gov/ncea/iris/index.cfm.

USEPA (U.S. Environmental Protection Agency) 2013. Summary Table. Regional Screening Levels. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm. May.

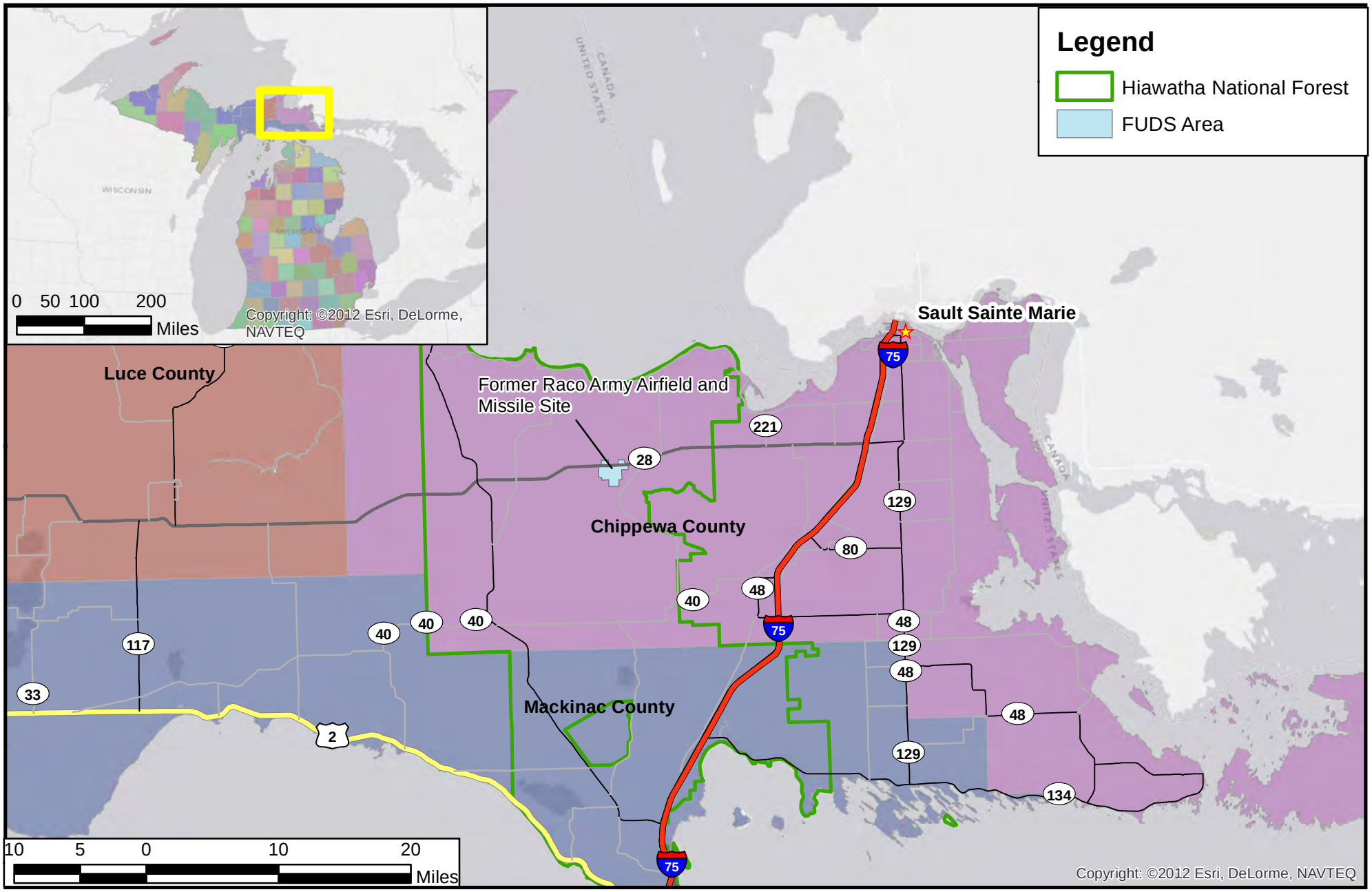
Vanlier and Deutsch 1958. *Michigan Geological Survey Division, Reconnaissance of the Ground-Water Resources of Chippewa County, Michigan*.

Woodruff, C.L. and Pearce, R. 1989. *Raco, A Case Study*. USACE Detroit District and Ronald Pearce, Sault Ste. Marie Area Office, USACE Detroit District, undated but post 1989 (Case Study)]

THIS PAGE INTENTIONALLY LEFT BLANK

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK



Base map source - ©2012 ESRI, DeLorme, NAVTEQ

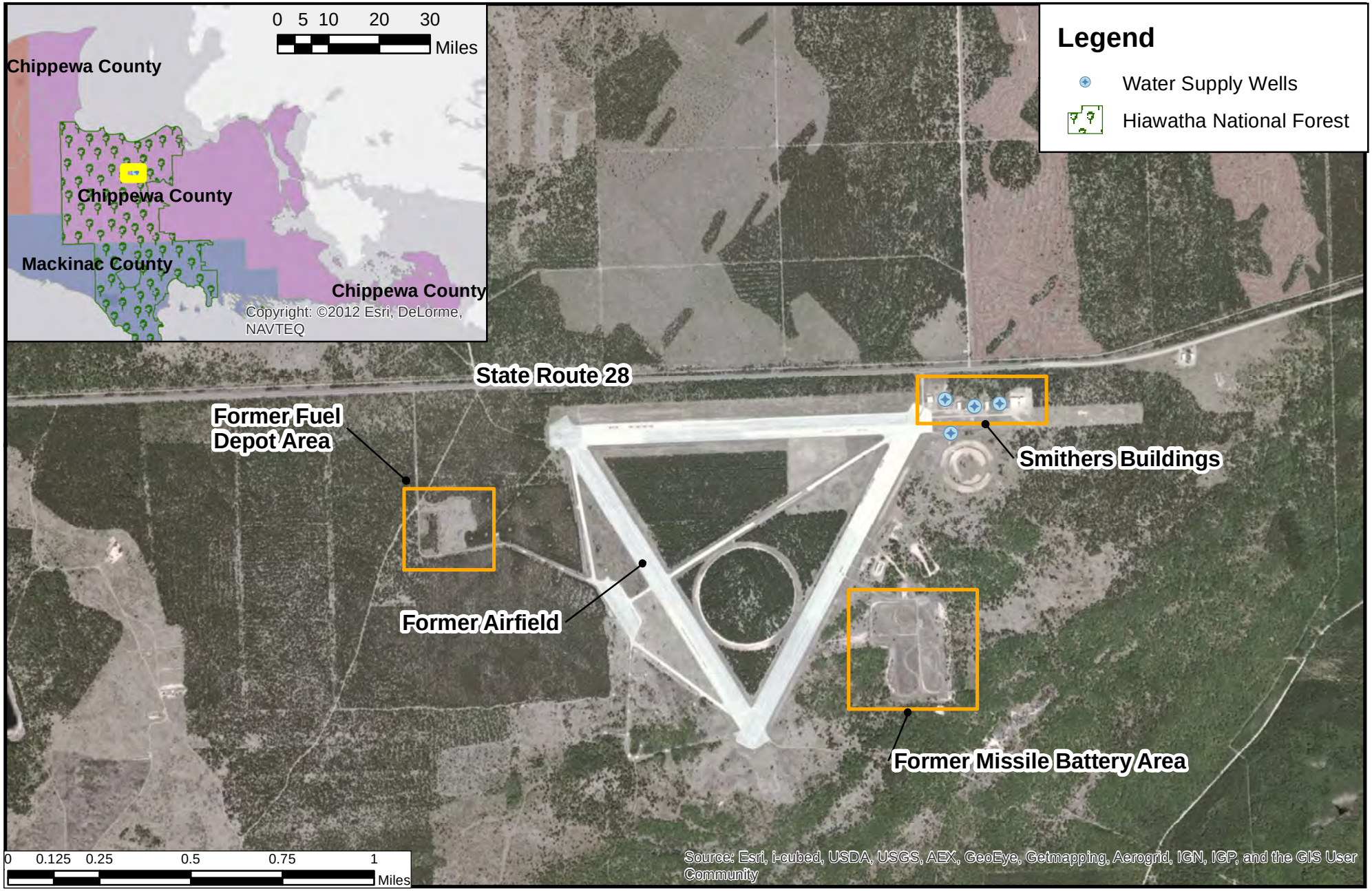
Figure 1.
Site location

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: December 2013



Base map source - ©2012 ESRI, DeLorme, NAVTEQ

Figure 2.
Site features

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: December 2013

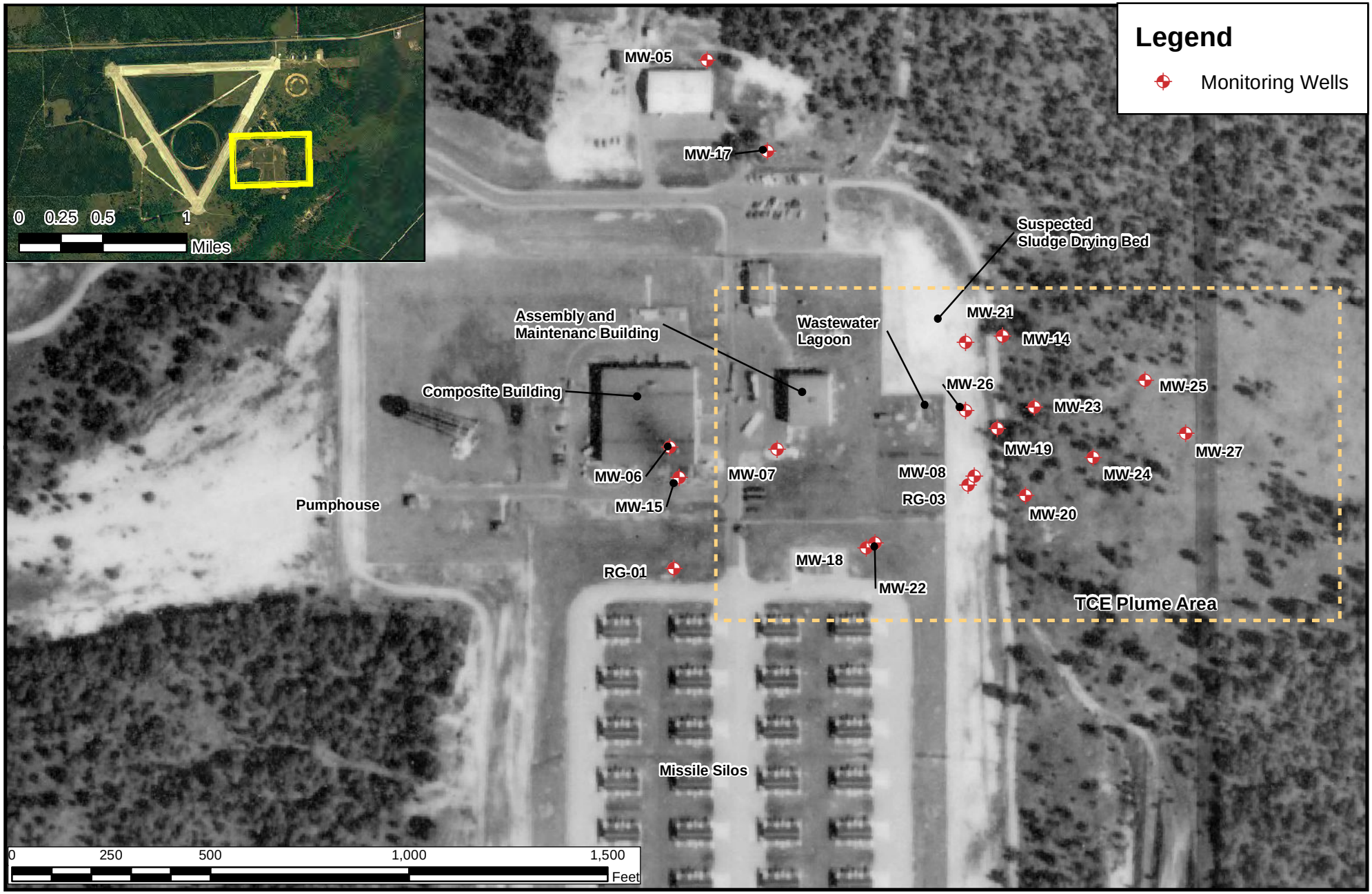


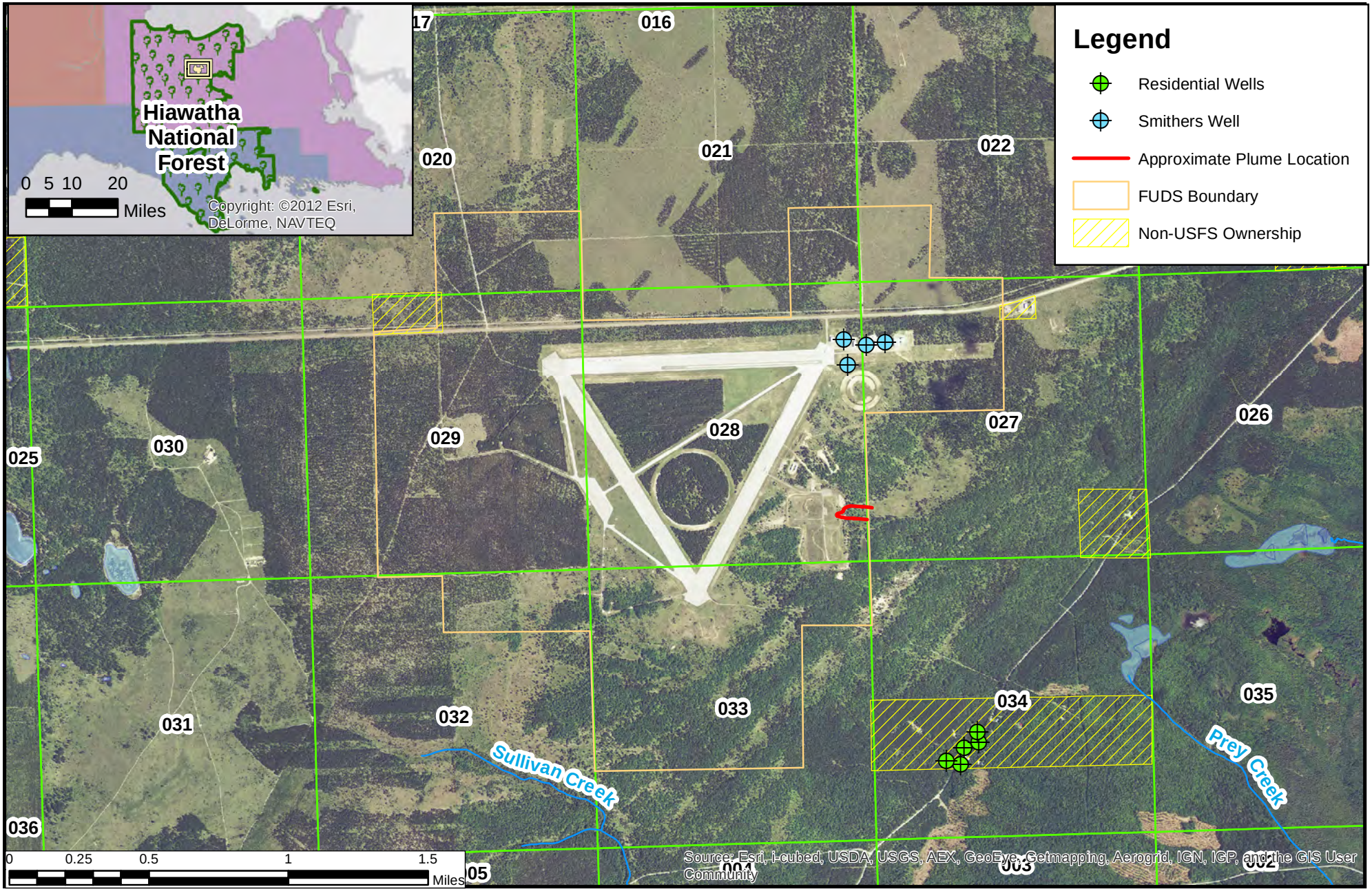
Figure 3.
Former Missile Battery Area
1972 aerial photograph

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume
Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: June 2014



Base map source - National Agricultural Imagery Program, USDA, 2012

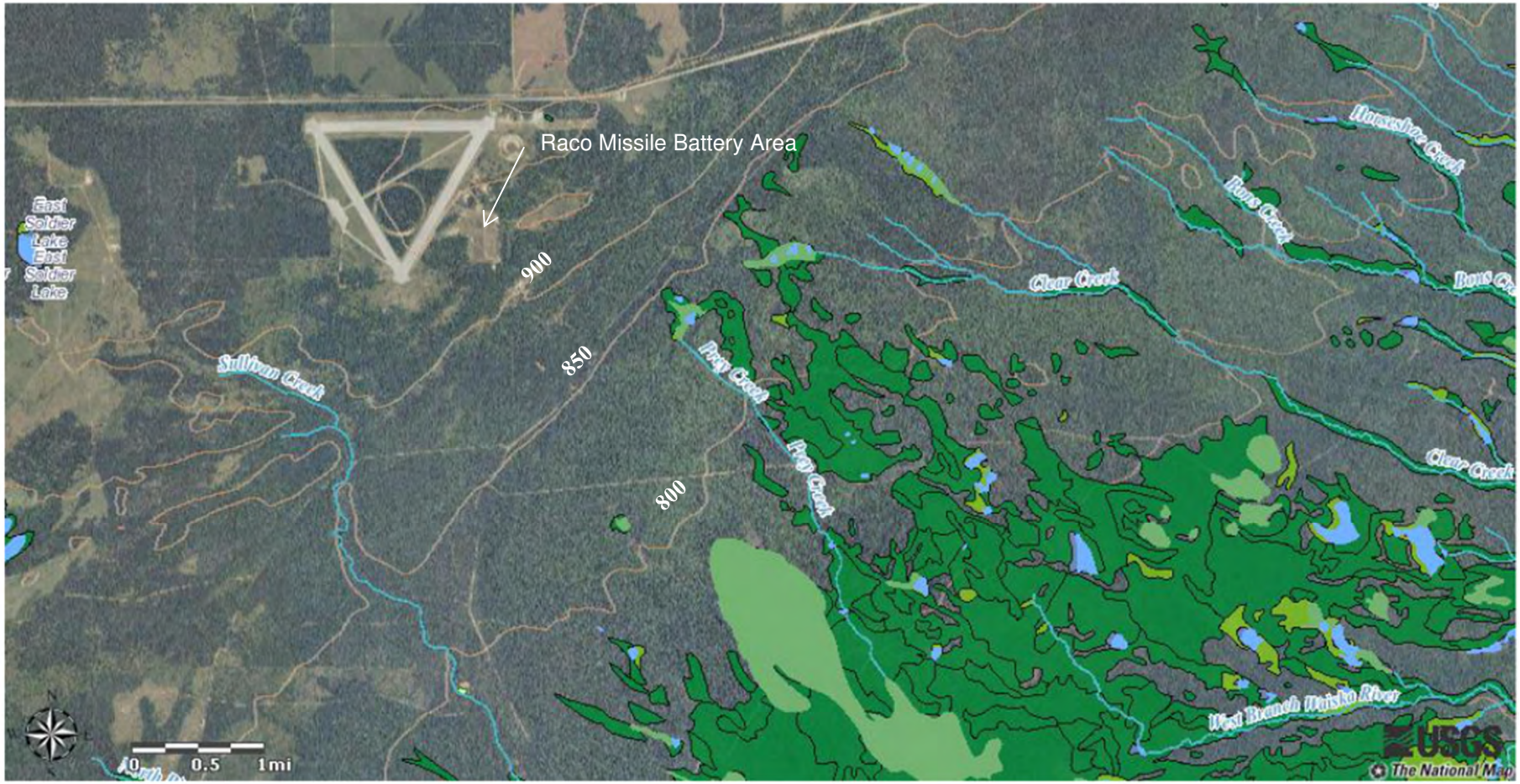
Figure 4.
Land use and ownership in the vicinity of the Raco Site

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

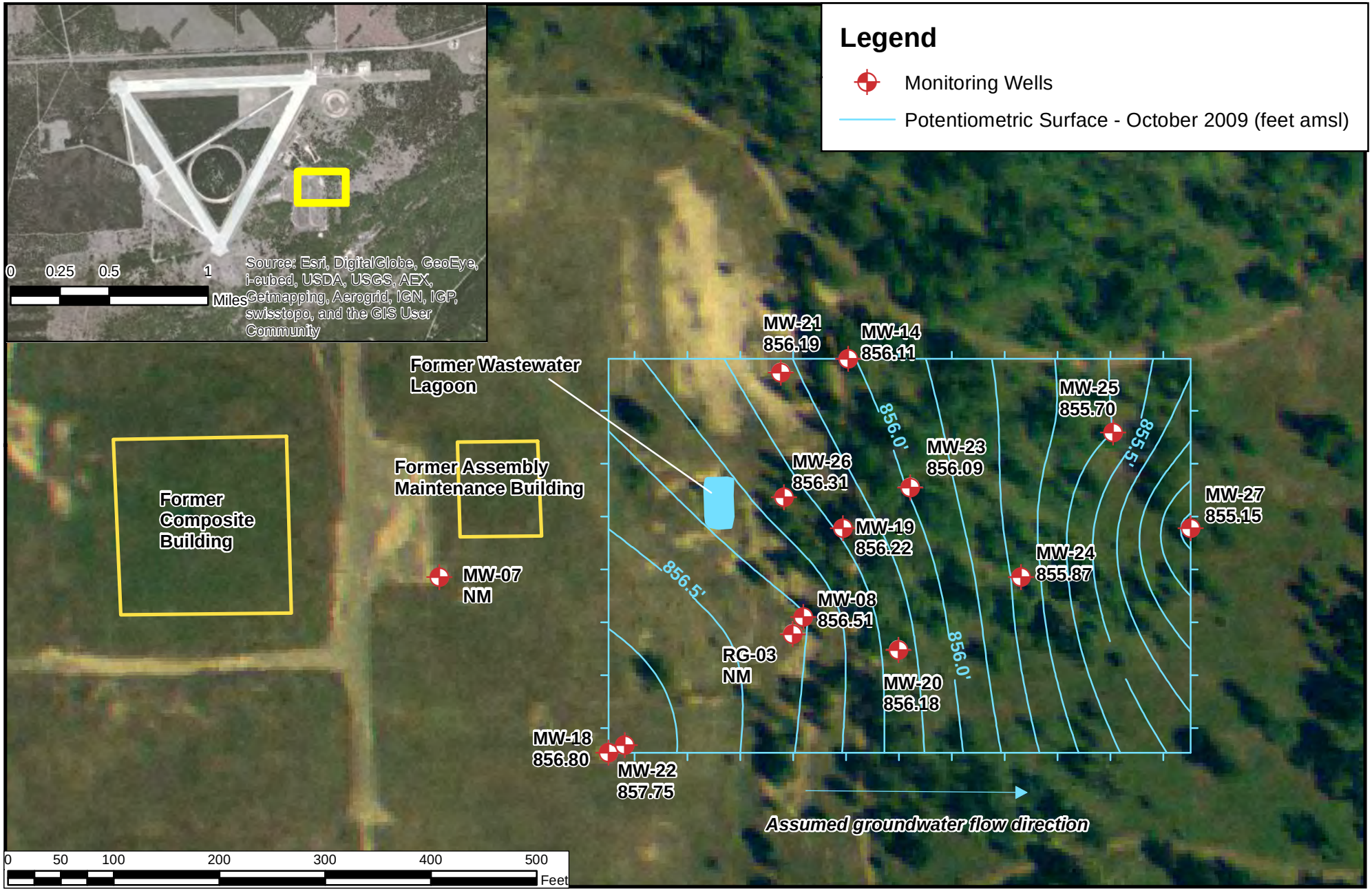


WETLANDS

Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland

Contours: feet above mean sea level

Figure 5. **Regional topography and surface waters**	**U.S. Army Corps of Engineers** **Louisville District**	**TCE Groundwater Plume, Former Raco Army Airfield and Missile Site** **Chippewa County, Michigan** **By: GEO Consultants, LLC** **Date: March 2014**



Base map source - Michigan Geographic Data Library, 2005

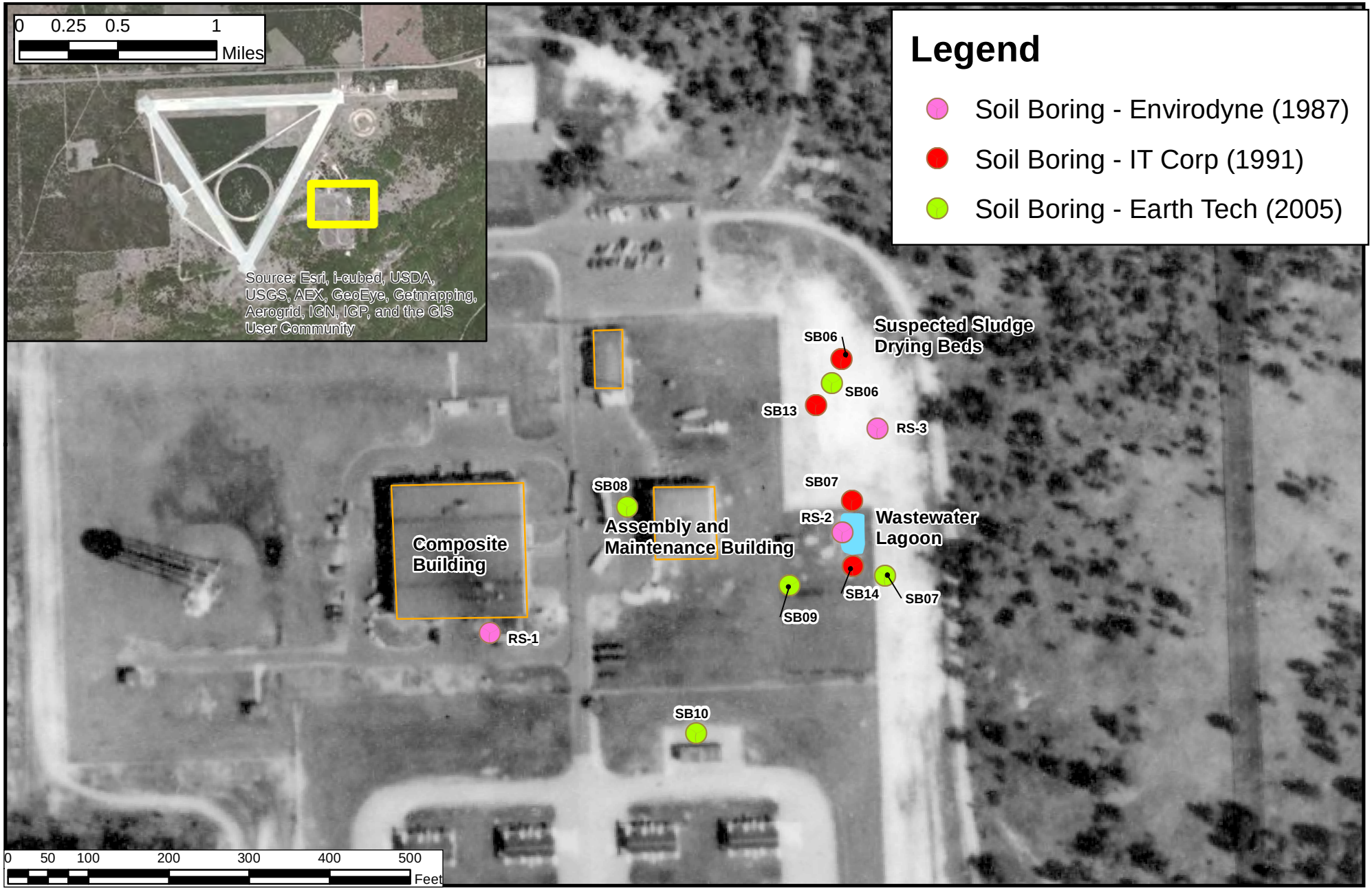
Figure 6.
Potentiometric map, former Missile Battery Area (October 2009)
Water levels shown in feet above mean sea level (amsl)

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: June 2014



Base map: 1972 Aerial Photograph

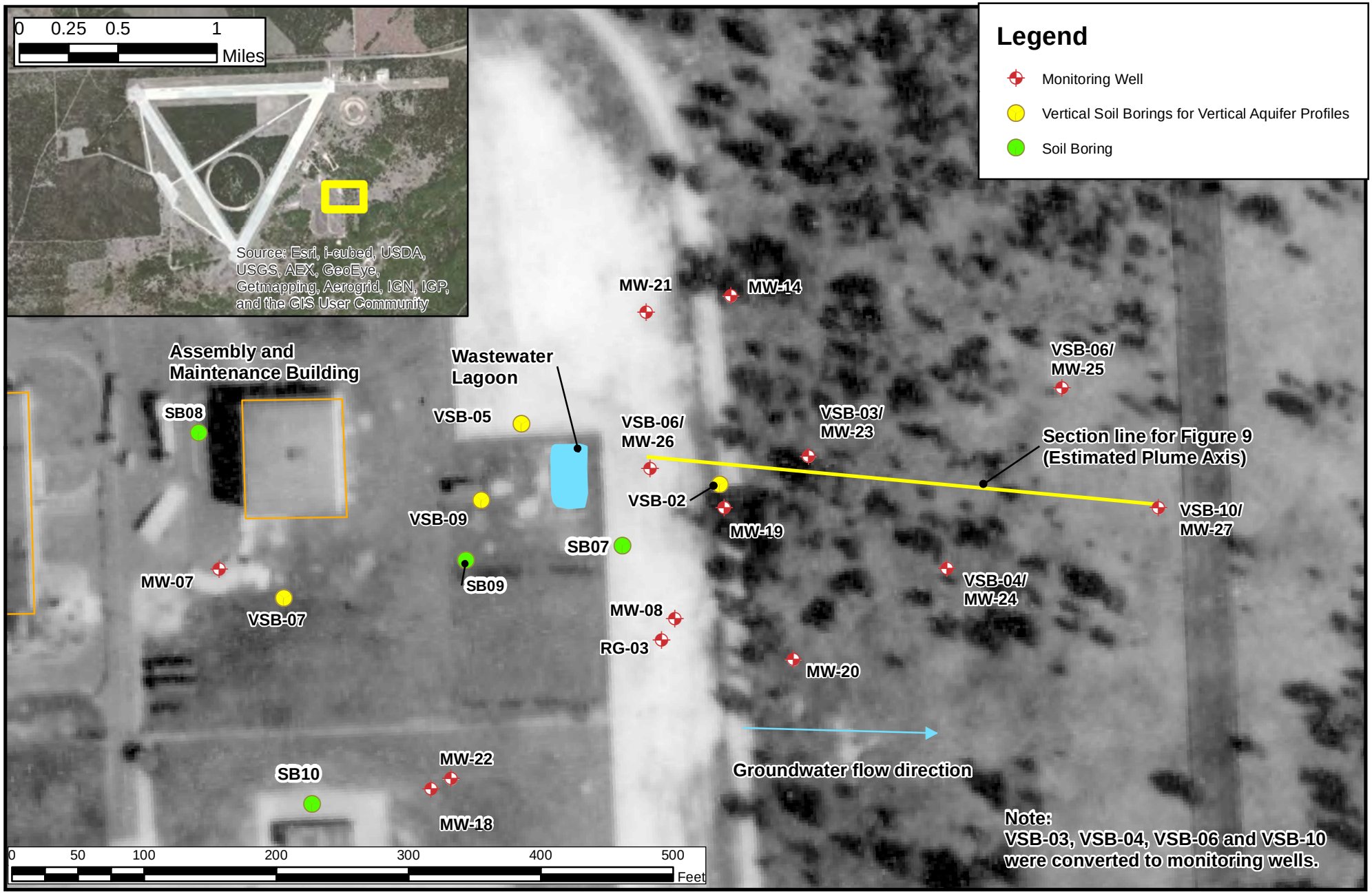
Figure 7. Soil sampling locations from previous investigations

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014



Base map: 1972 Aerial Photograph

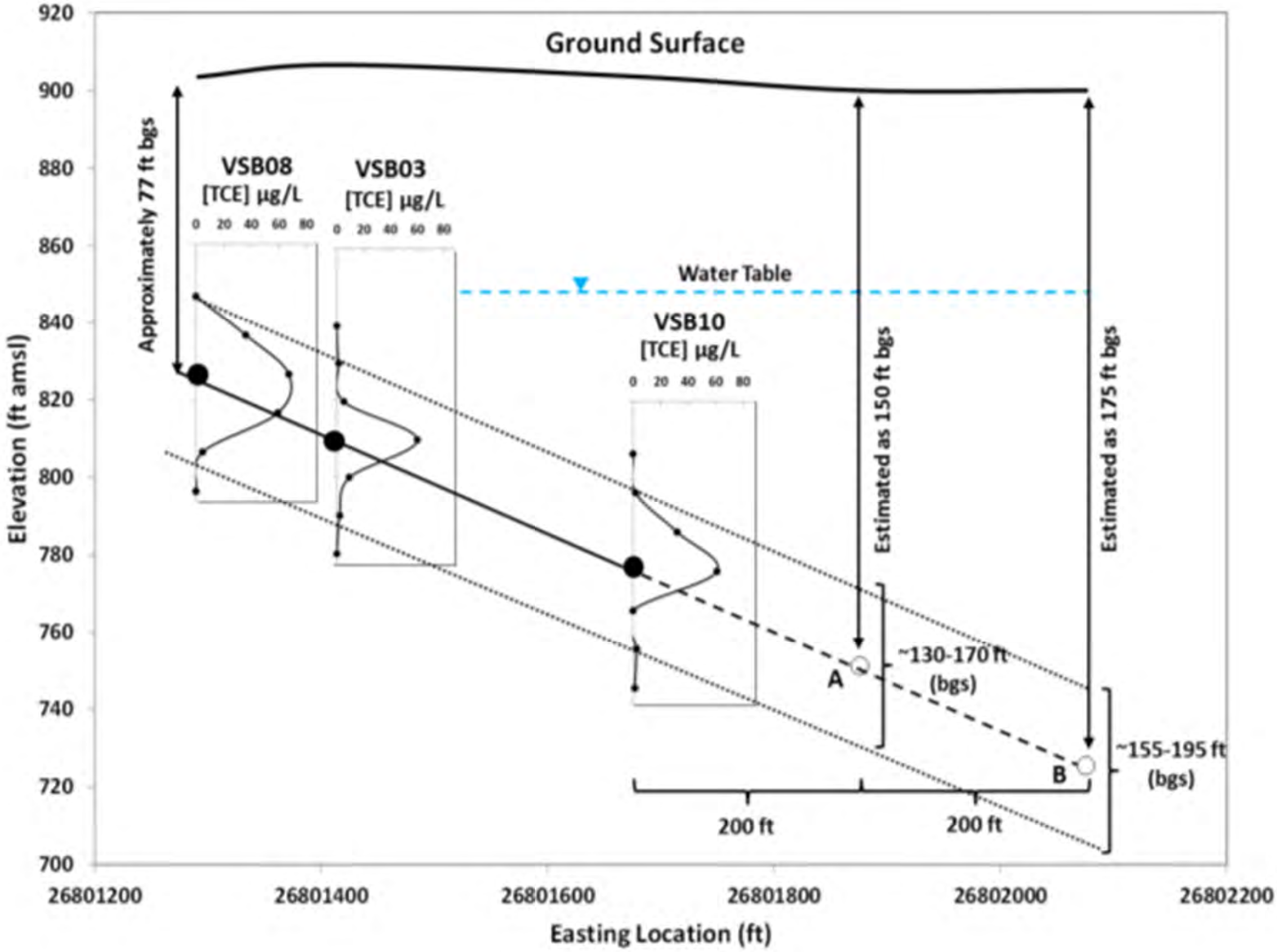
Figure 8. Groundwater sampling locations from previous investigations

U.S. Army Corps of Engineers
Louisville District

N

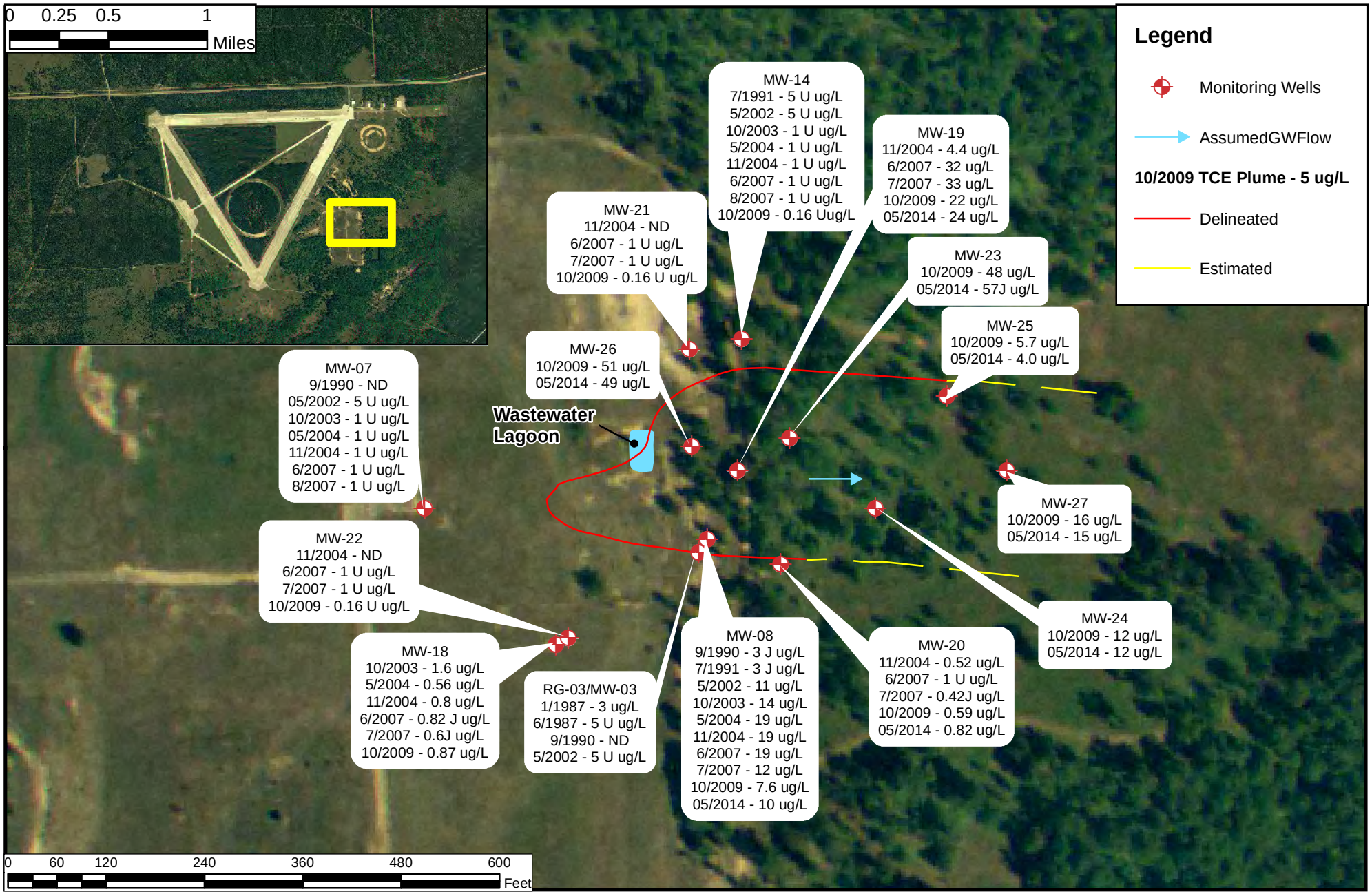
TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014



See Figure 8 for cross section location.

Figure 9. **Trichloroethene versus depth profiles from prior Vertical Aquifer Profile (VAP) investigation (GEO 2010) and proposed initial VAP locations**	**U.S. Army Corps of Engineers** **Louisville District**	**TCE Groundwater Plume, Former Raco Army Airfield and Missile Site Chippewa County, Michigan** **By: GEO Consultants, LLC** **Date: March 2014**



Base map source - Michigan Geographic Digital Library, 2005

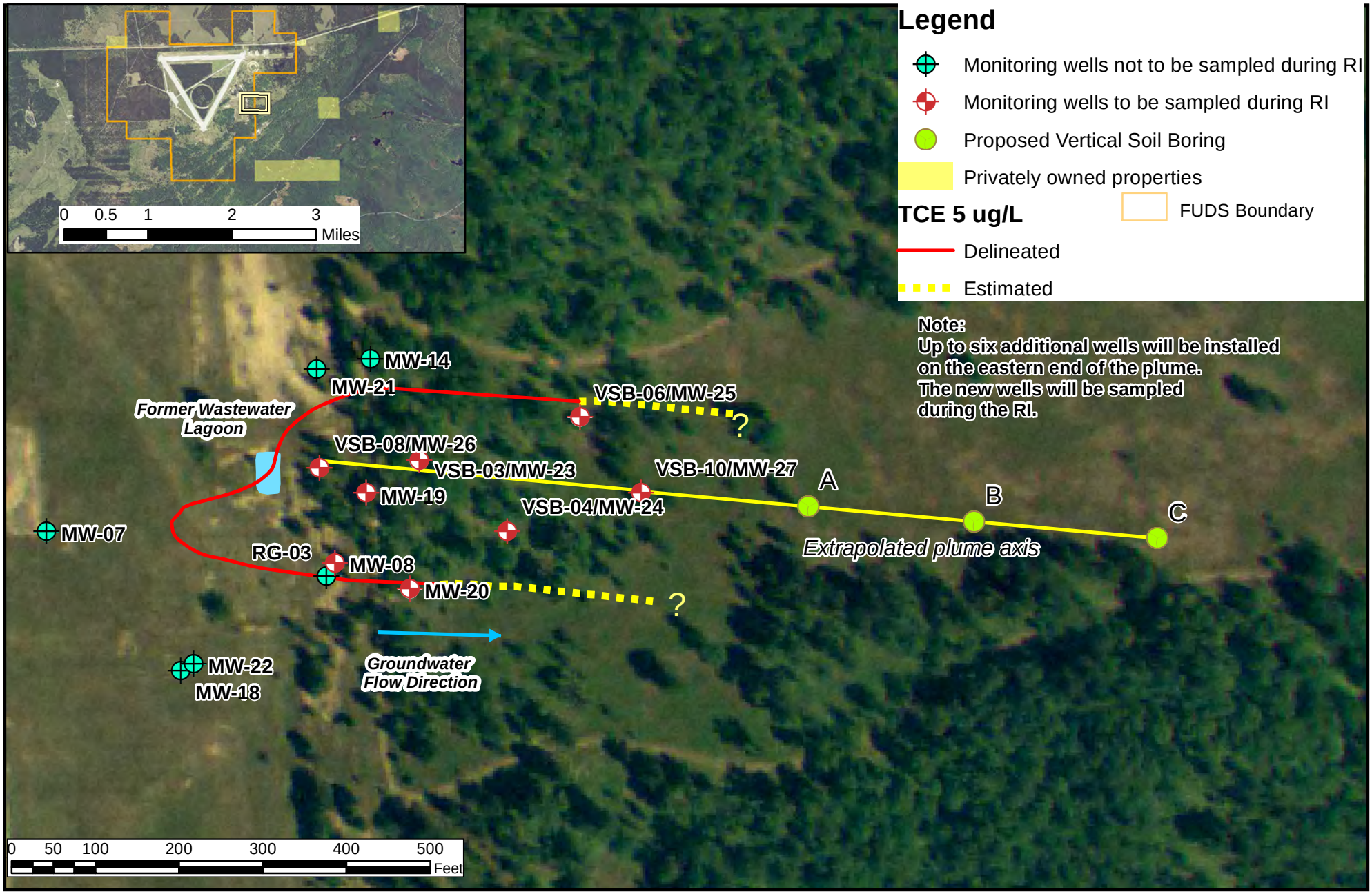
Figure 10.
Historical trichloroethene levels in existing monitoring wells

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: June 2014



Base map source - Michigan Geographic Data Library, 2005

Figure 11
Plan-view, initial Vertical Soil Borings for Vertical Aquifer Profile groundwater sampling

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

Impacted Media	Exposure Route	Industrial Worker[1]	Forest Area Worker[1]	Site Visitor Adult [2]	Site Visitor Child[2]	Potential Resident Adult[3]	Potential Resident Child[3]
TCE in GW	Ingestion	○	○	○	○	Δ	Δ
	Dermal Contact	○	○	X	X	Δ	Δ
	Inhalation	○	X	X	X	Δ	Δ

○ Pathway potentially complete, but unlikely; existing water supply wells are located 1 mile north/side-gradient of the TCE plume (Figure 2)
Δ Pathway completeness to be evaluated during the Remedial Investigation
X Pathway incomplete.

[1] Most likely/predictable use of the property.
[2] Site Visitors consist of industrial facility users or forest visitors.
[3] Potential residential receptors located over 1 mile away (Figure 4).

GW: groundwater

Figure 12.
Preliminary conceptual site exposure model

U.S. Army Corps of Engineers
Louisville District

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

Table 1. Coordinates and construction information for monitoring wells and Vertical Aquifer Profile (VAP) soil boreholes (VSBs) installed during previous investigations at the Raco Site

Well or Borehole ID	Monitoring Well Location	Northing[1][3]	Easting[1][3]	Screen length (feet)	Survey Marker/ Ground Elevation (feet amsl)[1][2][3]	Top of Casing[1][3] (feet amsl)	Total Depth [4] (ft below Top of Casing)	Total Depth [3] (ft below ground surface)	Screen Elevation (feet bgs)
RG-1/ MW-01	Missile Base Area			10.0			58.25		
RG-2/ MW-02	Missile Base Area			10.0			54.37		
RG-3/ MW-03	Missile Base Area	578389.2	26801299.7	10.0	904.03	906.57	58.08	55.54	45.54 - 55.54
RG-4/ MW-04	Fuel Depot			10.0			37.70		
-- MW-05	Missile Base Area			10.0			63.60		
-- MW-06	Missile Base Area			10.0			59.10		
-- MW-07	Missile Base Area	578442.8	26800965.3	10.0	905.30	906.81	59.01	57.50	47.50 - 57.50
-- MW-08	Missile Base Area	578405.0	26801309.7	10.0	904.10	905.59	75.65	74.16	64.16 - 74.16
-- MW-09	Near Northeast/Southwest Airfield runway			10.0			47.33		
-- MW-10	Middle of Airfield			10.0			44.82		
-- MW-11	Fuel Depot			10.0			45.58		
-- MW-12	West of Airfield			10.0			43.13		
-- MW-13	Fuel Depot			10.4			45.10		
-- MW-14	Missile Base Area	578649.1	26801352.0	10.4	907.98	909.52	58.87	57.33	46.93 - 57.33
-- MW-15	Missile Base Area			10.4			57.23		
-- MW-16	Fuel Depot			10.0			44.42		
-- MW-17	Missile Base Area			10.0			56.97		
-- MW-18	Missile Base Area	578276.5	26801125.4	10.0	905.68	908.11	59.02	56.59	46.59 - 56.59
-- MW-19	Missile Base Area	578489.0	26801347.2	10.0	905.26	907.60	93.93	91.59	81.59 - 91.59
-- MW-20	Missile Base Area	578374.1	26801399.6	10.0	907.64	909.85	89.00	86.79	76.79 - 86.79
-- MW-21	Missile Base Area	578636.9	26801288.3	10.0	903.20	905.58	93.95	91.57	81.57 - 91.57
-- MW-22	Missile Base Area	578284.3	26801140.6	10.0	905.47	907.72	91.63	89.38	79.38 - 89.38
VSB-03/ MW-23	Missile Base Area	578527.9	26801410.7	10.0	906.60	909.33	102.30	99.57	89.57 - 99.57
VSB-04/ MW-24	Missile Base Area	578443.1	26801515.6	10.0	905.40	908.01	102.30	99.69	89.69 - 99.69
VSB-06/ MW-25	Missile Base Area	578579.6	26801602.4	10.0	905.50	908.19	106.52	103.83	93.83 - 103.83
VSB-08/ MW-26	Missile Base Area	578518.5	26801291.2	10.0	903.50	906.25	89.92	87.17	77.17 - 87.17
VSB-10/ MW-27	Missile Base Area	578489.0	26801675.6	10.0	903.60	906.42	135.96	133.14	123.14 - 133.14
VSB-01 --	NA	578413.1	26800550.8	NA	902.70	NA	NA	NA	
VSB-02 --	NA	578507.0	26801343.9	NA	904.80	NA	NA	NA	
VSB-05 --	NA	578552.6	26801194.0	NA	904.30	NA	NA	NA	
VSB-07 --	NA	578421.0	26801014.3	NA	905.10	NA	NA	NA	
VSB-09 --	NA	578495.0	26801163.6	NA	904.90	NA	NA	NA	

[1]Horizontal coordinates are based on the Michigan State Plane Coordinate System (North Zone 2111). Elevations are based on the North American Vertical Datum 1929 (NAVD 1929)

[2] Survey marker elevations on the existing monitor wells, refer to a brass or aluminum disk set in the concrete base at each monitor well. Elevation shots at MW-23 through MW-27 were taken on the concrete pad adjacent to each MW protective housing. Elevation shots at the borings, were taken adjacent to the boring on undisturbed ground.

[3] Coordinates, elevations, and depths below ground surface only provided for wells that were surveyed in 2009 (GEO 2010). Reliable elevation data not available for other wells.

[4] Depths for wells surveyed in 2009 were measured and reported in GEO (2010). Depths for other wells obtained from previous investigation reports and monitoring well construction diagrams.

Table 2. Depth to water (feet below top of casing) and groundwater elevations (feet above mean sea level) in monitoring wells at the Raco Site

			Depth to water (ft below Top of Casing)													
			Groundwater Elevation [a] (ft AMSL)													
Well	Total Depth (feet below Top of Casing)	Top of Casing Elevation (ft amsl) [a]	9/7/1990	9/18/1990 - 9/23/1990	9/24/1990 - 9/25/1990	9/26/1990	11/12/1990 - 11/13/1990	11/17/1990	4/17/1991	7/16/1991	7/18/1991	8/20/1991	5/21/2002	6/2007	7/2007	10/28/2009
RG-1	58.25	--	48.85	48.83	48.94	49.21	48.92	49.15	49.00	47.84	47.84	47.91	49.51	--	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
RG-2	54.37	--	46.10	46.06	46.10	48.40	48.27	48.36	48.50	46.80	46.79	46.70	48.62	49.88	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
RG-3	58.08	906.57	48.88	48.88	49.84	49.92	49.95	49.90	49.91	48.54	48.53	48.63	50.06	--	--	--
			857.69	*857.69*	*856.73*	*856.65*	*856.62*	*856.67*	*856.66*	*858.03*	*858.04*	*857.94*	*856.51*	--	--	--
RG-4	37.70	--	35.90	35.83	37.15	37.30	37.15	37.17	37.35	35.74	35.74	35.92	Dry	--	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-05	63.60	--	--	57.05	57.10	57.06	52.20	57.11	57.00	55.73	55.74	55.79	57.43	58.53	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-06	59.10	--	--	51.37	51.35	51.30	--	51.28	51.40	49.97	49.74	49.97	51.61	52.59	52.22	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-07	59.01	906.81	--	49.64	49.58	49.60	49.56	49.61	49.53	48.25	48.24	48.34	49.85	50.95	50.56	--
				857.17	*857.23*	*857.21*	*857.25*	*857.20*	*857.28*	*858.56*	*858.57*	*858.47*	*856.96*	*855.86*	*856.25*	--
MW-08	75.65	905.59	--	48.90	48.90	48.95	48.94	48.93	48.96	47.59	47.58	47.58	49.11	49.58	49.92	49.08
				856.69	*856.69*	*856.64*	*856.65*	*856.66*	*856.63*	*858.00*	*858.01*	*858.01*	*856.48*	*856.01*	*855.67*	*856.51*
MW-09	47.33	--	--	41.26	41.26	41.27	38.10	--	41.18	40.04	40.02	40.00	41.75	43.02	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	44.82	--	--	40.60	40.61	40.60	40.49	--	40.70	39.22	39.20	39.33	40.9	44.82	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11	45.58	--	--	38.90	38.80	38.95	35.60	38.99	39.27	37.49	37.49	37.73	39.95	41.30	40.67	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-12	43.13	--	--	36.90	37.20	37.25	33.50	33.70	37.43	36.13	36.12	36.18	38.18	39.36	38.90	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	45.10	--	--	--	--	--	--	--	--	37.06	37.06	37.30	39.49	--	--	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-14	58.87	909.52	--	--	--	--	--	--	--	51.80	51.77	51.75	53.32	54.54	54.21	53.41
										857.72	*857.75*	*857.77*	*856.20*	*854.98*	*855.31*	*856.11*
MW-15	57.23	--	--	--	--	--	--	--	--	47.90	47.88	47.85	49.55	50.61	50.16	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-16	44.42	--	--	--	--	--	--	--	--	--	--	--	--	38.80	38.44	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 2. Depth to water (ft below top of casing) and groundwater elevations (feet above mean sea level) in monitoring wells at the Raco Site (Continued)

			Depth to water (ft below Top of Casing)													
			Groundwater Elevation [a] (ft AMSL)													
Well	Total Depth	Top of Casing Elevation (ft AMSL) [a]	9/7/1990	9/18/1990 - 9/23/1990	9/24/1990 - 9/25/1990	9/26/1990	11/12/1990 - 11/13/1990	11/17/1990	4/17/1991	7/16/1991	7/18/1991	8/20/1991	5/21/2002	6/2007	7/2007	10/28/2009
MW-17	56.97	--	--	--	--	--	--	--	--	--	--	--	--	49.91	49.60	--
			--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-18	59.02	908.11	--	--	--	--	--	--	--	--	--	--	--	52.46	51.92	51.31
			--	--	--	--	--	--	--	--	--	--	--	*855.65*	*856.19*	*856.80*
MW-19	93.93	907.60	--	--	--	--	--	--	--	--	--	--	--	52.43	52.09	51.38
			--	--	--	--	--	--	--	--	--	--	--	*855.17*	*855.51*	*856.22*
MW-20	89.00	909.85	--	--	--	--	--	--	--	--	--	--	--	54.72	54.38	53.67
			--	--	--	--	--	--	--	--	--	--	--	*855.13*	*855.47*	*856.18*
MW-21	93.95	905.58	--	--	--	--	--	--	--	--	--	--	--	50.46	50.12	49.39
			--	--	--	--	--	--	--	--	--	--	--	*855.12*	*855.46*	*856.19*
MW-22	91.63	907.72	--	--	--	--	--	--	--	--	--	--	--	52.12	51.70	49.97
			--	--	--	--	--	--	--	--	--	--	--	*855.60*	*856.02*	*857.75*
MW-23	102.30	909.3	--	--	--	--	--	--	--	--	--	--	--	--	--	53.24
			--	--	--	--	--	--	--	--	--	--	--			*856.09*
MW-24	102.30	908.0	--	--	--	--	--	--	--	--	--	--	--	--	--	52.14
			--	--	--	--	--	--	--	--	--	--	--			*855.87*
MW-25	106.52	908.19	--	--	--	--	--	--	--	--	--	--	--	--	--	52.49
			--	--	--	--	--	--	--	--	--	--	--			*855.70*
MW-26	89.92	906.25	--	--	--	--	--	--	--	--	--	--	--	--	--	49.94
			--	--	--	--	--	--	--	--	--	--	--			*856.31*
MW-27	135.96	906.42	--	--	--	--	--	--	--	--	--	--	--	--	--	51.27
			--	--	--	--	--	--	--	--	--	--	--			*855.15*

[a] Elevation of top of casing surveyed in November 2009 (GEO 2010). Groundwater elevation only calculated for wells that were surveyed in November 2009, i.e., with reliable Top of Casing elevations.

Appears to be an anomalous result.

Table 3. Climate data for Raco, Michigan

	January	February	March	April	May	June	July	August	September	October	November	December
Average High (°F)	25	29	39	53	66	75	79	77	68	55	41	30
Average Low (°F)	7	9	16	29	39	48	52	52	45	35	26	15
Mean (°F)	16	19	28	41	53	62	66	65	57	45	34	23
Average Precipitation (inches)	1.77	1.47	1.69	2.59	2.44	2.97	3.25	3.2	4.09	3.8	3.13	2.5
Record High (°F)	45	51	68	89	94	95	99	95	88	82	66	60
Record Low (°F)	-34	-34	-26	-4	20	23	33	29	15	12	-1	-22

Table 4. Monitoring wells at the former Raco Missile Battery Area sampled from 1987 to 2009

Well ID	Jan-87	Jun-87	Sep-90	Nov-90	Jul-91	Jun-96	May-02	Oct-03	May-04	Nov-04	Jun-07	Aug-07	Oct-09
RG-1/ MW-01	X	X	X	--	X	--	X	X	X	--	--	--	--
RG-2/ MW-02	--	X	X	--	--	--	X	X	X	--	X	X	--
RG-3/ MW-03	X	X	--	X	--	--	X	[1]	[1]	--	--	--	--
MW-05	--	--	X	--	--	X	X	X	X	--	X	X	--
MW-06	--	--	X	--	--	--	X	X	X	--	X	X	--
MW-07	--	--	X	--	--	--	X	X	X	X	X	X	--
MW-08	--	--	X	--	X	--	X	X	X	X	X	X	X
MW-09	--	--	X	--	--	--	X	X	X	--	--	--	--
MW-14	--	--	--	--	X	--	X	X	X	X	X	X	X
MW-15	--	--	--	--	X	--	X	X	--	--	--	--	--
MW-18	--	--	--	--	--	--	--	X	X	X	X	X	X
MW-19	--	--	--	--	--	--	--	--	--	X	X	X	X
MW-20	--	--	--	--	--	--	--	--	--	X	X	X	X
MW-21	--	--	--	--	--	--	--	--	--	X	X	X	X
MW-22	--	--	--	--	--	--	--	--	--	X	X	X	X
MW-23	--	--	--	--	--	--	--	--	--	--	--	--	X
MW-24	--	--	--	--	--	--	--	--	--	--	--	--	X
MW-25	--	--	--	--	--	--	--	--	--	--	--	--	X
MW-26	--	--	--	--	--	--	--	--	--	--	--	--	X
MW-27	--	--	--	--	--	--	--	--	--	--	--	--	X

[1] Obstruction encountered downhole, not sampled

X: Sampled, --: Not sampled or well had not been installed.

Table 5. Trichloroethene concentrations (µg/L) measured in monitoring wells located at the former Raco Missile Battery Area

Well ID	Jan-87	Jun-87	Sep-90	Nov-90	Jul-91	May-02	Oct-03	May-04	Nov-04	Jun-07	Aug-07	Oct-09	May-14
	[1]	[1]	[1]	[1]	[1]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	--
MW-01/RG-01	1.3 U	5 U	5 U	--	5 U	5 U	1 U	1 U	--	--	--	--	--
MW-02/RG-02	1.3 U	1.3 U	5 U	--	--	5 U	1 U	1 U	--	0.62 J	1 U	--	--
MW-03/RG-03	3	5 U	ND	--	5 U	5 U	--	--	--	--	--	--	--
MW-05	--	--	ND	--	--	5 U	1 U	1 U	--	1 U	1 U	--	--
MW-06	--	--	ND	--	--	5 U	1 U	1 U	--	1 U	1 U	--	--
MW-07	--	--	ND	--	--	5 U	1 U	1 U	1 U	1 U	1 U	--	--
MW-08*	--	--	3 J	--	3 J	***11***	***14***	***19***	***19***	***19***	***12***	***7.6***	***10***
MW-14	--	--	--	--	5 U	5 U	1 U	1 U	1 U	1 U	1 U	0.16 U	--
MW-15	--	--	--	--	5 U	5 U	1 U	--	--	--	--	--	--
MW-17						--	1 U	--	--	--	--	--	--
MW-18	--	--	--	--	--	--	1.6	0.56	0.8	0.82 J	0.6 J	0.87	--
MW-19*	--	--	--	--	--	--	--	--	4.4	***32***	***33***	***22***	***24***
MW-20*	--	--	--	--	--	--	--	--	0.52	1 U	0.42 J	0.59	0.82
MW-21	--	--	--	--	--	--	--	--	1 U	1 U	1 U	0.16 U	--
MW-22	--	--	--	--	--	--	--	--	1 U	1 U	1 U	0.16 U	--
MW-23*	--	--	--	--	--	--	--	--	--	--	--	***48***	***65***
MW-24*	--	--	--	--	--	--	--	--	--	--	--	***12***	***12***
MW-25*	--	--	--	--	--	--	--	--	--	--	--	***5.7***	4
MW-26*	--	--	--	--	--	--	--	--	--	--	--	***51***	***58***
MW-27*	--	--	--	--	--	--	--	--	--	--	--	***16***	***15***

Note: Results from October 2003 through October 2009 were taken using low-flow sampling methods. Samples taken from MW-08 in September 1990 and July 1991 were taken using a polytetrafluoroethylene bailer.

Value Value exceeds the USEPA MCL value of 5 µg/L (USEPA 2013, updated May 2013)

*These monitoring wells will be sampled during the RI field work.

U: TCE not detected; J: TCE concentration is an estimated value; ND: TCE not detected,no numerical value available from source/report.

[1] The detection limit was reported for non-detect values.

[2] Reporting Limit or Limit of Quantiation was reported for non-detect values.

Table 6. Trichloroethene concentrations (µg/L) measured during the previous Vertical Aquifer Profile (VAP) investigation (GEO 2010)

Boring No.	Depth (feet bgs)	Trichloroethene (Mobile laboratory[1]) (µg/L)	Trichloroethene (Fixed-base laboratory[2]) (µg/L)	Trichloroethene in associated monitoring well (Fixed-base laboratory) (µg/L)
	47-57	1.0 U	--	--
	57-67	1.0 U	--	--
	67-77	3.3	--	--
	77-87	1.8	--	--
VSB-02	87-97	6.2	7.9	No well installed
	97-107	1.0 U	--	--
	107-117	1.0 U	--	--
	117-127	1.0 U	0.16 U	--
	57	1.0 U	--	--
	67	1.0 U	--	--
	77	1.1	--	--
	87	5	--	--
VSB-03/MW-23	97	60	77	48
	107	9.3	--	--
	117	2.1	--	--
	127	1.0 U	0.7	--
	57	1.0 U	--	--
	67	1.0 U	--	--
	77	1.0 U	--	--
	87	3.3	--	--
VSB-04/ MW-24	97	12	14	12
	107	9.2	--	--
	117	1.0 U	0.17	--
	57	1.0 U	--	--
	67	1.0 U	--	--
	77	1.0 U	--	--
VSB-05	87	1.0 U	0.28	No well installed
	97	1.0 U	--	--
	107	1.0 U	0.16 U	--
	117	1.0 U	--	--
	57	1.0 U	--	--
	67	1.0 U	--	--
	77	1.0 U	--	--
	87	1.0 U	--	--
VSB-06/MW-25	97	1.0 U	0.16 U	5.7
	107	1.0 U	--	--
	117	1.0 U	0.16 U	--
	57	1.0 U	0.17	--
	67	1.0 U	--	--
VSB-07	77	1.0 U	--	No well installed
	87	1.0 U	--	--
	97	1.0 U	0.16 U	--
	107	1.0 U	--	--

Table 6. Trichloroethene concentrations (µg/L) measured during the previous Vertical Aquifer Profile (VAP) investigation (GEO 2010) (continued)

Boring No.	Depth (feet bgs)	Trichloroethene (Mobile laboratory[1]) (µg/L)	Trichloroethene (Fixed-base laboratory[2]) (µg/L)	Trichloroethene in associated monitoring well (Fixed-base laboratory) (µg/L)
	57	1.0 U	--	--
	67	36	--	--
VSB-08/MW-26	77	67	65	51
	87	59	--	--
	97	4.7	--	--
	107	1.0 U	--	--
	117	1.0 U	0.16 U	--
VSB-09	67	2	1.7	No well installed
	77	1.0 U	--	--
	87	1.0 U	0.16 U	--
	77	1.0 U	--	--
	87	1.0 U	--	--
	97	1.0 U	--	--
	107	1.9	--	--
	117	32	--	--
VSB-10/MW-27	127	61	55	16
	137	1.0 U	--	--
	147	2.4	--	--
	157	1.3	1.1	--

VSB: Vertical Soil Borehole; MW: Monitoring Well
bgs: below ground surface; U: TCE not detected.

Table 7. Monitoring well sampling summary and rationale for the Raco Site TCE Plume Remedial Investigation
V: Verification Sampling Event (Spring 2014); 1: First monitoring well sampling event (Fall 2014); 2: Second monitoring well sampling event (Spring 2015)

Well ID	Number of prior sampling events through 2009 [a]	TCE range of concentrations (ug/L) [a]	Water Quality Parameters [b]	Trichloroethene and dechlorination products [c]	Ferrous Iron	Monitored Natural Attenuation Parameters [d]	Compound Specific Isotope Analysis	CENSUS Molecular Biological Tool	Rationale for Sampling
MW-08	9	3J to 19	V, 1, 2	V, 1, 2	1, 2	--	--	--	TCE > 5 ug/L, multiple samplings since 1990
MW-19	4	4 to 33	V, 1, 2	V, 1, 2	1, 2	--	--	--	TCE > 5 ug/L, multiple samplings since 2004
MW-20	4	1U to 0.59	V, 1, 2**	V, 1, 2**	1, 2	--	--	--	Defines the southern plume boundary
MW-23	1	48	V, 1, 2	V, 1, 2	1, 2	1,2*	2*	2*	Located along plume axis based on 2009 data
MW-24	1	12	V, 1, 2	V, 1, 2	1, 2	--	--	--	Near the southern plume boundary
MW-25	1	5.7	V, 1, 2	V, 1, 2	1, 2	--	--	--	Near the northern plume boundary
MW-26	1	51	V, 1, 2	V, 1, 2	1, 2	1,2*	2*	2*	Located along plume axis based on 2009 data
MW-27	1	16	V, 1, 2	V, 1, 2	1, 2	1,2*	2*	2*	Located along plume axis based on VSB10 2009 data
MW-28 (To be installed)	--	--	V, 1, 2	V, 1, 2	1, 2	1,2*	2*	2*	New well
MW-29 (To be installed)	--	--	V, 1, 2	V, 1, 2	1, 2	1,2*	2*	--	New well
MW-30 (To be installed)	--	--	V, 1, 2	V, 1, 2	1, 2	1,2*	2*	--	New well
MW-31 (To be installed)	--	--	V, 1, 2	V, 1, 2	1, 2	--	--	--	New well
MW-32 (To be installed)	--	--	V, 1, 2	V, 1, 2	1, 2	--	--	--	New well
MW-33 (To be installed)	--	--	V, 1, 2	V, 1, 2	1, 2	--	--	--	New well

[a] Trichloroethene groundwater concentrations from previous investigations presented in Table 5.
[b] pH, temperature, specific conductance, dissolved oxygen, oxidation-reduction potential, turbidity
[c] To be measured in an off-site, fixed-base lab by Method 8260C.
[d] chloride, nitrite, nitrate, sulfate, sulfide, methane, ethane, ethene, carbon dioxide, alkalinity, dissolved organic carbon, in addition to water quality parameters
*Selected wells will be located along the plume axis; wells may change based on groundwater monitoring data collected during the Verification and First sampling events
**MW-20 may be excluded from further sampling after the Verification Sampling Event if trichloroethene is detected at less than 1 ug/L (i.e., comparable to previous results)

Table 8. Project team members and subcontractors

Name	Position/Role	Phone	Organization/Address*
Phyllis Hockett	Project Manager	502-315-7457	USACE/CELRL
Josh Van Bogaert	Technical Manager and Contracting Officer Representative	502-315-6333	USACE/CELRL
Douglas Buchanan	Geologist	502-315-6334	USACE/CELRL
Dr. David Brancato	Risk Assessor	502-315-6494	USACE/CELRL
Kathy Kranz	Chemist	502-315-6335	USACE/CELRL
William Harmon	Site Coordinator	517-284-5110	MDEQ
Carol Tracy	Geologist	517-284-5161	MDEQ
Eric Wildfang	Risk Assessor	517-284-5170	MDEQ
Jessica Stuntebeck	Geologist	414-297-3342	USFS
Larry Copeland	Program/Project Manager	270-462-3882	GEO
Natalie Magill	Technical Manager	270-462-3882	GEO
Kim Morris	Quality Manager	270-462-3882	GEO
Paul Lewers	Field Operations Manager Site Safety and Health Officer	618-203-9950	GEO
Tom Early	Senior Geologist	865-482-5916	GEO
Olivia West	Risk Assessor	865-671-4401	GEO
Dennis Robins	Driller	810-577-2665	Cascade Drilling
Nick Nigro	Project Manager, Mobile Laboratory	608-221-8700	ECCS
Pat Letterer	Project Manager,Fixed-base Laboratory (Chemical Analysis)	608-356-2760	CT Laboratories, 1230 Lange Ct., Baraboo, WI 53913
Laura Soeten	Laboratory data validation	760-634-0437	Laboratory Data Consultants, Inc.
Brooke Harrison	Ecological Reconnaissance	330-688-0111	EnviroScience, Inc.
TBD	Project Manager, Fixed-base Laboratory (CSIA)	412-826-5245	Microseeps, Inc., 220 William Pitt Way, Pittsburgh, PA 15238
TBD	Project Manager, Fixed-base Laboratory (CENSUS/MBT)	865-573-8188	Microbial Insights, Inc., 10515 Research Drive, Knoxville, TN 37932
TBD	Project Manager, Fixed-base Laboratory (Soil grain size analysis)	562- 347-2500	PTS Laboratories, 8100 Secura Way, Santa Fe Springs, CA 90670
TBD	Utility Locator	888-858-9830	Blood Hound, Inc.
William Karr	Surveyor	906-632-1500	Northwoods Land Surveying

CELRL: U.S. Army Corps of Engineers, Louisville District; GEO: GEO Consultants, LLC; MDEQ: Michigan Department of Environmental Quality; TBD: To Be Determined; USACE: U.S. Army Corps of Engineers; USFS: U.S. Forest Service; MBT: Molecular Biological Tools; CSIA: Compound Specific Isotope Analysis

*Address only provided for off-site, fixed-base laboratories since this information will be used for shipping samples.

Table 9. Raco Site TCE Plume Remedial Investigation/Feasibility Tasks and Follow-On Activities

Task	Approximate Dates
Task 1: Project Management	Throughout project
Task 2: Community Relations	Throughout project
Task 3: RI Field Activities/Data Management/Reporting	April 2014 - March 2016
Verification Sampling Event	May 2014
Vertical Aquifer Profiling and Monitoring Well Installation	Summer (August-September) 2014
First Round , Groundwater Sampling	Fall (September-October) 2014
Second Round, Groundwater Sampling	Spring (April) 2015
RI Report Preparation, Review, Revisions	April 2015-March 2016
Task 4: Baseline Risk Assessment*	April 2015 -March 2016
Task 5: Feasibility Study	March 2016-October 2016
Task 6: Proposed Plan	October 2016-April 2017
Task 7: Decision Document	April 2017-October 2017

*Results will be incorporated into RI Report

Table 10. Exposure parameters for potential receptors exposed to groundwater from the Raco Site

Parameter	Units	Industrial Worker	Source/ Note	Forest Area Worker [1]	Source/ Note	Site Visitor Adult [2]	Source/ Note	Site Visitor Child [2]	Source/ Note	Resident Adult [3]	Source/ Note	Resident Child [3]	Source/ Note
Ingestion of Groundwater													
Groundwater Ingestion Rate (IRs)	(L/day)	1	MDEQ	1	MDEQ	1	a	1	a	2	a	1	a
Exposure Frequency (EF)	(days/year)	245	MDEQ	80	[1]	30		30		350		350	
Exposure Duration (ED)	(years)	21	MDEQ	21	MDEQ	30		6		30		6	
Body Weight (BW)	(kg)	70		70		70		15		70		15	
Carcinogen Average Time (AT)	(days)	25,550		25,550		25,550		25,550		25,550		25,550	
Non-carcinogen Averaging Time (AT)	(days)	7665		7665		10950		2190		10950		2190	
Dermal Contact with Groundwater													
Skin Area (SA)	(cm^2)	18,000	b	18,000	b	NA		NA		18,000	b	6600	
Event Frequency (EV)	(events/day)	1	[4]	1	[4]	NA		NA		1		1	
Exposure Frequency (EF)	(days/year)	245	[4]	80	[1]	NA		NA		350		350	
Exposure Duration (ED)	(years)	21	[4]	21	[4]	NA		NA		30		6	
Event Duration (t_{event})	(hr/day)	0.58	b	0.58	b	NA		NA		0.58	b	1	b
Body weight (BW)	(kg)	70		70		NA		NA		70		15	
Carcinogen Averaging Time (AT)	(days)	25,550		25,550		NA		NA		25,550		25,550	
Non-carcinogen Averaging Time (AT)	(days)	7665		7665		NA		NA		10950		2190	
Inhalation of volatiles from groundwater													
Exposure Frequency (EF)	(days/year)	80		NA		NA		NA		350		350	
Exposure Duration (ED)	(years)	21		NA		NA		NA		30		6	
Exposure Time (ET)	(hrs/day)	8		NA		NA		NA		24		24	
Carcinogen averaging time (AT)	(days)	25,550		NA		NA		NA		25,550		25,550	
Non-carcinogen averaging time (AT)	(days)	7665		NA		NA		NA		10950		2190	

(a) Typical drinking water values from the Exposure Factors Handbook (USEPA 1997).

(b) USEPA (2004).

[1] Assumes Forest Area worker on site for 4 months per year.

[2] Site visitors consist of industrial facility users or forest visitors.

[3] Quantitative evaluation of risks to residential receptors will be contingent on completeness of the groundwater pathway from the Raco Site to the residential parcels located more than 1 mile downgradient of the site. Groundwater pathway completeness will be evaluated using RI data on plume delineation and stability.

[4] Set to be equilavent to the ingestion values.

MDEQ - RRD Operational Memorandum No. 1. Technical Support Document - Attachment 3, Part 201 Drinking Water Criteria, Part 213, Tier 1 Drinking Water Risk-Based Screening Levels. December 10, 2004. (MDEQ 2004)

APPENDICES

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

FIELD SAMPLING PLAN

THIS PAGE INTENTIONALLY LEFT BLANK

U.S. Army Corps of Engineers
Louisville District

Appendix A
Final Field Sampling Plan
Remedial Investigation/Feasibility Study
TCE Groundwater Plume
Former Raco Army Airfield and Missile Site
Chippewa County, Michigan
FUDS Property No. E05MI0026

Prepared for
U.S. Army Corps of Engineers
Louisville District
Contract No. W912BV-10-D-2000
Delivery Order CY01

November 2014

Final Field Sampling Plan
Remedial Investigation/Feasibility Study
TCE Groundwater Plume
Former Raco Army Airfield and Missile Site
Chippewa County, Michigan
FUDS Property No. E05M10026

Date Issued – November 2014

Prepared for
U.S. Army Corps of Engineers – Louisville District
600 Martin Luther King Jr. Place
Louisville, Kentucky 40202-2232

Prepared under
Contract No. W912BV-10-D-2000
Delivery Order CY01

THIS PAGE INTENTIONALLY LEFT BLANK

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Notice is hereby given that an Independent Technical Review (ITR) has been conducted that is appropriate to the level of risk and complexity inherent in the project for the Field Sampling Plan for the Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05M10026. During the ITR, compliance with established policy, principles, and procedures was verified. This included review of procedures to be used to create a product that meets the customer's needs, consistent with law and existing U.S. Army Corps of Engineers (USACE) policy.

11/05/14

Larry Copeland
Project Manager

Date

11/05/14

Katherine Sheedy
ITR Team Member

Date

11/10/14

Kim Morris
Quality Assurance Reviewer

Date

Significant concerns and the explanation of the resolution are as follows:

None.

As noted above, all concerns resulting from the independent technical review of the document have been considered.

11/09/14

Paul Lewers
ITR Team Leader, GEO Consultants, LLC

Date

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

LIST OF FIGURES vii
LIST OF TABLES vii

ACRONYMS AND ABBREVIATIONS ix

1. INTRODUCTION 1

2. OBJECTIVES AND SCOPE OF REMEDIAL INVESTIGATION FIELD ACTIVITIES 3

3. FIELD METHODS 5
3.1 UTILITY CLEARANCE 5
3.2 VAP DRILLING STRATEGY AND RATIONALE 6
3.2.1 Plume Axis Projection in Plan View 6
3.2.2 Plume Axis Projection in Cross Section 6
3.2.3 VAP Borehole Placement Strategy 7
3.3 VERTICAL AQUIFER PROFILING 8
3.4 BORING LOGS 9
3.5 SOIL SAMPLING 9
3.6 OVERVIEW OF GROUNDWATER WELL INSTALLATION 10
3.6.1 Permanent Monitoring Well Drilling 10
3.6.2 Permanent Monitoring Well Materials 11
3.6.3 Permanent Monitoring Well Installation 11
3.6.4 Permanent Monitoring Well Identification 13
3.6.5 Permanent Monitoring Well Development 13
3.6.6 Documentation 14
3.6.7 Logs and Monitoring Well Construction Diagrams 14
3.6.8 Monitoring Well Development Record 14
3.6.9 Bladder Pump Installation 15
3.6.10 Observed Water Level Form 15
3.7 GROUNDWATER SURVEY 16
3.8 GROUNDWATER MONITORING WELL SAMPLING EVENTS 16
3.9 PNEUMATIC SLUG TESTING 17
3.10 PIEZOMETER INSTALLATION 18
3.11 GENERAL SAMPLE REQUIREMENTS 18
3.11.1 Sample Containers and Preservation Techniques 18
3.11.2 Field Quality Control Samples 18
3.12 FIELD EQUIPMENT CALIBRATION DOCUMENTATION 19
3.13 PHOTOGRAPHS 20
3.14 DECONTAMINATION PROCEDURES 20
3.14.1 Decontamination Procedures for Drilling and Non-sample Contacting Equipment 20
3.14.2 Decontamination of Sample-Contacting Equipment 20
3.15 CHANGES IN THE FIELD PROGRAM 21

4. SAMPLE CHAIN-OF-CUSTODY/DOCUMENTATION 23
4.1 FIELD LOGBOOK 23
4.2 PHOTOGRAPHS 24
4.3 SAMPLE NUMBERING SYSTEM 24
4.4 SAMPLE DOCUMENTATION 25
4.4.1 Sample Labels 25
4.4.2 Chain-of-Custody Records 25

4.4.3 Custody Seals 26
4.4.4 Sample Packaging and Shipping 26
4.5 DOCUMENTATION PROCEDURES 27
4.5.1 Filing System 27
4.6 CORRECTIONS TO DOCUMENTATION 27

5. INVESTIGATION DERIVED WASTE 29
5.1 GENERAL MANAGEMENT PROCEDURES 29
5.1.1 Containment 29
5.1.2 Labeling 29
5.1.3 Staging 29
5.1.4 Record Keeping 30
5.1.5 Waste Inventory 30
5.2 WASTE HANDLING 30
5.2.1 Disposable Equipment 30
5.2.2 Decontamination Fluids 31
5.2.3 Monitoring Well Purging/Development Fluids 31
5.2.4 Drill Cuttings and Excess Soil Samples 31
5.3 MANAGEMENT AND DISPOSAL OF INVESTIGATION DERIVED WASTE 31
5.3.1 Non-Contaminated Soil or Water 31
5.3.2 Contaminated Soil or Water 31

6. DAILY QUALITY CONTROL REPORTING 33
6.1 SITE INFORMATION 33
6.2 WEATHER CONDITIONS 33
6.3 SUMMARY OF WORK PERFORMED 33
6.4 INSTRUMENT CALIBRATION 33
6.5 HEALTH AND SAFETY REQUIREMENTS 33
6.6 SAMPLE NUMBERS COLLECTED, INCLUDING QUALITY ASSURANCE SAMPLES 33
6.7 DEVIATIONS FROM THE APPROVED WORK PLAN 33
6.8 PROBLEMS ENCOUNTERED/CORRECTIVE ACTION TAKEN 34

7. CORRECTIVE ACTIONS 35

8. REFERENCES 37

LIST OF FIGURES

Figure A-1. Proposed locations for Vertical Aquifer Profile boreholes
Figure A-2. Trichloroethene concentration versus depth profiles from prior Vertical Aquifer Profile (VAP) investigation (GEO 2010) and proposed VAP locations along the extrapolated plume axis
Figure A-3. Drilling strategy flow chart for installation of VAP borings to complete delineation of the TCE plume at the Raco Site

LIST OF TABLES

Table A-1. Summary of Raco Site TCE Plume Remedial Investigation field activities
Table A-2. Monitoring well sampling events and rationale
Table A-3. Project team members and subcontractors
Table A-4. Existing monitoring well construction information
Table A-5. Sample containers, preservation methods, and hold times
Table A-6. Field and Quality Control samples

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
bgs	below ground surface
CELRL	U.S. Army Corps of Engineers, Louisville District
COC	Chain-of-Custody
CSIA	Compound specific isotope analysis
DI	deionized
DO	dissolved oxygen
DoD	Department of Defense
eV	electron volt
FCR	Field Change Request
FOM	Field Operations Manager
FS	Feasibility Study
FSP	Field Sampling Plan
FUDS	Formerly Used Defense Site
GEO	GEO Consultants, LLC
GPS	Global Positioning System
IDW	Investigation-Derived Waste
KBr	Potassium bromide
MBA	Missile Battery Area
MDEQ	Michigan Department of Environmental Quality
mL	milliliter(s)
MS	matrix spike
MSD	matrix spike duplicate
NaCl	Sodium chloride
NTU	nephelometric turbidity units
ORP	Oxidation-Reduction Potential (millivolts)
PID	photoionization detector
PM	Project Manager
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA	Quality Assurance
QC	Quality Control
Raco Site	former Raco Army Airfield and Missile Site
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SSHP	Site-Specific Safety and Health Plan
SU	Standard Unit
TCE	trichloroethene
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
VAP	Vertical Aquifer Profile
VOC	volatile organic compound
VSB	VAP soil boring or borehole
WP	Work Plan
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter

THIS PAGE INTENTIONALLY LEFT BLANK

1. INTRODUCTION

This Field Sampling Plan (FSP) describes field procedures and Quality Control (QC) requirements for a Remedial Investigation (RI)/Feasibility Study (FS) to be conducted at the former Raco Army Airfield and Missile Site (Raco Site) located in Chippewa County, Michigan. This FSP is included as Appendix A to the RI/FS Work Plan (WP). The overall purpose of the RI/FS is to characterize the nature and extent of risks posed by the trichloroethene (TCE) groundwater plume within the Missile Battery Area (MBA) of the Raco Site and to evaluate remedial options. The specific objectives of the RI/FS are (1) to horizontally and vertically delineate the boundary of the TCE groundwater plume to a concentration of 5 micrograms per liter (µg/L), (2) to perform an initial evaluation of the temporal stability of the TCE groundwater plume and the potential for natural attenuation, (3) to conduct a Baseline Risk Assessment to quantify risks from exposure to TCE-impacted groundwater, (4) to identify and evaluate potential remedial alternatives that may be implemented if there are unacceptable risks, and (5) to collect a sufficient quantity of hydrogeologic information and engineering data during the RI field work that will allow an evaluation of remedial alternatives in the FS. The RI/FS, including the field activities described in this FSP, will be performed by GEO Consultants, LLC (GEO) for the U.S. Army Corps of Engineers (USACE), Louisville District (CELRL) under the Department of Defense (DoD) Formerly Used Defense Sites (FUDS) Program. The lead regulatory agency is the Michigan Department of Environmental Quality (MDEQ). GEO will perform the RI field activities under the direction of CELRL.

Site background, previous investigations, and the overall approach to the RI are presented in the RI/FS WP (USACE 2014b). The FSP focuses primarily on procedures and QC for collecting field samples from the Raco Site. The FSP includes the following sections:

- Section 1. Introduction. Describes the organization of the FSP, and lists other associated documents.
- Section 2. Objectives and Scope of RI Field Activities. Lists the field tasks to be performed.
- Section 3. Field Methods. Describes procedures and equipment used to perform the field activities.
- Section 4. Sample Chain-of-Custody (COC)/Documentation. Describes the program to verify COC of environmental samples and the documentation of field sample collection and transfer of samples to analytical laboratories.
- Section 5. Investigation-Derived Waste (IDW). Describes the sorting and disposal of wastes generated during the field activities in order to meet regulatory requirements.
- Section 6. Daily Quality Control Reporting. Describes the documentation of QC activities.
- Section 7. Corrective Actions. Describes when corrective actions will be conducted and how the corrective action results will be documented.
- Section 8. References. Lists references used to support information presented in this document.

Other documents associated with this project include:

- Quality Control Plan (GEO 2013a), which focuses on QC measure for project management and document deliverables.
- Abbreviated Verification Sampling Event Work Plan (WP) (USACE 2014a), which describes activities for an initial sampling of selected monitoring wells to determine the potential extent of lateral plume movement since 2009. In addition, the data obtained will be integrated with results

from earlier investigations to assist in trend analysis activities. This sampling event is scheduled to take place in Spring 2014 prior to finalization of the RI/FS WP (USACE 2014b).

- Site-Specific Safety and Health Plan (SSHP) (GEO 2013b), which describes procedures for protecting workers and the environment during field work, conducted as a part of this RI/FS.
- RI/FS WP (USACE 2014b) which includes site background information, a summary of previous investigations, the overall approach to the RI, and a description of all RI/FS tasks.
- Quality Assurance Project Plan (QAPP), which is based on a Uniform Federal Policy-QAPP and provides a description of QC procedures for the analysis of field samples during RI/FS activities. The QAPP is included as Appendix B to the WP.

2. OBJECTIVES AND SCOPE OF REMEDIAL INVESTIGATION FIELD ACTIVITIES

The objectives of the RI field activities at the Raco Site are (1) to delineate the eastern end of the TCE plume (Figure A-1), which has not been delineated during previous investigations, to a concentration of 5 µg/L using Vertical Aquifer Profile (VAP), (2) to install monitoring wells on the eastern end of the plume, (3) to collect groundwater data from monitoring wells to be combined with historical data to perform an initial evaluation of plume stability as well as estimate risks to current and future receptors, (4) to collect data to support an evaluation of natural attenuation potential and status, and (5) to collect hydrogeologic and engineering data needed for evaluation of remedial alternatives in the FS. The field activities planned for the RI consist of the following (also summarized in Tables A-1 and A-2).

- A Verification Sampling Event[1] of selected existing monitoring wells to determine the potential for plume movement since prior sampling events (2009), and to evaluate whether the VAP drilling strategy (described in Section 3.2 of this FSP) needs to be modified. The data from the Verification Sampling Event will also be used for future trend analysis. An Abbreviated Work Plan (USACE 2014a) was prepared separately from the RI/FS Work Plan in order to expedite the review process and enable sampling in Spring 2014. Groundwater samples will be collected from eight existing wells within and on the margin of the TCE plume at the Raco Site (see Table A-2 for wells to be sampled and Figure A-1 for map of wells). Water levels will be measured to develop a potentiometric surface map. Field water quality parameters will be measured in groundwater and used to document compositional stability prior to sampling. Groundwater samples will be collected and sent to an off-site fixed-base laboratory for analysis of TCE and dechlorination products cis-1,2-dichloroethene (DCE), trans-1,2-DCE and vinyl chloride (VC).
- VAP and Monitoring Well Installation (Summer 2014)
  - VAP boreholes will be advanced using sonic drilling methods and a push-ahead groundwater sampling tool for vertical and lateral delineation of the eastern end of the TCE plume. Groundwater samples will be collected from discrete depths within the VAP boreholes and analyzed for TCE and dechlorination products in an on-site mobile laboratory. The VAP boreholes will be located east of the existing monitoring wells in the previously un-delineated portions of the TCE plume (Figure A-1; refer to Section 3.2 of this FSP for the VAP drilling strategy). Groundwater samples for on-site analysis will be collected from VAP boreholes until the TCE plume is delineated to 5 µg/L (refer to Section 3.2 of this FSP and Worksheet #11 of the QAPP for the field decision process to be used in plume delineation). Continuous soil cores from the VAP boreholes will be collected and logged. In addition, the soil samples will be collected and analyzed for grain size distribution and total organic carbon by off-site fixed-base laboratories.
  - Installation and development of up to six monitoring wells in selected VAP boreholes; well construction details (e.g., depths of 10-foot well screens) will be based on groundwater analysis results obtained from the VAP boreholes. The new monitoring wells will be developed and surveyed.

[1] The Verification Sampling Event is being used to supplement previous data and to verify the plume axis/configuration inferred from previous investigations.

  - If plume delineation has been achieved and less than 2400 lineal feet of borehole (the maximum drilling capacity for this project) have been drilled, nested piezometers may be installed to provide vertical groundwater gradient information that may be useful in the FS.
  - An ecological reconnaissance will also be conducted to evaluate the presence of ecological resources at the site.

- Two rounds of groundwater sampling (Fall 2014 and Spring 2015) in a combination of existing and newly installed monitoring wells (see Table A-2 for list of wells and Figure A-1 for map of existing well locations). Field water quality parameters and water levels will be measured during each event to document compositional stability prior to sampling. Groundwater samples during both events will be sent to an off-site laboratory for analysis of TCE and dechlorination products. During both events, a subset of monitoring wells will be sampled for analysis of the standard Monitored Natural Attenuation (MNA) screening parameters (see Table A-1 for parameter list). In addition to sampling for TCE, dechlorination products and MNA parameters, the following additional activities are planned.
  - During the Fall 2014 sampling event and after groundwater samples have been collected, slug tests will be performed in five monitoring wells to measure hydraulic conductivities.
  - During the Spring 2015 sampling event, a subset of monitoring wells will be sampled for compound-specific isotope analysis (CSIA) and CENSUS analysis. CENSUS analysis is a type of Molecular Biological Tool (MBT) for quantifying microbial organisms capable of degrading TCE and its dechlorination products. Both CSIA and CENSUS analysis will be used to evaluate natural attenuation at the Raco Site TCE plume.

Table A-3 shows project team members and subcontractors anticipated to be on-site during field activities as well as off-site fixed-base laboratories where samples will be sent for analysis.

3. FIELD METHODS

This section describes procedures to be used during field activities at the Raco Site. Any deviation from these procedures should be approved by the GEO Project Manager (PM). Significant deviations will require USACE approval. Deviations will be recorded in the Field Logbook by the Field Operations Manager (FOM).

As noted previously, the procedures to be used during the Verification Sampling Event were described in a separate Work Plan (USACE 2014a) in order to expedite the review process and allow for the sampling event to occur by Spring 2014. This section describes the methods to be used in the various field tasks that will be performed at the Raco Site. These include:

- utility clearance to be performed prior to any drilling at the Raco Site (Section 3.1)
- the VAP drilling strategy which describes how VAP borehole locations will be selected (Section 3.2)
- Groundwater sample collection from the VAP boreholes (Section 3.3)
- logging of VAP boreholes (Section 3.4)
- sampling of soils from the VAP boreholes (Section 3.5)
- groundwater well installation (Section 3.6)
- groundwater survey (Section 3.7)
- groundwater monitoring well sampling (Section 3.8)
- pneumatic slug testing (Section 3.9)
- piezometer installation (Section 3.10)
- general sample requirements (Section 3.11)
- field equipment calibration (Section 3.12)
- photographs (Section 3.13)
- decontamination procedures (Section 3.14)
- changes in the field program (Section 3.15)

3.1 UTILITY CLEARANCE

Prior to fieldwork involving subsurface activities, utilities will be located with the aid of the current property owner, MISS DIG System (Michigan One Call; a utility location service that requires 48 hour notification prior to commencing intrusive activities), and a utility locator subcontractor. If MISS DIG does not cover utilities within the property, the existing site maps from previous reports will be used to estimate the location of utilities. Utility clearance activities, including the ticket number, utilities notified, and the names of all persons granting utility clearance will be recorded. Subsurface activities will not be conducted within 5 feet of any marked underground utilities. In addition, all drilling rigs will be positioned so they are no closer than the height of the drill rig mast (measured laterally) from overhead power lines if present. All other vehicles will remain a minimum lateral distance of 15 feet from overhead utilities to reduce the possibility of arcing. Due to the presence of underground or overhead utilities, it may be necessary to offset boring locations, or modify sampling techniques. This will be done with the approval of the FOM and documented in the field logbook.

3.2 VAP DRILLING STRATEGY AND RATIONALE

3.2.1 Plume Axis Projection in Plan View

Existing groundwater data delineate the western part of a TCE plume that has a width of about 225 feet (Figure A-1). From west to east, VSB-08/MW-26, VSB-03/MW-23, and VSB-10/MW-27 lie in the central part of the plume. The highest concentrations of TCE observed in the plume were measured in these locations; thus, these wells are assumed to represent the approximate location of the plume axis. Constructing a linear fit to these three locations and extrapolating the line to the east represents an estimate of the plume axis that will persist assuming no deviation of plume migration direction occurs. The extrapolated plume axis in Figure A-1 extends 600 feet to the east of VSB10/MW-27, and three potential drilling locations (A, B, and C) are identified, each of which is progressively 200 feet further to the east. Some modification of these locations may occur based on the results of the Verification Sampling Event and decisions made in the field.

Though the plan-view plume orientation in Figure A-1 indicates an easterly groundwater flow and contaminant transport direction, information from the 2005 Michigan Groundwater Inventory Mapping Project suggests that a southeasterly flow direction for groundwater may dominate within a distance of one-mile to the east of the Raco Site. Such a change in groundwater flow direction could result in some southeasterly deviation to the TCE plume. However, only limited potentiometric data were available to support the groundwater contours provided by the Michigan mapping project, and the reliability of this information currently is unknown.

In summary, the plan-view plume trajectory illustrated in Figure A-1 will initially be guiding the drilling strategy for this project.

3.2.2 Plume Axis Projection in Cross Section

The VAP investigation performed in 2009 (GEO 2010) provided evidence for a downward component to TCE transport at the site. The TCE versus depth profiles from the VAP locations along the plume axis (Figure A-2) define a 40-foot thick plume descending linearly to the east at a rate of approximately 1 foot for every 10 feet of lateral distance. This will be considered when delineating the plume to the east of VSB-10/MW-27. Assuming that this rate of descent continues, the TCE profile depths at locations A and B are estimated by constructing a linear fit to results for the three VAP boreholes (VSB-08, VSB-03, and VSB-10) and projecting this line to locations A and B (Figure A-2). Location C will be further to the east along the extrapolated trend, but is not illustrated in Figure A-2. Based on this approach, a VAP borehole at location A would be approximately 170 feet deep with the TCE plume captured from about 130 to 170 feet below ground surface (bgs). At location B the depth would be nearly 200 feet bgs with the TCE plume captured from approximately 155 to 195 feet bgs. For location C the depth would be approximately 220 feet bgs with the TCE captured from approximately180 to 220 feet bgs.

It is unknown whether this rate of descent will continue. Thus, the confidence in the estimated profile depth is high for location A, but uncertainty increases to the east.

Considering this uncertainty, the VAP sampling depth interval will be expanded to increase the probability of bounding the plume. VAP groundwater sampling will begin at least 10 feet above the top of the projected profiles in Figure A-2 (e.g. at 120 feet bgs for location A and 145 feet bgs for location B) to account for a potential decrease in plume descent rate. In addition, if VAP samples at these locations are all non-detects or below 1µg/L, VAP sampling will be extended 30 feet below the bottom of the anticipated VAP profile (e.g. to a total depth of 200 feet bgs at location A and 225 feet bgs at location B)

to account for an increase in plume descent rate. If TCE is not detected in VAP samples obtained at these depths, then it will be assumed that the plume is not present at these locations.

In summary, changes in the lateral and vertical plume trajectory may be encountered during this investigation. Therefore, the initial phase of drilling planned for this project will begin at location A (higher confidence). Subsequent VAP boreholes will be based on results from the completed VAP boreholes, site hydrology, and data from prior investigations. The drilling strategy is described in the following section.

3.2.3 VAP Borehole Placement Strategy

The intent of this plan is to present a dynamic strategy that is flexible to account for new information as it is received in real-time. The strategy is illustrated in the flow chart on Figure A-3.

The first VAP borehole will be placed at location A, 200 feet to the east of VSB10/MW-27 (Figure A-1). As shown in Figure A-2, VAP groundwater sampling at location A will begin at a depth of 120 feet bgs. There are two potential outcomes of the profile data:

1) TCE groundwater concentrations observed at location A may be non-detects or below the 5 µg/L, indicating that the plume boundary is likely located to the west of location A. Following completion of VAP groundwater sampling at location A, two off-axis VAP boreholes would be drilled to provide lateral constraints for the plume boundary (see flow chart in Figure A-3). Because the width of the known part of the TCE plume is approximately 225 feet wide (Figure A-1), these off-axis VAP boreholes would be located approximately 100 to 150 feet to the north and south of location A. If TCE concentrations in both off-axis VAP locations are below 5 µg/L, then the plume has been delineated. One or more of the boreholes may be completed as sentinel well(s) for potential long term monitoring. If TCE concentrations in one of the off-axis VAP locations exceed 5 µg/L, then the estimated plume axis would be revised and used to guide placement of the next VAP borehole.

   Or,

2) TCE concentrations in groundwater samples from location A may exceed 5 µg/L, indicating that the plume boundary lies further to the east. Location B (200 feet down gradient of location A) would be the tentative location of the next borehole. However, depending on the magnitude of TCE concentrations observed at location A, an alternative location (lesser or greater than 200 feet) may be selected for VAP borehole B. If VAP borehole B also indicates that the borehole is located within the TCE plume, then the investigation would continue.

As the locations for additional VAP borings are evaluated, the project team will consider both potential changes in plume depth/rate of descent (Section 3.2.2) and changes in lateral direction (Section 3.2.1) For example, a VAP borehole may be required to the south of the linear plume axis trend to determine if a southeasterly plume deviation is present.

The decision to complete a VAP borehole as a monitoring well will be based on the VAP groundwater data obtained from the borehole. The initial approach is to install monitoring wells in those VAP boreholes where the maximum TCE groundwater concentrations exceed 5µg/L. For VAP boreholes with detectable TCE, but with all concentrations less than 5 µg/L, the decision to complete those boreholes with monitoring wells will be made in the field based on their location and relationship to data from surrounding VAP locations. VAP boreholes with TCE groundwater concentrations that are either all non-detects or are all below less than 1 µg/L) generally will not be completed as monitoring wells.

It should be noted that the objectives of groundwater sampling in VAP boreholes and monitoring wells are not duplicative. Data obtained from VAP boreholes will be used to guide future drilling activities, to delineate the plume to a concentration of 5 µg/L, and to identify boreholes that should be selected for monitoring well installation. Monitoring wells will provide groundwater data that will be used for evaluating plume stability and estimating risk.

3.3 VERTICAL AQUIFER PROFILING

For planning purposes, this project has the flexibility to obtain VAP sampling results from up to approximately 12 VAP borehole locations and a total drilling length of 2400 lineal feet, if that should be necessary. These results will be used to determine the vertical and horizontal extent of the TCE plume and augment plume delineation information obtained from existing monitoring wells. The VAP data will be used to optimally locate and screen the new wells to be installed. A more detailed discussion of the strategy used to guide VAP sampling during this project can be found in Section 3.2. The initial locations of VAP sampling are discussed in Section 3.2.3, but are preliminary in nature and may undergo some changes based on field decisions resulting from near real-time data received from the on-site mobile laboratory.

VAP sampling will be performed using a push-ahead vertical aquifer sampling system. A double-walled casing string (six-inch outer diameter) will be advanced using rotosonic drilling methods. A 2-foot screen point sampler and packer system will be placed inside the drill stem and advanced approximately 5 feet ahead of the drill string (to be determined based on field conditions) to isolate each interval following the soil removal/displacement. A bladder pump will be used to collect groundwater samples to be analyzed for VOCs using low-flow sampling methods. Standard water quality parameters (i.e., temperature, pH, specific conductance, dissolved oxygen [DO], oxidation-reduction potential [ORP] and turbidity) will be monitored using a Hydrolab® Quanta water quality meter and turbidity meter that are calibrated to the manufacturer's guidelines. Parameters will be considered stable when variations in temperature, pH, and specific conductance do not exceed ± 1°C, ± 0.2 Standard Unit (SU), and ± 3%, respectively, for three consecutive readings taken at 3 minute intervals. There are no stabilization criteria for turbidity. Groundwater samples will be analyzed for parameters described in QAPP Worksheet #18 (Appendix B). An on-site mobile laboratory will conduct the analysis for rapid turnaround (approximately 35 minutes). For the initial VAP borehole at location A (Figure A-1), the first groundwater sample will be collected at a depth of 120 feet bgs; this is 10 feet above the estimated depth of the TCE plume at this location (Figure A-2). For the second VAP borehole at location B (Figure A-1), the first groundwater sample will be collected at a depth of 145 feet bgs (Figure A-2) although this may be adjusted depending on the TCE VAP groundwater data from location A. Groundwater samples will be collected in 10 foot intervals at depths where the TCE plume is anticipated until one of the following conditions are met: two subsequent non-detect intervals, or one value below 5 µg/L followed by one non-detect interval are reported by the mobile-laboratory. If TCE is not detected in any groundwater sample from a VAP borehole, then groundwater sampling will terminate 30 feet below the projected depth of the TCE plume at this location (see Figure A-3).

All drilling activities (VAP sampling, soil coring [Section 3.4], and monitoring well installation [Section3.6]) will include assessment of potential air contamination within the breathing zone around the drilling rig. Measurement for the presence of TCE in air will be performed by using a 10.6 electron volt (eV) photoionization detector (PID). Based on information provided in the National Institute for Occupational Safety and Health Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg/npgd0629.html), TCE has been shown to exhibit an ionization potential of 9.45 eV which will allow for detection by the chosen PID.

3.4 BORING LOGS

Soil cores at each VAP borehole will be obtained in 10 foot increments by advancement of the core barrel. The core barrel will be brought to the surface and the core will be extruded into clear plastic bags and prepared for examination and subsequent sampling. A geologic log will be prepared in the field by a geologist using USACE-approved form MRK-55; a sample document form is located in Appendix C of the WP. Unconsolidated materials will be visually classified in accordance with the Unified Soil Classification System. The visual field classification will provide principal and minor soil constituents along with approximate proportions. In addition, the geologist will provide an estimate of the color, moisture content, relative plasticity (for cohesive soils), relative gradation (for cohesion-less soils), density, depositional type, and other visible features (i.e. structure, etc.).

It is not anticipated that bedrock will be encountered during drilling of boreholes; however, if it is, it will be described based on visual observations in accordance with standard geologic nomenclature. This nomenclature includes, but is not limited to: formation name (if known); rock type; relative hardness; density; texture; color; weathering; bedding; fractures, joints, and cavities; and other descriptive features, such as fossils. The depth and volume of any water lost to the subsurface during drilling will be recorded on the boring log.

Stratigraphic/lithologic changes will be identified by a solid horizontal line at the appropriate scale depth on the log. Gradation transitions will be indicated by a dashed horizontal line. All depths will be measured and recorded to the nearest 0.1 feet. The bottom of the hole will be identified on the log by solid double lines from margin to margin with a "bottom of hole" notation.

Additional information to be included on each boring log shall be:

- Depth to groundwater
- Individual sample depth
- Time and location of each sample collected
- Borehole diameter
- Sampler diameter, VAP screen sampling length and slot size
- Drilling/exploration method (i.e., direct push, auger, air rotary)
- Field instrumentation
- Evidence of contamination
- Odors

3.5 SOIL SAMPLING

Up to 24 soil samples will be collected from selected soil borings/depths and will come from sections of the soil boring undisturbed by the VAP sampling. These samples will be analyzed for grain size distribution and total organic carbon. Soil samples will be collected with disposable equipment and transferred into unpreserved sample containers (see Section 3.12.1). Upon receipt of the VAP samples, the locations of soil samples for total organic carbon (TOC) and grain size analysis will be decided based upon the TCE results. Within the TCE plume, one sample will be collected from the depth interval corresponding with the highest TCE groundwater concentration. The second sample will be collected from within the TCE plume, but focusing on a depth interval with a lithology differing from the first sample (if indicated). If the mobile laboratory results do not detect TCE in a borehole, soil sampling

locations may be selected in order to compare TOC and grain size results with those samples collected from with the plume.

Small subsamples of soil will be taken in plastic zip-top bags and labeled. These subsamples will be used to compare intra and inner well analysis for decisions regarding sampling locations.

3.6 OVERVIEW OF GROUNDWATER WELL INSTALLATION

Monitoring wells will be installed in selected VAP boreholes based on field data. Section 3.2 includes discussion of the rationale for identifying VAP boreholes that should be completed as monitoring wells. However, some flexibility will be necessary in the selection process based on available VAP data that have been received from the on-site mobile laboratory.

The monitoring wells for this project will consist of Schedule 40 polyvinyl chloride (PVC) with a 2-inch inner diameter and will be constructed using pre-packed screens. The pre-packed screens are 3.4-inch outer diameter with a 0.010-inch slotted schedule 40 PVC screen, surrounded by 20/40 mesh factory packed sand and mesh (http://geoprobe.com/20-in-id-x-34-in-od-prepacked-screen). The screens in all monitoring wells will be 10-foot in length. The target total depth for well completion and screen positioning will vary by borehole location and will be based on the details of the TCE profile data observed in the VAP borehole. Upon completion of installation, the location of each of the new monitoring wells will be surveyed by a licensed land surveyor in a datum consistent with previous events.

Groundwater samples will be collected from the monitoring wells to be installed as part of this RI/FS. Samples will be taken from the center of the installed screened interval. This depth will be determined based on VAP sampling results.

Before initiating any well borehole drilling, proposed locations will be marked in the field using a Global Positioning System (GPS) with sub-foot accuracy. As noted previously, locations will be offset, as needed, to avoid utilities or other site features that may prevent access to a proposed location.

3.6.1 Permanent Monitoring Well Drilling

Up to six new permanent monitoring wells (MW-28 through MW-33) will be installed in accordance with the Michigan Water Well Construction and Pump Installation Code, Part 127 of the Public Health Code Act 368 of 1978, Water Supply and Sewer Systems, and Administrative Rules. This act is in the process of being revised, and if applicable, all revisions passed prior to field work will be reviewed and followed. Monitoring wells will be installed in boreholes drilled using rotosonic drilling.

The general steps for well borehole drilling are as follows:

- Advance a rotosonic drill with 6 inch casing in 10 foot increments to collect soil cores.
- Continue drilling up to a total depth dictated by collection of VAP data.
- Install monitoring well with one centralizer near the top of the screen; the pre-packed screens will act as centralizers on the well bottom. The screened interval will be placed to intercept the region of the TCE plume with the highest concentration based on VAP data.

No drilling additives beyond potable water will be used without prior approval of the CELRL and MDEQ Project Geologist.

Boring logs will be completed by the field geologist, as described in Section 3.4.

Drilling equipment (drill rods, casing, and any tool entering the borehole) will be cleaned before arriving at the site. After arrival, but prior to fieldwork, drilling equipment (drill rods, casing, and any tool entering the borehole) will be cleaned again at the decontamination area. In addition, all downhole drilling equipment will be decontaminated between sample locations, as described in GEO-TEC-010, *Equipment Cleaning and Decontamination*.

3.6.2 Permanent Monitoring Well Materials

Casing/Screen

Well casings will consist of 2 inch inner diameter Schedule 40 PVC with flush-threaded joints. The pre-packed well screens (2, 5-foot lengths for 10-foot total) will have machine-slotted 0.010 inch openings. Well screens and well casings will be clean and free of foreign matter prior to use. Screen bottoms will be securely fitted with a threaded cap or plug of the same composition as the screen. No solvents or glues will be used for attachment.

Thermal or solvent-welded couplings on PVC casing will not be used. This also applies to thread or slip-joint couplings thermally welded to the casing by the manufacturer or in the field. The tops of all well casings will be covered with expandable well plugs.

Filter Pack, Bentonite, and Grout

Granular filter material that will fill the annular space between the pre-packed screen and drill casing will consist of appropriately sized, pre-washed (clean) silica sand. The filter material will be supplied by the drilling firm and inspected prior to use. The filter pack will be extended approximately 2 feet above the top of the screen. A 2 foot thick bentonite seal of 0.25 inch bentonite pellets will be placed above the filter pack. Bentonite (chips or pellets) used as a seal will not contain organic additives. Bentonite grout will be used to fill the annular space in the well above the bentonite seal. The drill casing will remain in the borehole throughout grouting to ensure that formation collapse will not occur. This is a preferred method of well completion. In monitoring wells completed at the site in 2009, following placement of the bentonite seal borehole, collapse was allowed to occur naturally as was observed in several boreholes. Then the remainder of the boreholes were grouted to the surface with bentonite.

Grout will be composed of bentonite clay grout, consisting of water and commercial bentonite clay (i.e., volclay grout) containing not less than 20% high solids. The mixture shall be in accordance with manufacturer's recommendations to achieve a weight of not less than 9.4 pounds per gallon of mix. Neither additives nor borehole cuttings will be mixed with the grout.

Water Source

A potable water source for rock core drilling will be located before initiation of field sampling and a sample will be collected for VOC analysis. The same source of water will be used throughout the drilling process. Drilling will not be initiated until analysis results have been received and it is verified that the water is not contaminated.

3.6.3 Permanent Monitoring Well Installation

Installation of the monitoring well at a selected VAP borehole will begin after the completion of drilling activities at that location. Once installation has begun, no breaks in the installation process will be made until a bentonite seal has been installed. Well installation should not be interrupted by the end of the driller's work shift, darkness, poor weather conditions, weekends, or holidays.

Temporary casing will remain in place during installation, and removed as well materials are installed. Casing will have an inner diameter sufficient to allow the installation of the prescribed diameter screen and casing, plus annular space to place the filter pack and grout.

Filter Pack Placement

All filter packs will be placed via gravity methods from the bottom of the boring around the pre-packed well screen and approximately 2 feet above the top of the screen. After filter pack placement, vibration will be used to settle the filter pack. If necessary, additional filter material will then be placed to achieve at least 2 feet of filter pack thickness above the well screen. The final depth to the top of the granular filter material will be directly measured by tape, recorded in the field logbook, and shown on the well construction diagram.

Bentonite Seal

Bentonite seals will be composed of commercially-available pellets or chips. Granular bentonite will be used if the seal is set above the water table. Bentonite seal material will be added to the borehole in increments of no more than 2 feet. Potable water will be added to hydrate the bentonite seal if the seal is installed above the water table. Bentonite seals will be approximately 2 feet thick, as directly measured with weighted tape immediately after placement, without allowance for swelling. Bentonite seals will be allowed a period of not less than 1 hours to hydrate before the bentonite grout is tremied into the remainder of the borehole. Granular bentonite will be hydrated according to the manufacturer's instructions.

Bentonite Grout Placement

All grout material prescribed in Section 3.6.2 will be combined in a rigid container and mechanically (not manually) blended to produce a thick, lump-free mixture throughout the mixing vessel. The grout will be placed using a side-discharge tremie pipe located just over the top of the seal. The tremie pipe will be raised slowly while keeping the discharge point of the tremie pipe just below the surface of the grout.

The grouting process will continue in one event until it reaches the ground surface inside the casing. When the grout reaches the surface, the casing will be removed and additional bentonite grout added, to account for the volume of the casing. The borehole will be checked for grout settlement and more grout will be added to fill the annular space to ground surface. This process will be repeated until firm grout remains at the ground surface. Incremental quantities of grout added in this manner will be recorded on the well construction diagram.

Surface Completion

When the grout has cured properly, a 3 foot by 3 foot, or larger, concrete pad and a protective cover will be placed around the monitoring well. The minimum pad thickness will be 4 inches at the edges. The top of the concrete pad will slope gently away from the protective cover, but will be constructed nearly flush with the surrounding surface.

Approximately 2.5 feet of the protective casing will extend above and below the ground surface. Two weep holes, 0.125 inch diameter, will be drilled in the cover approximately 1 inch above the concrete pad. The space between the riser pipe and the protective casing will be filled with clean sand or gravel.

The outside of the cover will be painted with a paintbrush. Paint color will be coordinated to match the previously installed wells. Painting will be completed and the paint dry prior to initial sampling of the

well. If temperatures are outside of the recommended range for painting, a rough coat of paint will be applied and touched up during a subsequent sampling event when temperatures are more favorable.

Four bumper posts will be installed around each monitoring well (outside of the concrete pad). Each post will be radially located 3 to 4 feet from the well and placed approximately 2 feet bgs. The top of the bumper posts will be installed higher than the top of the protective casing. The posts will be filled with sand or concrete, and after installation, painted using a paintbrush (color consistent with monitoring well protective casing). The paint must be dry before the monitoring well is sampled.

3.6.4 Permanent Monitoring Well Identification

Each monitoring well will be surveyed by a Michigan-licensed professional surveyor, and designated with an identification number affixed or painted on the outside of the protective casing. The concrete pad will be completed by permanently affixing a domed survey marker into the pad. The marker should be composed of brass, bronze, or aluminum alloy and will include the monitoring well identification number.

3.6.5 Permanent Monitoring Well Development

Newly installed monitoring wells will not be developed until 48 hours after grout installation. The wells will be developed by surging and pumping in alternating cycles. Surging will be performed using a surge block in 2 to 3 foot increments, followed by pumping until stable water quality parameters (pH, temperature, and specific conductance) are achieved. Initially, the lowermost part of the well screen will be surged. The pump will then be raised above the previously surged zone in successive 2 foot increments and the process repeated until the entire screen interval is developed. Upon completion of surging and pumping, the submersible purging pump will be lowered to the bottom of the well to remove any sediment that may accumulate during the development process. Well development fluids will be disposed of, as described in Section 5.

Standard water quality parameters (i.e., temperature, pH, specific conductance, DO, ORP and turbidity) will be monitored using a Hydrolab® Quanta water quality meter and turbidity meter that are calibrated to the manufacturer's guidelines.

After 3 well volumes have been removed (if well yield is extremely low, after 3 hours of purging the well at full capacity), water quality parameters will be measured in 3 minute increments until stable in 3 successive readings. The criteria for stability will be:

- pH varies ± 0.2 SU
- temperature varies ± 1°C
- specific conductance varies ±3%
- Although a goal of turbidity less than or equal to 10 nephelometric turbidity units (NTUs) will be set, it is unlikely that this goal can be met due to the natural characteristics of the groundwater observed at the site during previous sampling.

If water quality parameters do not stabilize to meet the above conditions, well development will be considered complete when 10 well volumes of water have been removed.

If well recharge is so slow that the required volume of water cannot be removed during development, the GEO PM will be informed and the CELRL Project Geologist will be contacted for guidance. The GEO PM also will be contacted if, after the required volume of water is removed, the water remains above 50 NTU, or excessive sediment remains in the well.

For each well, a 1 pint sample of the last water to be removed during development will be placed in a clear glass jar and photographed as described in Section 3.13.

3.6.6 Documentation

All field documentation forms can be found in Appendix C of the WP.

3.6.7 Logs and Monitoring Well Construction Diagrams

Boring logs will be completed, as described in Section 3.4. All pertinent information, including sampling time, depth, description, and analyses will be included on the boring log.

Each newly installed monitoring well will be depicted on a monitoring well construction diagram. Diagrams will be prepared by a geologist or geological engineer that is present during well installation. Depths will be verified during installation by measurement with a weighted tape. This diagram will show each component and their respective vertical positions including, but not limited to, the following:

- Well location (horizontal) to the nearest 0.1 foot
- Total measured depth of monitoring well and boring, filter pack, and bentonite seal to the nearest 0.01 foot
- Boring diameter
- Date and time of construction
- Any difficulties setting casing or completing boring
- Volume of water lost to subsurface during well installation
- Type and diameter of well surface casing
- Screened interval
- Screen length, material, slot size, and type (pre-packed)
- Method of grout placement, including the proportions of the materials used
- Depth of protective casing base bgs
- Concrete pad dimensions
- Water level with date and time of measurement
- Any deviation from the WP

3.6.8 Monitoring Well Development Record

Records of well development will be maintained on Well Development Forms for each newly installed well. An example of this form is in Appendix C of the WP. Well development forms will contain the following information:

- Project name and number
- Monitoring well number
- Date and time of well installation
- Specific well information, including open borehole interval and well elevations

- Well development method, including type and size of equipment used
- Quantity of fluid lost to borehole during drilling and well installation
- Quantity of fluid removed during development
- Date and time of measurement of field parameters
- Depth to water
- Total depth
- Time intervals for surging
- Time intervals for pumping

The following information will be recorded on the Well Development Form after removal of each borehole volume of fluid:

- Fluid removed in gallons
- Temperature
- pH
- Specific conductance
- Turbidity
- Physical characteristics of water, including clarity, color, particulates, and odor
- DO

DO will be measured for each borehole volume after the turbidity has dropped to less than 200 NTUs, if achievable.

3.6.9 Bladder Pump Installation

Following well development, a dedicated bladder pump will be installed in the majority of the newly installed wells. Wells that will be used for slug tests will not have bladder pumps installed at this time. The bladder pumps will be installed so that the pumping level is located at the approximate center of the screened interval. Sufficient tubing will be installed on each pump so that several feet of additional tubing is available at the surface to be connected to the pump controller.

3.6.10 Observed Water Level Form

Observed Water Level Forms will be completed for each new and existing well installed at the site to maintain records of water levels. Water levels during drilling, development, and purging and sampling activities will be recorded on the form. The following information will be noted on the Observed Water Level Form:

- Project name and number
- Monitoring well number
- Ground surface and top of pipe elevation (after completion of survey)
- Specific well information
- Date and time of water level measurement

- Name of field person who collected measurement
- Depth to water
- Measured total depth of well

An Observed Water Level Form can be found in Appendix C of the WP.

3.7 GROUNDWATER SURVEY

Following the completion of the new monitoring wells, a surveyor will determine the positions of new monitoring wells to the nearest 0.1 feet horizontal and tied into the State Plane System. Top of casing elevations, marked by a notch in the top of the riser pipes, will be surveyed to the nearest 0.01 feet, relative to mean sea level.

At least 24 hours after well development, groundwater elevations from all wells will be collected within a single day and recorded in the field from existing and newly installed wells for development of a site potentiometric surface map. All fluid level equipment will be decontaminated. Water levels will be taken in accordance with GEO-TEC-014, *Water Level Measurements (Well)*. Water levels will be measured and reported to the nearest 0.01 feet. Water level measurements should be made from the notch in the well casing, if available. The measurement will be taken from the northern side of the well casing, if a notch cannot be identified.

During groundwater sampling events, groundwater elevations will be taken prior to sampling from all wells and recorded for the development of a site potentiometric surface map.

3.8 GROUNDWATER MONITORING WELL SAMPLING EVENTS

Groundwater sampling activities will occur in three phases as listed below and summarized in Table A-1 and A-2 (refer to Section 3.8 of the RI/FS Work Plan for a discussion of how these monitoring wells were selected):

- A Verification Sampling Event of eight, selected, existing monitoring wells in the Spring 2014. A separate Work Plan (USACE 2014a) was prepared for this event to expedite review and enable sampling by Spring 2014.
- An initial round of sampling of 14 monitoring wells (existing and to be installed) in the Fall of 2014. This round will occur at least 2 weeks after the completion of well development on the newly installed monitoring wells.
- A second round of sampling of 14 monitoring wells (existing and to be installed) in the Spring of 2015 (approximately 6 months after the completion of the first round of sampling).

The construction information for the existing monitoring wells is shown in Table A-4 (Table 1 of the RI/FS Work Plan contains well construction data for all wells within the Raco Site). Groundwater samples from monitoring wells will be collected using dedicated bladder pumps and tubing. A low-flow sampling protocol will be followed to reduce the amount of IDW and to collect samples that are more representative of groundwater. The general steps for collecting groundwater will be as follows:

- Open and allow all wells to vent before taking static water level measurements. The wells are expected to reach equilibrium quickly based on previous hydraulic testing results.
- Measure the static water level in all on-site wells prior to initiation of sampling following GEO-TEC-014, *Water Level Measurements (Well)*.

- At each monitoring well, the dedicated Teflon-lined polyethylene tubing will be attached to the bladder pump control box. The static water level and tubing diameter will be used to calculate the required purge volumes. Water inside the tubing will be purged. Upon completion of vacating the stagnant water in the tubing, parameter stabilization measurements will commence.
- Standard water quality parameters (i.e., temperature, pH, specific conductance, turbidity) will be monitored until stable, using a Hydrolab® Quanta water quality meter and separate turbidity meter that are calibrated to the manufacturer's guidelines. Parameters will be considered stable when variations in temperature, pH, and specific conductance do not exceed ± 1°C, ± 0.2 SU, and ± 3%, respectively, for three consecutive readings at three minute intervals. All data will be recorded in the field logbook. DO and ORP will also be monitored by the Hydrolab® Quanta water quality meter but not used for stability assessment.
- After parameter stabilization, the pump discharge line will be removed from the flow-through cell prior to collection of water samples.
- Samples will be collected for parameters indicated in Tables A-1 and A-2.

3.9 PNEUMATIC SLUG TESTING

Slug testing will be completed on five monitoring wells to estimate hydraulic conductivity of the aquifer intercepted by the screened intervals of the tested wells. Monitoring well locations chosen for pneumatic slug testing will be determined in the field based on lithologic log information available for existing and new monitoring wells. Transducers will be deployed in each well near the top of the screened interval to monitor the pressure/water level before, during, and after the test. A pneumatic manifold will be used to seal the well head. An air compressor will be used to pressurize the system to get a water level decrease of approximately 10 feet. Once the pressure readings on the transducer have stabilized, the pressure will be released and the water level recovery will be monitored as shown in Diagram 3. Pneumatic slug testing will take place following the first round of groundwater sampling.

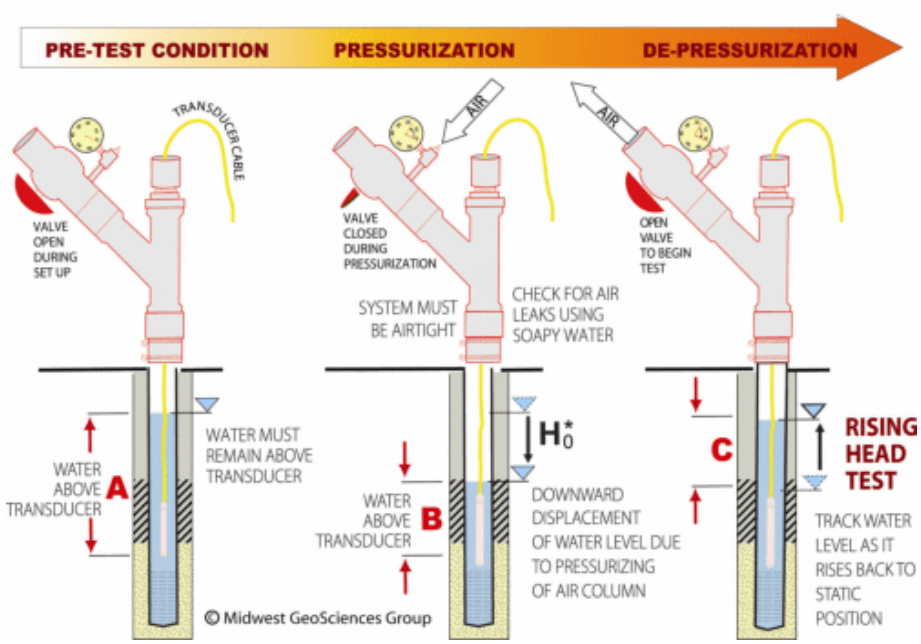


Diagram 1. Pneumatic Slug Test (www.midwestgeo.com)

3.10 PIEZOMETER INSTALLATION

Figure A-2 illustrates that the TCE profiles for VSB-08, VSB-03, and VSB-10 define a linear plume gradient descending toward the east. This trend suggests that there is a downward vertical groundwater potentiometric gradient across the site that drives the TCE plume to greater depths at progressively more easterly locations. The descent of the TCE plume to the east is consistent with surficial characteristics of the region. The Raco Site is located on a plateau of glacial outwash at an elevation of 900 feet above mean sea level (amsl). The ground elevation drops off relatively quickly to the east and within about one mile at an elevation of approximately 850 feet amsl discharge of groundwater occurs and feeds streams draining to the east as well as some wetlands (see Figure 5 of the RI/FS Work Plan). These characteristics suggest a downward groundwater flow in the upland area where the TCE plume at the MBA of the Raco Site is located.

The drilling capacity for this project has been set to a maximum of 2400 lineal feet. If plume delineation has been achieved before this maximum drilling capacity is reached, a VAP borehole location will be selected for installation of three piezometers nested within a single borehole and completed at 50, 100, and 300 feet bgs, respectively. The location will be determined in the field based on water level and groundwater TCE data that are available at the time. If the VAP borehole is located within the boundary of the TCE plume, then groundwater samples will be collected and analyzed by the mobile field laboratory during the drilling. Although the engineering data obtained from the piezometers may be useful for evaluating remedial alternatives in the FS, piezometer installation will be dependent on availability of drilling capacity after the TCE plume has been delineated. Plume delineation is a primary objective of the RI/FS whereas characterizing the vertical gradient using piezometers is not considered a critical element of this project.

3.11 GENERAL SAMPLE REQUIREMENTS

3.11.1 Sample Containers and Preservation Techniques

Table A-5 summarizes sample containers, preservation techniques, and sample holding times for the analytical methods.

3.11.2 Field Quality Control Samples

QC samples will be collected, as summarized in Table A-6 and described below. QC sample collection information will be documented on field data sheets. The primary laboratory to be used for this project will be CT Laboratories – Baraboo, Wisconsin.

Field Duplicates. One field duplicate sample for a specific matrix/analysis will be collected for every 10 samples for VOC analysis. The field duplicate sample will be identified with a unique sample identification number, and labeled as described in Section 4.3. No field duplicate samples will be collected for MNA parameters, CSIA, or CENSUS analysis of groundwater samples. Field duplicates will be collected for total organic carbon analysis of soil samples. No field duplicates will be collected for soil grain size analysis.

Matrix Spikes and Matrix Spike Duplicates. One matrix spike (MS)/matrix spike duplicate (MSD) pair will be collected for every 20 samples for a specific matrix/analysis. The COC record will be completed to notify the laboratory that a MS/MSD should be completed in addition to the original sample. Samples for MS/MSD analyses will be collected for VOCs in groundwater from the permanent monitoring wells. No MS/MSD samples will be collected for MNA parameters, CSIA, or CENSUS

analysis of groundwater samples. No MS/MSD samples will be collected for total organic carbon analysis of soils. MS/MSDs are not applicable to soil grain size analysis.

Split Samples. One split sample will be collected for every 20 groundwater samples for analysis of TCE and dechlorination products. The split sample will be collected in concert with an original sample and will be sent to a laboratory of CELRL choosing for the same analysis as the original sample. The split sample will be identified with a unique sample identification number to distinguish the split sample from original and field duplicate samples and labeled, as described in Section 4.3. Split samples will be collected for VOCs in VAP groundwater samples and during the first and second round of groundwater sampling. Split samples will also be collected and analyzed during the Verification Sampling Event (USACE 2014a).

Equipment Rinseate Blanks. One equipment rinseate blank set will be collected per day of field collection of original samples. To prepare an equipment rinseate blank, deionized (DI) water will be flushed over sampling equipment and collected for analysis. The rinseate will be placed directly into the containers specified for groundwater samples. The equipment rinseate blank will be analyzed for the same parameters as the original sample and shipped to the primary laboratory for analysis.

Trip Blanks. Trip blanks will consist of pre-filled, 40 milliliter (mL) vials of DI water. A trip blank will be included in every cooler shipped to laboratories containing samples for VOC analysis.

3.12 FIELD EQUIPMENT CALIBRATION DOCUMENTATION

Field measurement instruments must be calibrated according to the manufacturer's instructions prior to the commencement of the day's activities with the exception of the spectrophotometer for ferrous iron analysis for which the instrument's internal calibration will be used. Calibration information shall be documented in the designated field logbook. Information to be recorded includes the date, the operator, and the calibration standards (concentration, manufacturer, lot number, expiration date, etc.). Project personnel using measuring equipment or instruments in the field shall be trained in the calibration and usage of the equipment, and are personally responsible for ensuring that the equipment has been properly calibrated prior to its use. All field instruments must undergo response verification checks at the end of the day's activities and at any other time that the user suspects or detects anomalies in the data being generated. Previous water quality data are available for the existing monitoring wells and would be used by the field crew to determine if field data appear anomalous. At any time if the data do not appear relatively consistent with previous sampling activities, response verification checks would be completed. The checks consist of exposing the instrument to a known source of analyte (e.g., a calibration solution) or absorbance (e.g., a gel standard for the spectrophotometer) and verifying a response. If an unacceptable instrument response is obtained during the check (i.e., not within specifications), the measurements bracketed by the initial calibration or the last acceptable response verification result and the unacceptable verification response check shall be qualified as suspect in the data sheets, and the problem documented in the site logbook. Any field equipment found to be out of calibration shall be recalibrated. When instrumentation is found to be out of calibration or damaged, an evaluation shall be made to ascertain the validity of previous test results since the last calibration check. If it is necessary to ensure the acceptability of suspect items, the originally required tests shall be repeated (if possible) using properly calibrated equipment. Any field instrument consistently found to be out of calibration shall be repaired or replaced.

Field equipment shall be maintained at its proper functional status in accordance to manufacturer manual specifications. A check of the equipment shall be performed before field activities begin, and any potential spare parts (e.g., batteries, connectors, etc.) and maintenance tools will be brought on-site, to minimize equipment downtime during the field activities. Visual checks of the equipment will be conducted on a daily basis. Routine preventive maintenance shall be performed to ensure proper operation

of the equipment. Any maintenance performed on field equipment will be documented on instrument calibration and maintenance forms, or in a designated field logbook, and shall be undertaken only by personnel who have the appropriate skills and/or training in the type of maintenance required.

3.13 PHOTOGRAPHS

All existing monitoring wells in the MBA will be photographed at the start of the project. Upon completion of construction of each new monitoring well, a photograph of the well also will be taken. The photograph will show the monitoring well designation number, the condition of the monitoring well, and the location of the well in relation to its surroundings.

Sample points will be documented using photographs. These photographs may include the soil borings, the sample itself, collection activities, and surrounding areas. A photograph will also be taken of a sample of water from each monitoring well after development. For each well, a 1 pint sample of the last water to be removed during development will be placed in a clear glass jar and labeled with the monitoring well number, date, and turbidity measurement of the sample. No preservation of these samples is required. Each sample will be agitated and immediately photographed close-up with a digital camera using a back-lit setup to show water clarity. Disposal of the water samples will be in the same manner as development water disposal.

3.14 DECONTAMINATION PROCEDURES

3.14.1 Decontamination Procedures for Drilling and Non-sample Contacting Equipment

A single decontamination area will be set up by the drill crew prior to drilling in an area approved by the FOM and land owner. A pad will be constructed in such a manner that decontamination fluids will be collected.

Drilling equipment, tools, and non-factory packaged well construction materials will be decontaminated by the drill crew prior to drilling operations and between borings. Drill rods will be cleaned using a high pressure, hot water sprayer or steam cleaning machine and laboratory grade detergent. The exposed exterior and interior surfaces of the drilling and sampling equipment will be cleaned until visible soil and other debris are removed.

The decontamination area will be approved by the FOM prior to use. Waste generated during the decontamination procedures will be managed, as described in Section 5.

3.14.2 Decontamination of Sample-Contacting Equipment

Non-disposable and non-dedicated tools, which contact the sample, will be decontaminated prior to the collection of each sample. This sampling equipment includes, but is not limited to, sample spoons, knives, bowls, and bailers.

Sampling equipment will be decontaminated according to the following procedure:

- Fill a nonmetallic wash tub to a depth of about 6 inches with potable water. Mix a detergent solution in the tub. The solution shall consist of 1 tablespoon of non-phosphate laboratory grade detergent (e.g. Liquinox®) per gallon of water.
- Scrub all sampling equipment with a stiff-bristled brush.
- Transfer the equipment to another wash tub that is partially filled with potable water and rinse. This tub will be used to collect all rinses.

- Rinse the sampling equipment with potable water.
- Rinse the equipment with DI water.
- Place the equipment on clean plastic and allow it to air dry.

Store the equipment, covered with plastic or aluminum foil, upon the completion of decontamination. Down-hole drilling tools used for sampling may alternatively be decontaminated with the use of high-pressure hot water.

Retain decontamination fluids for disposal, as described in Section 5.2.2.

3.15 CHANGES IN THE FIELD PROGRAM

During the field investigation, all changes to the survey and/or sampling program must be documented on a Field Change Request (FCR) form. FCRs will be numbered serially, starting with the number "01". Copies of the FCR must be maintained by the field team and by the PM in the project management files. FCR forms will include an explanation of the problem and a proposed solution. Each FCR must be approved by the GEO PM (or designee) and the CELRL PM (or designee) before implementation of the change occurs. At a minimum, copies of the approved FCR form will be distributed to USACE, MDEQ, and the following GEO personnel: the PM and the Project QC Manager, and other field staff as applicable, and the project files. The PM will be responsible for the controlling, tracking, implementing, and distributing of all identified changes/FCR forms.

THIS PAGE INTENTIONALLY LEFT BLANK

4. SAMPLE CHAIN-OF-CUSTODY/DOCUMENTATION

4.1 FIELD LOGBOOK

Information pertinent to the investigation will be recorded in a bound logbook with consecutively numbered water-resistant pages according to GEO-TEC-005 *Logbooks*. The field personnel responsible for the entries will sign and date each entry or page. All logbook entries will be made in indelible ink. The time and date of each entry will be noted in the logbook.

The logbook should contain sufficient information so that sampling activities can be reconstructed. Logbooks will be kept in the field personnel's possession or a secure place during the investigation. Following the investigation, logbooks will become part of the project file. The following list contains typical field logbook entries:

- Date
- Weather conditions
- Names of field personnel
- Calibration record of field equipment
- Name and location of area of investigation
- Location of sample (may include a sketch)
- Type of sample (soil, groundwater, sediment, etc.)
- Time (military) of sample collection
- Sample identification number
- Interval and depth of sample
- Field screening results
- Sample collection procedure/equipment
- Sample description (color, odor, etc.)
- Field observations of sampling event
- Parameters requested for analyses
- Field measurements
- Duplicate sample information
- Equipment decontamination procedures
- Sample shipment information
- Number assigned COC
- Monitoring well number
- Water level and total depth measurements with technique
- Well purge equipment and technique
- Purge volume and time

- Field measurements for each well volume of groundwater removed
- Sample withdrawal procedure/equipment
- Management of IDW

4.2 PHOTOGRAPHS

Sample points will be documented using photographs. These photographs may include the soil borings, the sample itself, collection activities, and surrounding areas. Photographs taken to document sampling points will be referenced by a GPS.

4.3 SAMPLE NUMBERING SYSTEM

All samples will be identified with a unique sample number. Sample numbers will be used on sample labels, COCs, field logbooks, and all other applicable documentation. The sample numbering system will be comprised of the location (VSB11, MW-27, etc.), sample location (as shown in the maps in Figure A-1), sample depth (for soil and VAP samples), and sampling date.

Example sample IDs include:

- VSB11-8090-091314 (Sample taken from VSB11, from a depth range of 80 to 90 feet bgs, taken on September 13, 2014) – Applicable to soil and VAP samples
- MW27-091314 (Sample taken from MW-27 on September 13, 2014) – Applicable to groundwater monitoring well samples

Sample numbers for field duplicates will be labeled "DUP-date-#", where "#" is a designation of the number of duplicates in order for that day. For example, the first sample taken on a particular date would be labeled "DUP-date-1", the second "DUP-date-2", etc. Sample times for duplicate samples should be recorded as 12:00 to not reveal the identity of the duplicated sample by deduction from sampling times. Actual identity, sample time, and location of duplicate samples will be recorded in the field logbook.

- DUP-091314-1 (The first duplicate taken on September 13, 2014)
- DUP-091314-2 (The second duplicate taken on September 13, 2014)

Sample numbers for equipment blanks will consist of "EB," a designator code to indicate which sampling equipment it was collected for (e.g., "VAP" for VAP samples), and the date when the equipment blank was collected. No equipment blanks are anticipated for groundwater samples collected from monitoring wells.

- EB-VAP-091314 (Equipment blank taken during VAP sampling on September 13, 2014)

Trip blanks will accompany each cooler shipped to the laboratory containing samples for VOC analyses. The trip blanks will be labeled with "TB," followed by the date. If more than one cooler in a shipment contains samples for VOC analyses, then the trip blank number will be followed by a consecutive alphabetic or numeric suffix.

- TB-091314-1 (Trip Blank shipped on September 13, 2014, first cooler of day)
- TB-091314-2 (Trip Blank shipped on September 13, 2014, second cooler of day)

4.4 SAMPLE DOCUMENTATION

4.4.1 Sample Labels

Each sample collected and transferred to a laboratory for analysis will be identified with a sample label containing specific information regarding the sample. The labels and ink will be waterproof. Each completed sample identification label will be securely fastened to the sample container. Complete sample labels will include the following information:

- Date
- Time (military) of sample collection
- Type of analyses requested
- Sample number
- Sample collection depth (for subsurface soil samples)
- Location of sample collection
- Type of preservative
- Initial(s) of sampler(s)

4.4.2 Chain-of-Custody Records

The COC will be employed as physical evidence of sample custody in accordance with GEO-TEC-006, *Sample Chain of Custody*. Field personnel will initiate a COC with acquisition of the sample. Transferred possession of samples will be recorded on the COC by both the person relinquishing and the person receiving the samples by signing, dating, and noting the time the transfer of possession takes place.

A COC will be prepared for each cooler shipped or transported to the laboratory (both on-site and off-site). All samples packed in the cooler will be recorded on the COC accompanying that cooler.

The following information is to be included on the COC:

- Sample numbers
- Signature(s) of field personnel
- Date of collection
- Time (military) of collection
- Sample type (solid, etc.)
- Number of containers
- Parameters requested for analysis
- Signature of person(s) involved in the chain of possession
- Inclusive dates and times of possession
- Notations regarding the possible compromise of sample integrity

The completed COC will be enclosed in a plastic bag and placed in the cooler, above the iced samples.

4.4.3 Custody Seals

From the time the coolers are packed until they are opened in the laboratory, custody seals will be used to preserve the integrity of the cooler during shipment. Custody seals must be attached so that it is necessary to break the seals to open the cooler. The custody seals will be covered with clear tape. All samples will be shipped overnight to the laboratory in coolers sealed on two opposite sides, with custody seals. As long as the COCs are sealed inside the sample cooler, and custody seals remain intact, commercial carriers are not required to sign the custody form.

4.4.4 Sample Packaging and Shipping

Samples will be packed and shipped according to requirements for low hazard level samples. All samples will be shipped within 24 hours of collection.

The following procedure will be used to pack samples being shipped by overnight carrier.

- Place each sample bottle in an individual, sealable plastic bag. All VOC vials for the same sample shall be placed in the same plastic bag. Trip blanks will be packed in the same manner as the VOC samples.
- Remove as much air as possible from the plastic bag prior to sealing.
- Tape drains shut on shipping cooler with duct tape.
- Place inert packing material, such as bubble wrap, in the bottom of the cooler.
- Place the sample containers in the cooler in an upright position so they do not touch. Group all aqueous VOC samples into one common cooler, if possible. Place one trip blank in each cooler containing aqueous VOC samples. Place one temperature blank in each cooler.
- Add sufficient ice, double packaged in sealable plastic bags, to keep samples approximately 4 degrees Celsius.
- Fill the remaining volume of the cooler with packing material.
- Sign the COC and indicate the time and date the cooler is sealed or relinquished to an overnight delivery service. Record the time in the field logbook.
- Copy the completed COCs. Seal the original COC and cooler receipt form in a large, sealable, plastic bag and placed inside of the cooler above the samples.
- Close the lid and latch the cooler. Tape the cooler shut on both ends, wrap the cooler several times with the strapping tape. Do not cover any labels.
- Attach a completed shipping label to the top of the cooler. Coolers will be shipped to the respective laboratories performing the analyses shown in Table A-6. Shipping addresses and points of contact can be found in Table A-3.
- Place the airbill with the laboratory address on top of the cooler.
- Put "This Side Up" labels on both ends of cooler lid and up arrow symbols on all four sides of the cooler.
- Affix signed and dated custody seals over lid openings (front right and back left corners of the cooler). Cover the seals with clear, plastic tape.

4.5 DOCUMENTATION PROCEDURES

4.5.1 Filing System

A filing system consisting of an on-site file, record data file, and a project file will be established to organize and maintain data. The on-site file will be maintained at the site under the direction of the FOM. The file will consist of copies of record documents generated in the field. The file contents will include, but will not be limited to the following:

- Field logbooks
- WP and appendices (this FSP, QAPP, and supporting documentation)
- SSHP
- Contract specifications
- Subcontractor agreements
- Material Safety Data Sheets for chemicals used on the site
- Field instrument operating manuals (PID, Hydrolab®)
- List of important phone numbers
- Shipping forms
- Equipment calibration records

The project data file will be maintained in the PM's office. It will include, but will not be limited to the following:

- Chemical laboratory data file including copies of the COCs, Cooler Receipt Forms, requests for chemical analysis, and the laboratory results
- Field data file including boring log originals, field logbooks, field transmittals, and photographs
- Project-related correspondence and meeting notes

In addition to these items, the on-site file will also be added to the project data file as the field work is completed.

4.6 CORRECTIONS TO DOCUMENTATION

Original recorded data will be written with indelible ink. Accountable serialized documents will not be destroyed or thrown away, even if they are illegible or contain inaccuracies that require a replacement document. Errors will be corrected by marking a line through the error, entering the correct information, and initialing and dating the correction. The erroneous information will not be obliterated. Any subsequent error discovered later on an accountable document will be corrected, initialed, and dated by the person who made the entry.

THIS PAGE INTENTIONALLY LEFT BLANK

5. INVESTIGATION DERIVED WASTE

5.1 GENERAL MANAGEMENT PROCEDURES

Soil cuttings generated from monitoring well installation and soil borings will be contained in roll-off bins. Once analytical results from the soil borings are received, judgment as to whether soils are disposed of on-site or off-site will be made. During the previous investigations (GEO 2008, 2010), IDW was classified as F-listed waste. This may have been an incorrect classification since there is currently no historical information regarding operations at the Raco MBA to require an F-listing of the IDW. There is an ongoing search for historical records. If historical information that supports an F-listing is not found, the appropriateness of classifying the IDW from the RI as F-listed waste will be evaluated and may be revised.

Purge water generated from monitoring well development and sampling activities, as well as drilling fluids, will be stored (in 55-gallon drums or polyethylene tanks) and sampled. If sample analysis from the site inspection indicates water is suitable for discharge (Section 5.3.1), it will be discharged to the ground surface away from the well and any natural drainage ways. If the analysis indicates the water is contaminated, it will be disposed of off-site at a proper treatment facility.

Personal protective equipment such as gloves, coveralls, etc. will be disposed as non-hazardous solid waste.

5.1.1 Containment

IDW will be collected in containers in good condition. IDW that will be moved from the site as hazardous or special waste will be placed in Department of Transportation-approved storage containers that are acceptable for transporting hazardous waste. These containers are normally made of steel construction, but may be made of other materials depending on the waste to be contained. Storage and shipping containers for hazardous waste will conform to hazardous materials regulations.

5.1.2 Labeling

Waste containers will be clearly labeled using an indelible marker, paint, and/or preprinted label. The label will indicate the type of materials contained and the date the material was originally accumulated. The labels will also include “USACE Louisville District,” a contact name, and phone number.

5.1.3 Staging

IDW containers will be staged at a pre-designated location (IDW staging area) until arrangements for disposal can be made. The containers will be segregated according to contents. Solids will be staged separately from free liquids. Secondary containment will be provided for all containers that hold free liquids. Secondary containment will consist of plastic sheeting with a minimum thickness of 6 one-thousands of an inch (6 mil) on a level and firm ground surface. The secondary containment area will be provided with 6 inch berms (minimum) to contain, at a minimum, the volume of the largest container of IDW in the event of a spill. The berms can be constructed of corrugated plastic tubing, lumber, bermed earth, and/or sand. The IDW staging area will have restricted access to minimize the possibility for unauthorized entry.

5.1.4 Record Keeping

Record keeping associated with IDW management will include the field logbook, chemical analytical results, and a drum inventory. Records will be maintained as part of the project files.

5.1.5 Waste Inventory

An inventory of waste containers used for IDW will be maintained on waste item container log forms. Waste item container log forms will be updated throughout all field activities to allow for inspection of waste containers and for determining the number and contents of waste containers. The following information will be noted on the log form:

- Project name and number
- Waste container number
- Area of Interest from which contents were collected
- Location (sampling point, boring number)
- Date waste container was filled
- Contents
- Waste container condition

The waste item container log forms will be completed on a daily basis as the waste containers are filled. Periodic inspections of the secondary containment area during field activities will be noted in the field logbook. An example of the form is shown in Appendix C of the WP.

5.2 WASTE HANDLING

The following types of wastes will be generated as a result of field investigations and related activities:

- Disposable equipment (personal protective clothing, sampling equipment, etc.)
- Decontamination fluids
- Drilling fluids
- Development fluids
- Drill Cuttings

5.2.1 Disposable Equipment

Disposable equipment is expected to generate the smallest quantity of waste produced from the investigations.

The disposable equipment (used gloves, paper towels, grout bags, etc.) will be placed in plastic trash bags and disposed of as municipal solid waste. The trash bags will be placed daily in a trash dumpster to be identified in the field. No trash bags will be placed in private trash dumpsters without the permission of the owner of the dumpster.

5.2.2 Decontamination Fluids

Decontamination fluids will be collected in 55 gallon drums or polyethylene tanks, appropriately labeled, and placed in the secondary containment section of the IDW staging area. If analytical results from sampling do not indicate the presence of contamination (see Section 5.3.2), the fluids will be disposed of by land application. If environmental samples associated with these materials are determined to be hazardous waste, the drummed fluids will be disposed of as hazardous waste.

5.2.3 Monitoring Well Purging/Development Fluids

Purge water generated from monitoring well development and sampling activities, as well as drilling fluids will be treated in the same manner as decontamination fluids, except that the determination of hazardous waste will be based on results of the groundwater sample from the associated monitoring well.

5.2.4 Drill Cuttings and Excess Soil Samples

Drill cuttings and excess soil samples are produced during drilling and subsurface soil sampling. This IDW typically consists of soil, rock, fill material, and miscellaneous debris. Generally, the material will be drummed, appropriately labeled, and temporarily stored on-site in the IDW staging area until sample results can be evaluated.

Analytical results of the soil sampling will be used to determine proper disposal of the material. If the results of the sampling indicate that cuttings or materials are hazardous, the containers/drums will be handled as hazardous (see Section 5.3 below).

5.3 MANAGEMENT AND DISPOSAL OF INVESTIGATION DERIVED WASTE

IDW will be managed on-site by the Field Geologist. A list of IDW drums will be made and transferred to the PM at the completion of the field activities. Each IDW container will be labeled “Hazardous Waste – Pending Analysis”. The PM will then be responsible for disposal of the IDW. The following sections define how IDW will be disposed.

5.3.1 Non-Contaminated Soil or Water

Water with contaminants present at levels less than U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels will be considered non-contaminated and will be disposed of as directed by the CELRL PM. Soil that meets the criteria of USEPA Regional Screening Level and Resource Conservation and Recovery Act (RCRA) guidelines for non-contaminated soil may be disposed on land at the site, as directed by the land owner and USACE. USACE will consult with the land owner for on land disposal preferences. All drums will be relabeled “Non-Hazardous Waste” prior to disposal, and the initial date of waste accumulation will remain the same.

5.3.2 Contaminated Soil or Water

Water that meets the RCRA definition of hazardous waste will be treated as hazardous waste and will be disposed at an approved hazardous waste management unit off-site. Water that does not meet the RCRA definition of a hazardous waste will be disposed of in accordance with federal and state requirements. An authorized USACE hazardous material employee will sign hazardous waste manifests.

Soil that does not meet the RCRA definition of hazardous waste will be managed as special waste. Special waste will be disposed at the local sanitary landfill in accordance with federal and state

requirements. Appropriate testing for landfill disposal will be conducted. Soil that meets the RCRA definition of hazardous waste will be treated as hazardous waste. The IDW will be managed as follows:

- The label will be revised to state "Hazardous Waste" by marking through the term “Pending Analysis” and the initial date of waste accumulation will remain the same.
- Comply with Subpart I of 40 Code of Federal Regulations 265 (Use and Management of Containers), including weekly inspection of container storage areas to look for leaks and deterioration caused by corrosion or other factors.
- Properly manifest and dispose of the waste materials as a hazardous waste within 90 days of the initial date of accumulation on the container. Manifests will be signed by a trained and authorized USACE hazardous materials employee.

6. DAILY QUALITY CONTROL REPORTING

Daily activities will be recorded by the QC Inspector on field checklists to verify that all procedures outlined in the WP are implemented. The following field activities will be summarized on the field checklists:

6.1 SITE INFORMATION

In order to accurately track field activities from one site location to another, site-specific information will be recorded on the checklists. Information such as site location, date, crew numbers, names of crew members, and the name of the FOM (or delegated site manager) will be recorded on these forms.

6.2 WEATHER CONDITIONS

General weather conditions such as air temperature, precipitation, relative wind speed and direction, and relative humidity will be estimated daily and recorded.

6.3 SUMMARY OF WORK PERFORMED

A brief description of the daily field activities performed at the Raco Site will be recorded on the checklist. This section will only include general field type activities such as drilling or monitoring well installation. Actual drilling locations and locations where samples are collected will not be included in this section. Specific information on the samples collected will be provided in the field logbook.

6.4 INSTRUMENT CALIBRATION

Instrumentation used for sampling and verification of instrument calibration during daily field activities will be recorded on the checklists. Additional instruments used will be written in the space provided. Further information on calibration procedures will be recorded on the calibration log for each instrument used during daily field activities.

6.5 HEALTH AND SAFETY REQUIREMENTS

The level of protection used during daily field activities, and any other health and safety modifications from the SSHP, will be recorded. Modifications that may occur during field activities include upgrading to higher levels of protection based on air monitoring data (obtained by PID) and other chemical or physical hazards encountered at the Raco Site that were not previously known to exist.

6.6 SAMPLE NUMBERS COLLECTED, INCLUDING QUALITY ASSURANCE SAMPLES

Samples collected, including QA/QC samples, will be recorded in the field notebook.

6.7 DEVIATIONS FROM THE APPROVED WORK PLAN

Any anticipated deviations in field activities that are not specified in the WP will be recorded on the field checklists and FCR. Correction of the actual deviations will not be performed until a written request is submitted to the GEO PM or designee and approval, written or verbal, has been granted by the PM. CELRL will be informed of deviations via email by the GEO PM prior to deviation implementation.

6.8 PROBLEMS ENCOUNTERED/CORRECTIVE ACTION TAKEN

Any deviation from these procedures should be approved by the GEO PM or designee and recorded in the field logbook.

During daily field activities, any problems encountered will be recorded on the checklists. Corrective actions taken for each incident will be recorded on a non-conformance report and submitted to the CELRL PM. The CELRL PM will be notified of each problem encountered and the date and time of when notification is given will be recorded.

The QC Inspector will verify completion by signing and dating the checklists. The field checklists will be completed daily. Copies of the completed forms will be placed in the project file. The field checklists can be found in Appendix C of the WP.

7. CORRECTIVE ACTIONS

Discrepancies discovered by field, laboratory, or office personnel will be immediately brought to the attention of the GEO PM. The GEO PM will, if possible, take immediate corrective action. If a discrepancy is identified, GEO will follow Quality System Procedure 8.5, Rev. 1, Corrective and Preventive Action, which fulfills the requirements of International Organization for Standards 9001:2000, Sections 7.2 and 8.5. During this process, measures will be taken to rectify deficiencies and investigate the cause of the deficiency, test failure, or customer complaint in order to eliminate the cause. If the problem is not readily correctable, the GEO PM will contact the Project Development Team, explain the discrepancy, and reach a mutually agreeable solution. The GEO PM will then implement the solution and submit a memo to the project file detailing the problem and its resolution.

The QAPP (Appendix B) contains additional details regarding corrective actions. Specifically, Worksheets #6 (Communication Pathways), #29 (Project Document and Records), Worksheet #31 (Planned Project Assessments), and Worksheet #32 (Assessment Findings and Corrective Action Responses) provides procedures for development, documentation and approval of corrective actions.

THIS PAGE INTENTIONALLY LEFT BLANK

8. REFERENCES

GEO (GEO Consultants, LLC 2008. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Environmental Site Investigation (Phase III), Hiawatha National Forest, Raco, Michigan*.

GEO (GEO Consultants, LLC 2010. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Remedial Investigation/Feasibility Study Activities, Hiawather National Forest, Raco, Michigan.*

GEO (GEO Consultants, LLC) 2013a. *Quality Control Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* November.

GEO (GEO Consultants, LLC) 2013b. *Site-Specific Safety and Health Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* December.

International Organization for Standardization 9001:2000, Sections 7.2, and 8.5.

Rayne, T., Bradbury, K., and Mickelson, D. 1996. Variability of hydraulic conductivity in uniform sandy till, Dane County, Wisconsin. Wisconsin Geological and Natural History Survey, Information Circular 74.

USACE (U.S. Army Corps of Engineers) 2013a. *Performance Work Statement for Raco TCE Groundwater Plume.* Revised August.

USACE (U.S. Army Corps of Engineers) 2013b. *Quality Assurance Surveillance Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026*. Submitted to U.S. Army Corps of Engineers, Louisville District. November.

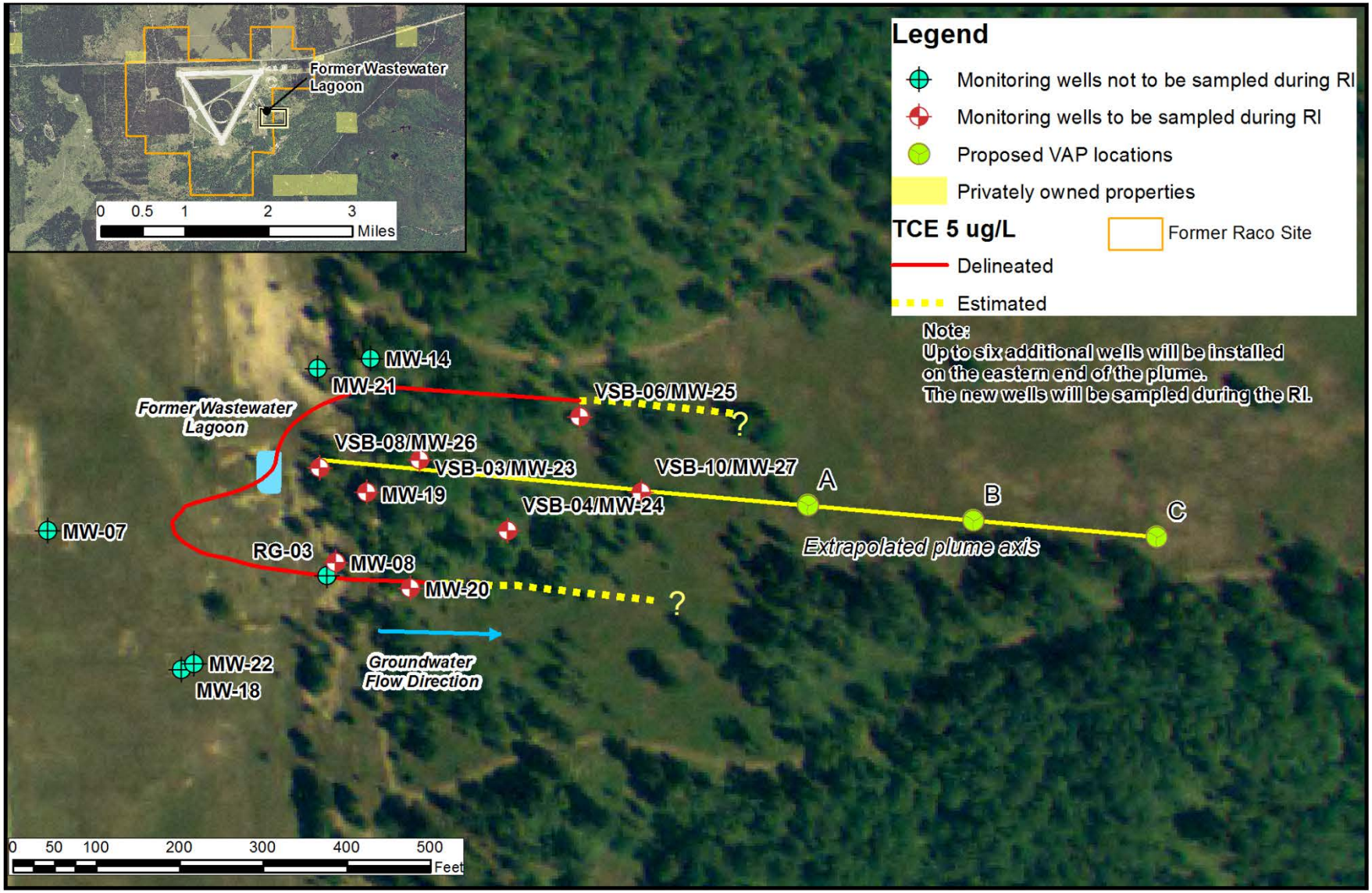
USACE (U.S. Army Corps of Engineers) 2014a. *Draft-Final Abbreviated Verification Sampling Event Work Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* January.

USACE (U.S. Army Corps of Engineers) 2014b. *Draft Work Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026*. March.

THIS PAGE INTENTIONALLY LEFT BLANK

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK



Base map source - Michigan Geographic Data Library, 2005

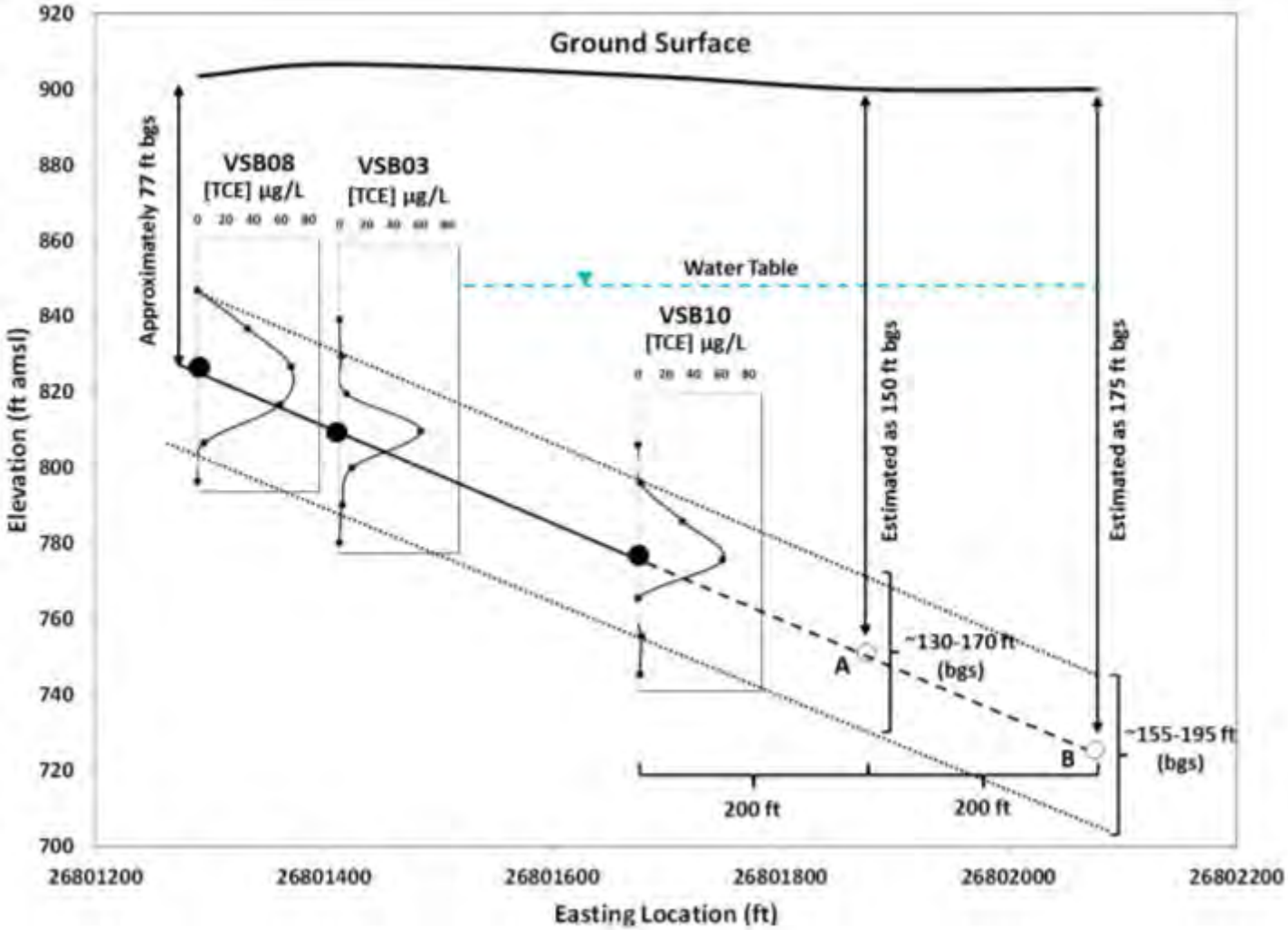
Figure A-1
Proposed locations for Vertical Aquifer Profile boreholes

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014



See Figure A-1 for cross section location.

Figure A-2.
Trichloroethene concentration versus depth profiles from prior Vertical Aquifer Profile (VAP) investigation (GEO 2010) and proposed VAP locations along the extrapolated plume axis

U.S. Army Corps of Engineers
Louisville District

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

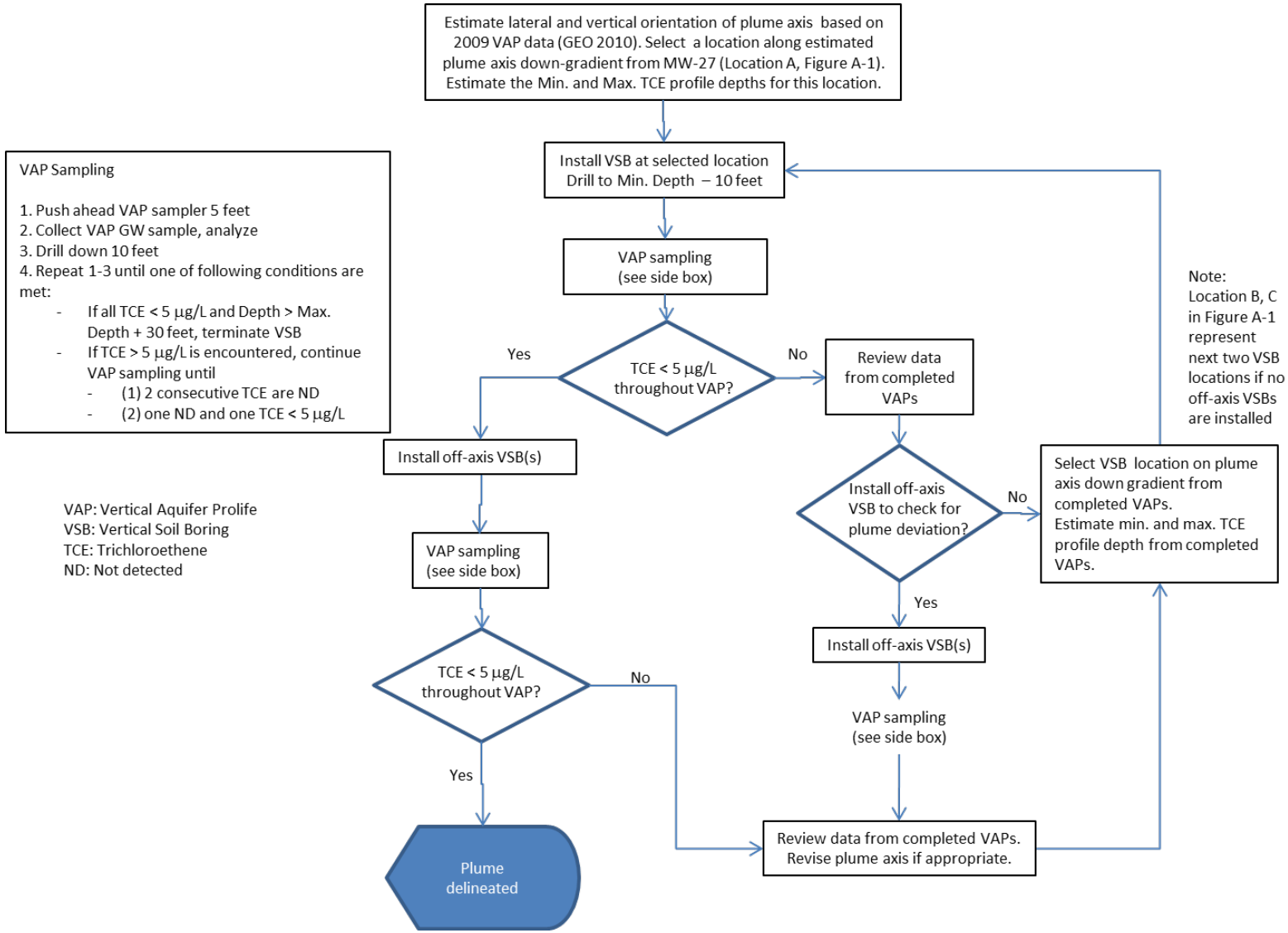


Figure A-3.
Drilling strategy flow chart for installation of VAP borings to complete delineation of the TCE plume at the Raco Site

U.S. Army Corps of Engineers
Louisville District

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

Table A-1. Summary of Raco TCE Plume Remedial Investigation field activities

Field Sampling Event	Field Activity	Number of wells/tests (Table A-3 for wells to be sampled)	Sample Matrix/Sampling Method	Analyte Group	Parameter
Verification Sampling - Spring 2014	Measure Water Levels	8	NA		Water level
	Sampling of existing groundwater monitoring wells	8	Groundwater/Low-flow sampling from monitoring wells	VOCs	TCE, cis and trans-1,2-DCE, VC
				Water Quality Parameters	Temperature
					pH
					Specific conductance
					Dissolved Oxygen
					Oxidation-Reduction Potential
					Turbidity
Vertical Aquifer Profiling and Monitoring Well Installation - Summer 2014	Measure Water Levels	3	NA		Water Level
	Vertical Aquifer Profiling	2400 lineal feet total, 12 VSBs	Soil/ Rotosonic drilling VSB	Soil properties	Total Organic Carbon
					Grain size distrbution
			Groundwater, Low-flow sampling from VAP 2-foot sampler	VOCs	TCE, cis and trans-1,2-DCE, VC
				Water Quality Parameters	Temperature
					pH
					Specific conductance
					Dissolved Oxygen
					Oxidation-Reduction Potential
					Turbidity
	Monitoring Well Installation and Development	Install and Develop 6 monitoring wells in selected VSBs	NA	NA	NA
	Nested Piezometer Installation	1 nested piezometer *conditional on availability of excess drilling capacity after plume delineation	NA	NA	NA
	Surveying of Monitoring Wells and VAP boreholes	Up to 16 monitoring wells/12 VSBs	NA	NA	NA
	Ecological Site Reconnaissance	NA	NA	NA	NA

Table A-1. Summary of Raco TCE Plume Remedial Investigation field activities (continued)

Field Sampling Event	Field Activity	Number of wells/tests	Sample Matrix/Sampling Method	Analyte Group	Parameter
1st Groundwater Sampling Event - Fall 2014	Measure Water Levels	14 + piezometers (if installed) + others if accessible	NA	NA	Water level
	Sampling of Monitoring Wells	14	Groundwater/Low-flowsampling from monitoring wells	VOCs	TCE, cis and trans-1,2-DCE, VC
				Water Quality Parameters	Temperature
					pH
					Specific conductance
					Dissolved Oxygen
					Oxidation-Reduction Potential
					Turbidity
		6	Groundwater/Low-flow sampling from monitoring wells	MNA Parameters	Chloride
					Nitrate
					Nitrite
					Sulfate
					Methane
					Ethane
					Ethene
					Carbon dioxide
					Dissolved Organic Carbon
					Alkalinity
					Sulfide
					Ferrous iron
	Slug Test	5	NA	Hydraulic Properties	Hydraulic Conductivity

Table A-1. Summary of Raco TCE Plume Remedial Investigation field activities (continued)

Field Sampling Event	Field Activity	Number of wells/tests	Sample Matrix/Sampling Method	Analyte Group	Parameter
2nd Groundwater Sampling Event - Spring 2015	Measure Water Levels	14 + piezometers (if installed)	NA		Water level
	Sampling of Monitoring Wells	14	Groundwater/Low-flow sampling from monitoring wells	VOCs	TCE, cis and trans-1,2-DCE, VC
				Water Quality Parameters	Temperature
					pH
					Specific conductance
					Dissolved Oxygen
					Oxidation-Reduction Potential
					Turbidity
		6	Groundwater/Low-flow sampling from monitoring wells	MNA Parameters	Chloride
					Nitrate
					Nitrite
					Sulfate
					Methane
					Ethane
					Ethene
					Carbon dioxide
					Dissolved Organic Carbon
					Alkalinity
					Sulfide
					Ferrous iron
		4	Groundwater/Low-flow sampling from monitoring wells	Microbial populations	CENSUS/Molecular Biological Tools
		6	Groundwater/Low-flow sampling from monitoring wells	Isotopic ratio	Compound Specifid Isotope Analysis

1,2-cis- and trans-DCE: Dichlroethene; MNA: Monitored Natural Attenuation; NA: Not applicable; TCE: Trichloroethene; VAP: Vertical Aquifer Profiling; VC: vinyl chloride; VOC: Volatile Organic Compound; VSB: Vertical Soil Boring

Table A-2. Monitoring well sampling events and rationale

Well ID	Number of prior sampling events through 2009	TCE range of concentrations (ug/L)	Water Quality Parameters [1]	TCE and dechlorination products [2]	Monitored Natural Attenuation Parameters [3]	Compound Specific Isotope Analysis	CENSUS Molecular Biological Tool	Rationale for Sampling
MW-08	9	3J to 19	V, 1, 2	V, 1, 2	--	--	--	TCE > 5 ug/L, multiple samplings since 1990
MW-19	4	4 to 33	V, 1, 2	V, 1, 2	--	--	--	TCE > 5 ug/L, multiple samplings since 2004
MW-20	4	1U to 0.59	V, 1, 2**	V, 1, 2**	--	--	--	Defines the southern plume boundary
MW-23	1	48	V, 1, 2	V, 1, 2	1,2*	2*	2*	Located along plume axis based on 2009 data
MW-24	1	12	V, 1, 2	V, 1, 2	--	--	--	Near the southern plume boundary
MW-25	1	5.7	V, 1, 2	V, 1, 2	--	--	--	Near the northern plume boundary
MW-26	1	51	V, 1, 2	V, 1, 2	1,2*	2*	2*	Located along plume axis based on 2009 data
MW-27	1	16	V, 1, 2	V, 1, 2	1,2*	2*	2*	Located along plume axis based on VSB10 2009 data
MW-28 (To be installed)	--	--	1, 2	1, 2	1,2*	2*	2*	New well
MW-29 (To be installed)	--	--	1, 2	1, 2	1,2*	2*	--	New well
MW-30 (To be installed)	--	--	1, 2	1, 2	1,2*	2*	--	New well
MW-31 (To be installed)	--	--	1, 2	1, 2	--	--	--	New well
MW-32 (To be installed)	--	--	1, 2	1, 2	--	--	--	New well
MW-33 (To be installed)	--	--	1, 2	1, 2	--	--	--	New well

[1] pH, temperature, specific conductance, dissolved oxygen, oxidation-reduction potential, turbidity

[2] To be measured in an off-site, fixed-base lab by Method 8260C.

[3] Ferrous iron, chloride, nitrite, nitrate, sulfate, sulfide, methane, ethane, ethene, carbon dioxide, alkalinity, dissolved organic carbon, in addition to water quality parameters

*Selected wells will be located along the plume axis; list of wells may change based on groundwater monitoring data to be collected during the Verification and First sampling events.

**MW-20 may be excluded from further sampling after the Verification Sampling Event if TCE is detected at less than 1 ug/L (i.e., comparable to previous results)

TCE: Trichloroethene

Note: The sampling plans shown above are subject to change based on field data and coordination with stakeholders.

V: Verification Sampling Event (Spring 2014); 1: First monitoring well sampling event (Fall 2014); 2: Second monitoring well sampling event (Summer 2015)

Table A-3. Project team members and subcontractors

Name	Position/Role	Phone	Organization/Address*
Phyllis Hockett	Project Manager	502-315-7457	USACE/CELRL
Josh Van Bogaert	Technical Manager	502-315-6333	USACE/CELRL
Douglas Buchanan	Geologist	502-315-6334	USACE/CELRL
Dr. David Brancato	Risk Assessor	502-315-6494	USACE/CELRL
Kathy Kranz	Chemist	502-315-6335	USACE/CELRL
William Harmon	Site Coordinator	517-284-5110	MDEQ
Carol Tracy	Geologist	517-284-5161	MDEQ
Eric Wildfang	Risk Assessor	517-284-5170	MDEQ
Jessica Stuntebeck	Geologist	414-297-3342	USFS
Larry Copeland	Program/Project Manager	270-462-3882	GEO
Natalie Magill	Technical Manager	270-462-3882	GEO
Kim Morris	Quality Manager	270-462-3882	GEO
Paul Lewers	Field Operations Manager Site Safety and Health Officer	618-203-9950	GEO
Tom Early	Senior Geologist	865-482-5916	GEO
Olivia West	Risk Assessor	865-671-4401	GEO
Don Bond	Driller (Project Manager)	810-523-3957	Cascade Drilling
Chris Barden	Driller (Crew Leader)	810-397-1678	Cascade Drilling
Nick Nigro	Project Manager, Mobile Laboratory	608-221-8700	Environmental Chemistry Consulting Services, Inc. (ECCS)
Pat Letterer	Project Manager, Fixed-base Laboratory (Chemical Analysis)	608-356-2760	CT Laboratories, 1230 Lange Ct., Baraboo, WI 53913
Laura Soeten	Laboratory data validation	760-634-0437	Laboratory Data Consultants, Inc.
Brooke Harrison	Ecological Reconnaissance	330-688-0111	EnviroScience, Inc.
TBD	Project Manager, Fixed-base Laboratory (CSIA)	412-826-5245	Microseeps, Inc., 220 William Pitt Way, Pittsburgh, PA 15238
TBD	Project Manager, Fixed-base Laboratory (CENSUS/MBT)	865-573-8188	Microbial Insights, Inc., 10515 Research Drive, Knoxville, TN 37932
TBD	Project Manager, Fixed-base Laboratory (Soil grain size analysis)	562- 347-2500	PTS Laboratories, 8100 Secura Way, Santa Fe Springs, CA 90670
TBD	Utility Locator	888-858-9830	Blood Hound, Inc.
William Karr	Surveyor	906-632-1500	Northwoods Land Surveying

CELRL: U.S. Army Corps of Engineers, Louisville District; CSIA: Compound Specific Isotope Analysis; GEO: GEO Consultants, LLC; MBT: Molecular Biological Tools; MDEQ: Michigan Department of Environmental Quality; TBD: To Be Determined; USACE: U.S. Army Corps of Engineers; USFS: U.S. Forest Service

*Address only provided for off-site, fixed-base laboratories since this information will be used for shipping samples.

Table A-4. Existing monitoring well construction information

	Northing[1] (feet)	Easting[1] (feet)	Screen length (feet)	Survey Marker/ Ground Elevation (feet amsl)[2]	Top of Casing[1][3] (feet amsl)	Total Depth [4] (feet below Top of Casing)	Bottom of well elevation (feet amsl)	Total Depth [3] (feet bgs)	Well Screen Depth (feet bgs)
MW-08	578405.0	26801309.7	10.0	904.10	905.59	75.65	829.94	74.16	64.16 - 74.16
MW-19	578489.0	26801347.2	10.0	905.26	907.60	93.93	813.67	91.59	81.59 - 91.59
MW-20	578374.1	26801399.6	10.0	907.64	909.85	89.00	820.85	86.79	76.79 - 86.79
MW-23	578527.9	26801410.7	10.0	906.60	909.33	102.30	807.03	99.57	89.57 - 99.57
MW-24	578443.1	26801515.6	10.0	905.40	908.01	102.30	805.71	99.69	89.69 - 99.69
MW-25	578579.6	26801602.4	10.0	905.50	908.19	106.52	801.67	103.83	93.83 - 103.83
MW-26	578518.5	26801291.2	10.0	903.50	906.25	89.92	816.33	87.17	77.17 - 87.17
MW-27	578489.0	26801675.6	10.0	903.60	906.42	135.96	770.46	133.14	123.14 - 133.14

[1]Wells surved in 2009 (GEO 2010). Horizontal coordinates are based on the Michigan State Plane Coordinate System (North Zone 2111). Elevations are based on the North American Vertical Datum 1929 (NAVD 1929)

[2] Survey marker elevations on the existing monitor wells, refer to a brass or aluminum disk set in the concrete base at each monitor well. Elevation shots at MW-23 through MW-27

amsl: above mean sea level; bgs: below ground surface

[3] Coordinates, elevations, and depths below ground surface only provided for wells that were surveyed in 2009 (GEO 2010).

[4] Depths for wells surveyed in 2009 were measured and reported in GEO (2010).

Table A-5. Sample containers, preservation methods, and hold times

Sample Medium	Analytes/Method	Container	Preservation	Holding Time
Groundwater	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	5 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, HCl, pH<2, no headspace	14 days
Groundwater	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260B (mobile lab)	3 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, no headspace	Analyzed in on-site mobile lab within 24 hours
Groundwater	Ferrous Iron/Hach 8146	[1]	[1]	[1]
Groundwater	Nitrate/9056A	125 mL HDPE bottle	Cooled to 4°C	48 hours
Groundwater	Chloride, Sulfate, Nitrite/9056A	125 HDPE bottle	Cooled to 4°C	48 hours
Groundwater	Sulfide/9034	500 mL HDPE botle	Cooled to 4°C NaOH, ZnAc	7 days
Groundwater	Dissolved Organic Carbon/9060	2 x 40 mL amber glass bottle	Cooled to 4°C, HCl, pH<2	28 days
Groundwater	Alkalinity/310.2	250 mL HDPE bottle	Cooled to 4°C	14 days
Groundwater	Methane, Ethane, Ethene, Carbon Dioxide/RSK 175	3 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, HCl, pH<2, no headspace	7 days
Groundwater	Compound Specific Isotope Analysis/Lab-specific	9 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, HCl, pH<2, no headspace	14 days
Groundwater	CENSUS/Molecular Biological Tool	1 L HDPE bottle	Cooled to 4°C	24-48 hours
Soil	Total Organic Carbon/9060	4 ounce plastic cup	Cooled to 4°C	14 days
Soil	Grain size distribution/ASTM D4464	1 L HDPE bottle	None required	None

[1] Field analysis; will be analyzed immediately upon collection.

1,2-cis- and trans-DCE: Dichlroethene; HCl; hydrochloric acid; HDPE: high density polyethylene; NaOH: sodium hydroxide; TCE: Trichloroethene; VC: vinyl chloride; VOA: volatile organic analysis; ZnAc: zinc acetate

Table A-6. Field and Quality Control samples

Sampling Procedure	Analytes/ Method	Laboratory* *All are off-site, fixed-base unless noted otherwise.	Number of field samples	Field duplicates	MS/MSD Pairs	QA Split Samples	Trip Blanks	Equipment blanks
Verification Sampling Event - Spring 2014	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	CT Laboratories	8	1	1	1	1/sample cooler	0
VAP Groundwater Sampling - Summer 2014	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260B	ECCS (on-site mobile) USACE QA Lab (TBD) for splits	120	12	6	12	1/sample cooler	1/day
Soil Sampling - Summer 2014	TOC/9060	CT Laboratories	24	2	0	0	0	0
	Grain size distribution/ASTM D422	PTS Laboratories	24	0	0	0	0	0
First Round - Groundwater Sampling - Fall 2014	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	CT Laboratories USACE QA Lab (TBD) for splits	14	2	1	2	1/sample cooler	0
	MNA: Chloride, Nitrite, Nitrate, Sulfate/9056A	CT Laboratories	6	0	0	0	0	0
	175	CT Laboratories	6	0	0	0	0	0
	MNA: Dissolved Organic Carbon/9060	CT Laboratories	6	0	0	0	0	0
	MNA: Alkalinity/310.2	CT Laboratories	6	0	0	0	0	0
	MNA: Sulfide/9034	CT Laboratories	6	0	0	0	0	0
	MNA: Ferrous Iron/Hach 8146	GEO Consultants (on-site)	14	0	0	0	0	0
Second Round - Groundwater Sampling - Spring 2015	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	CT Laboratories USACE QA Lab (TBD) for splits	14	2	1	2	1/sample cooler	0
	MNA: Chloride, Nitrite, Nitrate, Sulfate/9056A	CT Laboratories	6	0	0	0	0	0
	175	CT Laboratories	6	0	0	0	0	0
	MNA: Dissolved Organic Carbon/9060	CT Laboratories	6	0	0	0	0	0
	MNA: Alkalinity/310.2	CT Laboratories	6	0	0	0	0	0
	MNA: Sulfide/9034	CT Laboratories	6	0	0	0	0	0
	MNA: Ferrous Iron/Hach 8146	GEO Consultants (on-site)	14	0	0	0	0	0
	Compound Specific Isotope Analysis	Microseeps, Inc.	6	0	0	0	0	0
	CENSUS/Molecular Biological Tool	Microbial Insights, Inc.	4	0	0	0	0	0

NOTES: Wells to be sampled in Round 1 and 2 are identified in Table A-5. USACE QA Lab To be determined.

DCE: dichloroethene; MNA: Monitored Natural Attenuation; MS/MSD: Matrix Spike/Matrix Spike Duplicate; NA: Not applicable; TCE: Trichloroethene; TOC: total organic carbon; QA: Quality Assurance; VAP: Vertical Acquifer Profiling; VC: vinyl chloride

APPENDIX B

QUALITY ASSURANCE PROJECT PLAN

THIS PAGE INTENTIONALLY LEFT BLANK

U.S. Army Corps of Engineers
Louisville District

Appendix B
Final Quality Assurance Project Plan
Remedial Investigation/Feasibility Study
TCE Groundwater Plume
Former Raco Army Airfield and Missile Site
Chippewa County, Michigan
FUDS Property No. E05MI0026

Prepared for
U.S. Army Corps of Engineers
Louisville District
Contract No. W912BV-10-D-2000
Delivery Order CY01

November 2014

Final Quality Assurance Project Plan
Remedial Investigation/Feasibility Study
TCE Groundwater Plume
Former Raco Amy Airfield and Missile Site
Chippewa County, Michigan
FUDS Property No. E05M10026

Date Issued – November 2014

Prepared for
U.S. Army Corps of Engineers – Louisville District
600 Martin Luther King Jr. Place
Louisville, Kentucky 40202-2232

Prepared under
Contract No. W912BV-10-D-2000
Delivery Order CY01

THIS PAGE INTENTIONALLY LEFT BLANK

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Notice is hereby given that an Independent Technical Review (ITR) has been conducted on this Quality Assurance Project Plan for the Remedial Investigation/Feasibility Study for the TCE Groundwater Plume at the Former Raco Army Airfield and Missile Site located in Chippewa County, Michigan that is appropriate to the level of risk and complexity inherent in the project. During the ITR, compliance with established policy, principles, and procedures was verified. This included review of procedures to be used to create a product that meets the customer's needs, consistent with law and existing U.S. Army Corps of Engineers (USACE) policy.

Larry Copeland
Project Manager

11/05/14
Date

Katherine Sheedy
ITR Team Member

11/05/14
Date

Kim Morris
Quality Assurance Reviewer

11/10/14
Date

Significant concerns and the explanation of the resolution are as follows:

None.

As noted above, all concerns resulting from the independent technical review of the document have been considered.

Paul Lewers
ITR Team Leader, GEO Consultants, LLC

11/09/14
Date

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

CONTENTS v

LIST OF FIGURES vii

ACRONYMS AND ABBREVIATIONS ix

1. INTRODUCTION 1
- QAPP Worksheet #1 – Title and Approval Page 3
- QAPP Worksheet #2 – QAPP Identifying Information 4
- QAPP Worksheet #3 – Distribution List 9
- QAPP Worksheet #4 – Project Personnel Sign-Off Sheet 10
- QAPP Worksheet #5 – Project Organizational Chart 11
- QAPP Worksheet #6 – Communication Pathways 12
- QAPP Worksheet #7 – Personnel Responsibilities and Qualifications Table 15
- QAPP Worksheet #8 – Special Personnel Training Requirements 17
- QAPP Worksheet #9 – Project Scoping Session Participants Sheet 18
- QAPP Worksheet #10 – Conceptual Site Model 23
- QAPP Worksheet #11 – Project/Data Quality Objectives 27
- QAPP Worksheet #12 – Measurement Performance Criteria 35
- QAPP Worksheet #13 – Secondary Data Criteria and Limitations 41
- QAPP Worksheet #14 – Summary of Project Tasks 42
- QAPP Worksheet #15 – Reference Limits and Evaluation Table 45
- QAPP Worksheet #16 – Project Schedule / Timeline Table 47
- QAPP Worksheet #17 – Sampling Design and Rationale 48
- QAPP Worksheet #18 – Sampling Locations and Methods/Standard Operating Procedure Requirements 51
- QAPP Worksheet #19 – Sample Containers, Preservation and Holding Times 56
- QAPP Worksheet #20 – Field Quality Control Sample Summary 57
- QAPP Worksheet #21 – Project Sampling Standard Operating Procedure References 58
- QAPP Worksheet #22 – Field Equipment Calibration, Maintenance, Testing, and Inspection Table 59
- QAPP Worksheet #23 – Analytical Standard Operating Procedure References 60
- QAPP Worksheet #24 – Analytical Instrument Calibration 61
- QAPP Worksheet #25 – Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table 62
- QAPP Worksheet #26 – Sample Handling System 63
- QAPP Worksheet #27 – Sample Custody 64
- QAPP Worksheet #28 – Quality Control Samples 65
- QAPP Worksheet #29 – Project Documents and Records 74
- QAPP Worksheet #30 – Analytical Services 75
- QAPP Worksheet #31 – Planned Project Assessments 76
- QAPP Worksheet #32 – Assessment Findings and Corrective Action Responses 77
- QAPP Worksheet #33 – Quality Assurance Management Reports 78
- QAPP Worksheet #34 – Verification (Step I) Process 79
- QAPP Worksheet #35 – Validation (Steps IIa and IIb) Process 80
- QAPP Worksheet #36 – Validation (Steps IIa and IIb) Summary 81
- QAPP Worksheet #37 – Usability Assessment 82

2. REFERENCES 85

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure B-1. Conceptual Site Model
Figure B-2. Proposed locations for Vertical Aquifer Profile borings
Figure B-3. Trichloroethene concentration versus depth profiles from prior Vertical Aquifer Profile (VAP) investigation (GEO 2010) and proposed VAP locations along the extrapolated plume axis
Figure B-4. Drilling strategy flow chart for installation of VAP borings to complete delineation of the TCE plume at the Raco Site

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS AND ABBREVIATIONS

AAF	Army Airfield
ADR	Automated Data Review
amsl	above mean sea level
ASTM	American Society for Testing Materials
bgs	below ground surface
BLRA	Baseline Risk Assessment
CAS	Chemical Abstract Service
CELRL	U.S. Army Corps of Engineers, Louisville District
CSIA	Compound Specific Isotope Analysis
CX	U.S. Army Corps of Engineers, Center of Expertise
DCE	Dichloroethene
DoD	Department of Defense
DQO	Data Quality Objective
ECCS	Environmental Consulting Services, Inc.
ELAP	Environmental Laboratory Accreditation Program
FOM	Field Operations Manager
FS	Feasibility Study
FSP	Field Sampling Plan
FUDS	Formerly Used Defense Site
GEO	GEO Consultants, LLC
HDPE	High-density Polyethylene
ISO	International Organization for Standardization
L	liter(s)
LCS	laboratory control sample(s)
LCSD	laboratory control sample duplicate
LOD	Limit of Detection
LOQ	Limit of Quantitation
MBA	Missile Battery Area
MBT	Molecular Biological Tool
MCL	Maximum Contaminant Level
MDEQ	Michigan Department of Environmental Quality
MDL	Method Detection Limit
mL	milliliter(s)
mg/kg	milligram(s) per kilogram
MNA	Monitored Natural Attenuation
MS	matrix spike(s)
MSD	matrix spike duplicate
MW	monitoring well
PM	Project Manager
PQL	Project Quantitation Limit
PSHO	Project Safety and Health Officer
QA	Quality Assurance
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	Quality Control
QSM	Quality Systems Manual
Raco Site	former Raco Army Airfield and Missile Site
RI	Remedial Investigation
RL	Reporting Limit

RPD	relative percent difference
RSL	Regional Screening Level
SOP	Standard Operating Procedure
SSHO	Site Safety and Health Officer
SSHP	Site-Specific Safety and Health Plan
TCE	trichloroethene
TM	Technical Manager
TOC	total organic carbon
UFP	Uniform Federal Policy
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
VAP	Vertical Aquifer Profile
VOC	volatile organic compound
VSB	VAP soil boring or borehole
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
$\delta^{13}C$	stable carbon isotopic signature of a sample = $[(R_{Sample}/R_{Standard}) - 1] \times 10^3$ where $R = {}^{13}C/{}^{12}C$. The standard reference used is *Pee Dee Belamnite*.

1. INTRODUCTION

This Quality Assurance Project Plan (QAPP) describes Quality Control (QC) procedures for Remedial Investigation (RI)/Feasibility Study (FS) activities on the trichloroethene (TCE) groundwater plume at the Formerly Used Defense Site (FUDS) former Raco Army Airfield and Missile Site (Raco Site) located in Chippewa County, Michigan. This QAPP is included as Appendix B to the RI/FS Work Plan (USACE 2014b). The overall purpose of the RI/FS is to characterize the nature and extent of risks posed by the TCE groundwater plume within the former Missile Battery Area (MBA) of the Raco Site and to evaluate remedial options. The specific objectives of the RI/FS are (1) to horizontally and vertically delineate the boundary of the TCE groundwater plume to a concentration of 5 micrograms per liter (µg/L), (2) to perform and initial evaluation of the temporal stability of the TCE groundwater plume and the potential for natural attenuation, (3) to conduct a Baseline Risk Assessment (BLRA) to quantify risks from exposure to TCE-impacted groundwater, (4) to identify and evaluate potential remedial alternatives that may be implemented if there are unacceptable risks, and (5) to collect a sufficient quantity of hydrogeologic information and engineering data during the RI field work that will allow an evaluation of remedial alternatives in the FS. The RI/FS, including the activities described in this QAPP, will be performed by GEO Consultants, LLC (GEO) under the Department of Defense (DoD) FUDS Program. GEO is performing the RI for the U.S. Army Corps of Engineers (USACE), Louisville District (CELRL) under Contract Number W912BV-10-D-2000, Delivery Order CY01. The lead regulatory agency is the Michigan Department of Environmental Quality (MDEQ). GEO will perform the RI field activities under the direction of USACE/CELRL.

The format of this QAPP is in accordance with the guidance presented in the Uniform Federal Policy (UFP)-QAPP Manual (USEPA 2005). The QAPP focuses primarily on the QC procedures associated with the analysis of field samples to ensure that the data are usable for the RI/FS. This QAPP is Appendix B of the Work Plan, which provides a detailed summary of site history, previous investigations, and overall technical approach. Procedures to be followed during the field activities are described in Appendix A, the Field Sampling Plan (FSP). Other planning documents include the Site-Specific Safety and Health Plan (SSHP, GEO 2013b), which describes procedures to be followed during the field activities to ensure safety of field personnel, as well as the protection of the environment. The RI includes a Verification Sampling Event[1], during which selected existing monitoring wells will be sampled to evaluate the potential for plume movement since the last sampling event in 2009 as well as to provide additional temporal data for future trend analysis. The sampling design for plume delineation, which is currently based on historical data through 2009, may be revised based on the data to be collected during the Verification Sampling Event. An Abbreviated Work Plan (USACE 2014a) was prepared separately for this task so that the Verification Sampling Event can occur in Spring 2014 prior to finalization of the RI/FS Work Plan.

The personnel listed in this QAPP are responsible for field activities and analytical data related to sampling activities listed in the Performance Work Statement [revised August 19, 2013 (USACE 2013a)], the RI/FS Work Plan and applicable appendices.

[1] The Verification Sampling Event is being used to supplement previous data and to verify the plume axis/configuration inferred from previous investigation data.

THIS PAGE INTENTIONALLY LEFT BLANK

QAPP Worksheet #1 – Title and Approval Page

Quality Assurance Project Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026
Document Title

U.S. Army Corps of Engineers (USACE), Louisville District (CELRL)
Lead Organization

N. Magill, Ph.D.; O.R. West, Ph.D., P.E./GEO Consultants, LLC
Preparer's Name and Organizational Affiliation

325 Kentucky Avenue, Kevil, Kentucky 42053, 270-462-3882, magilln@geoconsultantsllc.com; westor@geoconsultantsllc.com
Preparer's Address, Telephone Number, and E-mail Address

June 6, 2014
Preparation Date

Contractors's Project Manager: _____
Signature

Larry C. Copeland/GEO
Printed Name/Organization/Date

Lead Organization's Project Manager:_____
Signature

Phyllis Hockett/CELRL
Printed Name/Organization/Date

QAPP Worksheet #2 – QAPP Identifying Information

Site Name/Project Name: Former Raco Army Airfield and Missile Site, Remedial Investigation/Feasibility Study, TCE Groundwater Plume
Site Location: Chippewa County, Michigan
Site Number/Code: FUDS Property No. E05M10026
Contractor Name: GEO Consultants LLC (GEO)
Contract Number: W912BV-10-D-2000, Delivery Order CY01
Contract Title: Raco Trichloroethene (TCE) Groundwater Plume
Work Assignment Number (Optional): Not applicable

1. Identify guidance used to prepare QAPP:

   Uniform Federal Policy (UFP) for Quality Assurance Project Plans (QAPPs), Evaluating, Assessing and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual (March 2005), Part 2A (Original): UFP-QAPP Workbook (March 2005), Optimized UFP-QAPP Worksheets (March 2012)

2. Identify regulatory programs:

   - Comprehensive Environmental Response, Compensation, and Liability Act and, as amended by the Superfund Amendments and Reauthorization Act,
   - the National Contingency Plan,
   - the Defense Environmental Restoration Program, and
   - Formerly Used Defense Sites Program.

3. Indicate whether the QAPP is a generic or a project-specific QAPP.

   Project-specific

4. List dates of scoping sessions that were held:

   Refer to Worksheet #9 for scoping session participants, major discussion points and decisions.

   July 10, 2013
   August 1, 2013
   August 6, 2013
   August 14, 2013
   September 26, 2013
   November 20, 2013
   December 9, 2013
   December 16, 2013
   December 17, 2013
   January 28, 2014

QAPP Worksheet #2 – QAPP Identifying Information (Continued)

The following table shows where information required in QAPPs, as specified in U.S. Environmental Protection Agency (USEPA) (2002), can be found in the QAPP worksheets.

Required QAPP Element(s) and Corresponding QAPP section(s)	Crosswalk to QAPP Worksheet #	Information Provided in QAPP Worksheet
Project Management and Objectives		
2.1 Title and Approval Page	1	- Title and Approval Page
2.2 Document Format and Table of Contents		
2.2.1 Document Control Format		
2.2.2 Document Control Numbering System		
2.2.3 Table of Contents		- Table of Contents
2.2.4 QAPP Identifying Information	2	- QAPP Identifying Information
2.3 Distribution List and Project Personnel Sign-Off Sheet		
2.3.1 Distribution List	3	- Distribution List
2.3.2 Project Personnel Sign-Off Sheet	4	- Project Personnel Sign-Off Sheet
2.4 Project Organization		
2.4.1 Project Organizational Chart	5	- Project Organizational Chart
2.4.2 Communication Pathways	6	- Communication Pathways
2.4.3 Personnel Responsibilities and Qualifications	7	- Personnel Responsibilities and Qualifications Table
2.4.4 Special Training Requirements and Certification	8	- Special Personnel Training Requirements Table
2.5 Project Planning/Problem Definition		
2.5.1 Project Planning (Scoping)	9	- Project Scoping Session Participants Sheet
2.5.2 Problem Definition, Site History, and Background	10	- Conceptual Site Model

QAPP Worksheet #2 – QAPP Identifying Information (Continued)

Required QAPP Element(s) and Corresponding QAPP Section(s)	Crosswalk to QAPP Worksheet #	Information Provided in QAPP Worksheet
2.6 Project Quality Objectives and Measurement Performance Criteria	11	- Project/Data Quality Objectives
2.6.1 Development of Project Quality Objectives Using the Systematic Planning Process		
2.6.2 Measurement Performance Criteria	12	- Measurement Performance Criteria Table
2.7 Secondary Data Evaluation	13	- Sources of Secondary Data and Information - Secondary Data Criteria and Limitations Table
2.8 Project Overview and Schedule	14	- Summary of Project Tasks
2.8.1 Project Overview	15	- Reference Limits and Evaluation Table
2.8.2 Project Schedule	16	- Project Schedule/Timeline Table
Measurement/Data Acquisition		
3.1 Sampling Tasks		
3.1.1 Sampling Process Design and Rationale	17	- Sampling Design and Rationale - Sample Location Map
3.1.2 Sampling Procedures and Requirements	18	- Sampling Locations and Methods/ Standard Operating Procedure (SOP) Requirements Table
3.1.2.1 Sampling Collection Procedures		
3.1.2.2 Sample Containers, Volume, and Preservation	19 20	- Analytical Methods/SOP Requirements Table - Field Quality Control (QC) Sample Summary Table
3.1.2.3 Equipment/Sample Containers Cleaning and Decontamination Procedures	21	- Sampling SOPs
3.1.2.4 Field Equipment Calibration, Maintenance, Testing, and Inspection Procedures	22	- Field Equipment Calibration, Maintenance, Testing, and Inspection Table
3.1.2.5 Supply Inspection and Acceptance Procedures		
3.1.2.6 Field Documentation Procedures		

QAPP Worksheet #2 – QAPP Identifying Information (Continued)

Required QAPP Element(s) and Corresponding QAPP Section(s)	Crosswalk to QAPP Worksheet #	Information Provided in QAPP Worksheet
3.2 Analytical Tasks		
3.2.1 Analytical SOPs	23	- Analytical Standard Operating Procedures (SOPs)
3.2.2 Analytical Instrument Calibration Procedures	24	- Analytical Instrument Calibration Table
3.2.3 Analytical Instrument and Equipment Maintenance, Testing, and Inspection Procedures	25	- Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table
3.2.4 Analytical Supply Inspection and Acceptance Procedures		
3.3 Sample Collection Documentation, Handling, Tracking, and Custody Procedures	26	- Sample Handling System
3.3.1 Sample Collection Documentation		
3.3.2 Sample Handling and Tracking System		
3.3.3 Sample Custody	27	- Sample Custody Requirements
3.4 Quality Control Samples	28	- QC Samples Table
3.4.1 Sampling Quality Control Samples		
3.4.2 Analytical Quality Control Samples		
3.5 Data Management Tasks		
3.5.1 Project Documentation and Records	29	- Project Documents and Records Table
3.5.2 Data Package Deliverables		
3.5.3 Data Reporting Formats	30	- Analytical Services Table
3.5.4 Data Handling and Management		
3.5.5 Data Tracking and Control		
Assessment/Oversight		
4.1 Assessments and Response Actions		
4.1.1 Planned Assessments	31	- Planned Project Assessments Table
4.1.2 Assessment Findings and Corrective Action Responses	32	- Assessment Findings and Corrective Actions Responses
4.2 Quality Assurance Management Reports	33	- Quality Assurance Management Reports Table
4.3 Final Project Report		

QAPP Worksheet #2 – QAPP Identifying Information (Continued)

Required QAPP Element(s) and Corresponding QAPP Section(s)	Crosswalk to QAPP Worksheet #	Information Provided in QAPP Worksheet
	Data Review	
5.1 Overview		
5.2 Data Review Steps 5.2.1 Step I: Verification 5.2.2 Step II: Validation	34	- Verification (Step I) Process Table
5.2.2.1 Step IIa Validation Activities 5.2.2.2 Step IIb Validation Activities	35	- Validation (Steps IIa and IIb) Process Table - Validation (Steps IIa and IIb) Summary Table
5.2.3 Step III: Usability Assessment 5.2.3.1 Data Limitations and Actions from Usability Assessment 5.2.3.2 Activities	36	- Usability Assessment
5.3 Streamlining Data Review 5.3.1 Data Review Steps To Be Streamlined 5.3.2 Criteria for Streamlining Data Review 5.3.3 Amounts and Types of Data Appropriate for Streamlining	Not applicable	

QAPP Worksheet #3 – Distribution List

QAPP Recipients	Title	Organization	Telephone Number	E-mail Address
Phyllis Hockett	Project Manager	USACE/CELRL	502-315-7457	Phyllis.M.Hockett@usace.army.mil
Josh Van Bogaert	Technical Manager	USACE/CELRL	502-315-6333	Joshua.Vanbogaert@usace.army.mil
Dr. David Brancato	Risk Assessor	USACE/CELRL	502-315-6494	David.J.Brancato@usace.army.mil
Kathy Krantz	Chemist	USACE/CELRL	502-315-6335	Kathy.J.Kranz@usace.army.mil
Douglas Buchanan	Hydrogeologist	USACE/CELRL	502-315-6334	Douglas.M.Buchanan@usace.army.mil
William Harmon	Site Coordinator	MDEQ	517-284-5110	HARMONW@michigan.gov
Carol Tracy	Geologist	MDEQ	517-284-5161	TRACYC1@michigan.gov
Eric Wildfang	Risk Assessor	MDEQ	517-284-5170	WILDFANGE@michigan.gov
Larry Copeland	Project Manager	GEO	270-462-3882	copelandl@geoconsultantsllc.com
Jessica Stuntebeck	Geologist	USFS	414-297-3342	jjstuntebeck@fs.fed.us
Kim Morris	Quality Program Manager	GEO	270-462-3882	morrisk@geoconsultantsllc.om
Natalie Magill	Technical Manager	GEO	270-462-3882	magilln@geoconsultantsllc.com
Tom Early	Geologist/ Hydrogeologist	GEO	865-482-5916	tomearly89@gmail.com
Olivia West	Risk Assessor/ Environmental Engineer	GEO	865-671-4401	westor@geoconsultantsllc.com
Paul Lewers	Field Operations Manager	GEO	270-462-3882	lewersp@geoconsultantllc.com
Pat Letterer	Laboratory Project Manager	CT Laboratories (Primary Analytical Laboratory)	608-356-2760	pletterer@ctlaboratories.com
Nick Nigro	Laboratory Project Manager	Environmental Chemistry Consulting Services, Inc. (ECCS) (Mobile Laboratory)	608-221-8700	nkn@eccsmobilelab.com

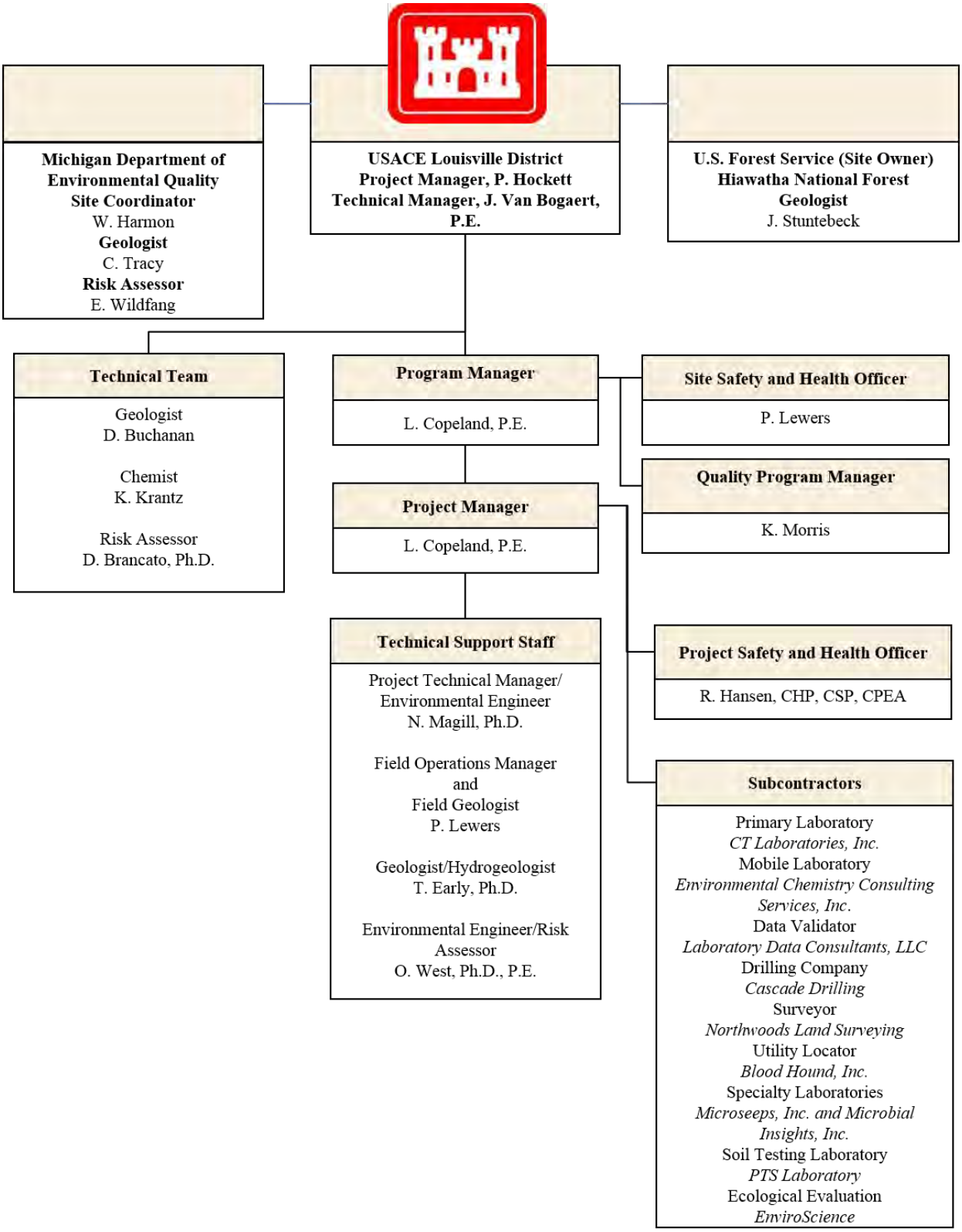
USACE/CELRL - U.S. Army Corps of Engineers/Louisville District; MDEQ - Michigan Department of Environmental Quality; GEO - GEO Consultants, LLC
USFS - U.S. Forest Service

QAPP Worksheet #4 – Project Personnel Sign-Off Sheet

Project Personnel	Title	Telephone Number	Signature	Date QAPP Read Email Receipt
Phyllis Hockett	USACE/CELRL Project Manager	502-315-7436		
Josh Van Bogaert	USACE/CELRL Technical Manager	502-315-6333		
Dr. David Brancato	USACE/CELRL Risk Assessor	502-315-6494		
Kathy Krantz	USACE/CELRL Chemist	502-315-6335		
Douglas Buchanan	USACE/CELRL Hydrogeologist	502-315-6334		
William Harmon	MDEQ Site Coordinator	517-284-5110		
Carol Tracy	MDEQ Geologist	517-284-5161		
Eric Wildfang	MDEQ Risk Assessor	517-284-5170		
Jessica Stuntebeck	USFS Hiawatha National Forest Geologist	414-297-3342		
Larry Copeland	GEO Project Manager	270-462-3882		
Kim Morris	GEO Quality Program Manager	270-462-3882		
Paul Lewers	GEO Field Operations Manager	270-462-3882		
Pat Letterer	CT Laboratories Project Manager (Analytical Laboratory)	608-356-2760		
Nick Nigro	Environmental Chemistry Consulting Services, Inc. (ECCS)Project Manager (Mobile Laboratory)	608-221-8700		

USACE/CELRL - U.S. Army Corps of Engineers/Louisville District; MDEQ - Michigan Department of Environmental Quality; GEO - GEO Consultants, LLC
USFS - U.S. Forest Service

QAPP Worksheet #5 – Project Organizational Chart



QAPP Worksheet #6 – Communication Pathways

Communication Drivers	Responsible Entity	Name	Phone Number	Procedure (timing, pathways, etc.)
Approval for project modifications, corrective actions, and delay in field work.	U.S. Army Corps of Engineers, Louisville District (CELRL) Project Manager (PM)	Phyllis hockett (CELRL)	502-315-7457	All project documentation and reports will be provided to the CELRL PM and TM by the GEO Consultants, LLC (GEO) PM.
	and/or Technical Manager (TM)	Josh Van Bogaert (CELRL)	502-315-6333	
Management of all project phases/field corrective actions related to Raco	GEO PM	Larry Copeland (GEO)	270-462-3882	During the field work, the GEO PM (or designee) will communicate daily with the Field Operations Manager (FOM) via phone, fax, or email to obtain updates regarding the field activities. The GEO PM (or designee) will notify the CELRL PM [or designee(s)] of field change requests, via phone, email, or fax by close of business on the next business day.
Management of field operations	FOM	Paul Lewers (GEO)	270-462-3882 618-203-9950 (cell)	During the field work, the FOM will communicate daily with the GEO PM via phone, fax, or email to provide updates regarding field activities, including any recommendations for field changes. During field work, the FOM will communicate with the Project Safety and Health Officer (PSHO) and report any safety issues that arise during field operations.

QAPP Worksheet #6 – Communication Pathways (Continued)

Communication Drivers	Responsible Entity	Name	Phone Number	Procedure (timing, pathways, etc.)
Field management of contractor safety and health	Site Safety and Health Officer (SSHO)	Paul Lewers (GEO)	270-462-3882 618-203-9950 (cell)	The SSHO will monitor field operations and communicate with the PSHO during field work to ensure that operations are conducted safely and in accordance with the Site-Specific Safety and Health Plan (SSHP). The SSHO will then communicate such issues to the GEO PM and with the CELRL PM (if deemed necessary by the SSHO).
Management of contractor safety and health	PSHO	Randy Hansen (Leidos, formerly SAIC)	314-486-6916	The Contractor PSHO will communicate daily with the Contractor FOM/SSHO during the field work of any safety issues and concerns that arise during the field activities. If required, the Contractor PSHO will coordinate modifications to the SSHP with the Contractor PM and CELRL. The Contractor PSHO will communicate these changes to the SSHP to the FOM to ensure that the changes are implemented.
Management of project quality assurance	GEO TM	Natalie Magill (GEO)	270-462-3882	Corrective actions needed to address Quality Assurance (QA) issues, as related to field project activities, will be communicated immediately to appropriate personnel via face-to-face, telephone, or electronic means. The GEO PM will be kept informed of these corrective actions and will be responsible for ensuring the corrective actions are implemented.

QAPP Worksheet #6 – Communication Pathways (Continued)

Communication Drivers	Responsible Entity	Name	Phone Number	Procedure (timing, pathways, etc.)
Management of sampling and laboratory analytical Quality Control (QC)	GEO TM	Natalie Magill (GEO)	270-462-3882	The GEO TM (or designee) will review daily field documentation as related to analytical sampling to ensure that documentation is accurate and samples are being collected. The TM (or designee) will consult with the laboratory to ensure that data received meet project needs. The GEO TM (or designee) will report any issues regarding analytical QC that cannot be resolved with the laboratory to the GEO PM.
Management of laboratory QC	Laboratory PM	Pat Letterer (CT Laboratories)	800-228-3012	QC issues with the samples will be communicated by the laboratory to the GEO TM within two business days of the occurrence. The GEO TM will determine if consultation with the GEO PM is necessary to resolve any issues.
Management of laboratory QC	Laboratory PM	TBD (Environmental Chemistry Consulting Services, Inc.)	608-221-8700	QC issues with the samples will be communicated by the laboratory to the GEO TM as soon as possible after the occurrence. The GEO TM will determine if consultation with the GEO PM is necessary to resolve any issues.

QAPP Worksheet #7 – Personnel Responsibilities and Qualifications Table

Name	Title	Organizational Affiliation	Responsibilities	Education and Experience Qualifications
Phyllis Hockett	Project Manager (PM)	USACE/CELRL	Overall oversight of project schedule, scope, budget, and team coordination	--
Josh Van Bogaert	Technical Manager	USACE/CELRL	Technical oversight of project	BS Chemical Engineering 10 years experience
Dr. David Brancato	Project Risk Assessor	USACE/CELRL	Provide technical support to CELRL PM	BS Chemistry, MS Pharmacology, PhD Natural Health 40 years experience
Douglas Buchanan	Hydrogeology	USACE/CELRL	Provide technical support to CELRL PM	BS/MS Geology 28 years experience
Kathy Kranz	Project Chemist	USACE/CELRL	Provide technical support to CELRL PM	BS Biomedical Sciences 36 years experience
Shelton Poole	Health and Safety	CELRL	Provide technical support to CELRL PM	BS Chemistry, MS Environmental System Management 31 years experience
William Harmon	Site Coordinator	MDEQ	Leads state regulatory team.	--
Carol Tracy	Geologist	MDEQ	Provide technical support to MDEQ site coordinator	--
Eric Wildfang	Risk Assessor	MDEQ	Provide technical support to MDEQ site coordinator	--
Jessica Stuntebeck	Geologist	USFS, Hiawatha National Forest	Point of contact for USFS, coordination of field work schedule with Smithers Winter Testing Center (currently occupying Raco Site)	--
Larry Copeland	Program Manager and PM	GEO	Oversight of CELRL projects for GEO, responsible for ensuring compliance with Performance Work Statement (USACE 2013a)	BS Chemical Engineering 44 years experience
Natalie Magill	Technical Manager (TM)	GEO	Technical lead and will ensure field sampling and laboratory analysis satisfy project quality objectives	PhD Environmental Engineering Sciences 4 years experience

Name	Title	Organizational Affiliation	Responsibilities	Education and Experience Qualifications
Kim Morris	Quality Program Manager	GEO	Ensure compliance with project Quality Control Plan (GEO 2013a)	BS Business 13 years experience
Tom Early	Geologist/Hydrogeologist	GEO	Provide technical support to GEO TM	PhD Geochemistry 37 years experience
Olivia West	Risk Assessor, Environmental Engineer	GEO	Provide technical support to GEO TM	PhD Civil Engineering 22 years experience
Paul Lewers	Field Operations Manager	GEO	Overall management of field sampling activities	BS Geology 32 years experience
Paul Lewers	Site Safety and Health Officer (SSHO)	GEO	Ensure compliance with project Site-Specific Safety and Health Plan (SSHP) (GEO 2013b)	BS Geology 32 years experience
Randy Hansen	Project Safety and Health Officer	Leidos (formerly SAIC)	Assist the SSHO in ensuring compliance with project SSHP	BS in Applied Science and Technology – Radiation Protection 24 years experience
Pat Letterer	Laboratory PM	CT Laboratories	Overall management of fixed-base laboratory sample analyses	--
TBD	Laboratory PM	Environmental Chemistry Consulting Services, Inc.	Overall management of mobile laboratory sample analyses	--

USACE/CELRL - U.S. Army Corps of Engineers/Louisville District; MDEQ - Michigan Department of Environmental Quality; GEO - GEO Consultants, LLC; PM – Project Manager; PMP – Project Management Professional; USFS - U.S. Forest Service

QAPP Worksheet #8 – Special Personnel Training Requirements

For this project, the GEO Consultants, LLC's (GEO's) Technical Manager (TM) will function as the Contractor Quality Assurance Manager (QAM) and the Contractor Project Chemist roles as defined in the *DoD Policy and Guidelines for Acquisitions Involving Environmental Sampling or Testing* (DoD 2007). The qualifications of the GEO TM (see Worksheet #7) exceed the minimum qualifications for the Contractor QAM and Project Chemist specified in Section 8 of DoD (2007). The minimum qualifications are

1. The Contractor QAM will have a minimum of a bachelor's degree with at least 4 years of experience in the laboratory and/or as part of a consultant project management team. If the QAM is not a degreed chemist, the QAM must have knowledge and experience in the sampling and analysis of environmental media, and associated quality assurance.

2. The Contractor Project Chemist will have a minimum of a Bachelor's degree in chemical, environmental, biological sciences, physical sciences, or engineering, with at least 30 semester hours in chemistry, supplemented by course work in mathematics through differential and integral calculus, at least 6 semester hours of physics, and at least 2 years of experience in areas of environmental sampling and analytical testing relevant to the project. An advanced degree in one of the above disciplines may be substituted for equivalent experience.

No other specialized training is required for GEO Consultants, LLC personnel beyond those listed above and in the Site-Specific Safety and Health Plan for the former Raco Army Airfield and Missile Site, (GEO 2013b).

QAPP Worksheet #9 – Project Scoping Session Participants Sheet

The following table documents the project scoping sessions including dates, participants and major discussion points and decisions made at each scoping session.

Date/Location: July 10, 2013/Teleconference Participants: U.S. Army Corps of Engineers (USACE), Louisville District (CELRL) (J. Van Bogaert, C. Coombs); Michigan Department of Environmental Quality (MDEQ) (C. Tracy, W. Harmon) Subject: Remedial Investigations (RI)/Feasibility Study (FS) Discussion with MDEQ - All concurred the dissolved phase plume is delineated to the west, north, and south. Additional delineation is needed laterally and vertically at the east end of the plume. - This RI will not include any additional source characterization. If needed, it would be performed in a pre-design investigation during the Remedial Design phase. - MDEQ and USACE agreed the need for source remediation will be determined by the RI results, specifically on the temporal state of the plume (i.e., expansion or increasing concentrations would suggest ongoing source contamination). - This RI will focus on dissolved phase plume delineation and fate and transport as well as provide feasibility study-level data to evaluate potential Remedial Actions.
Date/Location: August 01, 2013/Teleconference Participants: USACE/CELRL (J. Van Bogaert, C. Coombs, G. Moore); MDEQ (C. Tracy, W. Harmon) Subject: Scoping Call with MDEQ - The strategy for the RI/FS with respect to Monitored Natural Attenuation (MNA) data needs was discussed. - Data gathered during the RI is intended to be sufficient to evaluate (not demonstrate) MNA in the FS. - USACE and MDEQ discussed similarities/differences between Federal and MDEQ guidance on MNA. The similarities are: (1) both require the plume does not pose a current risk to any receptors, (2) both require a performance monitoring plan and contingency remedy specified in the Decision Document and implemented during the Remedial Action. The primary differences are: (1) Federal guidance does not require evidence for biological degradation, (2) modeling requirements are less stringent in Federal guidance. - USACE suggested 2 rounds of sampling 6 months apart for all relevant wells during the RI in addition to historical data to provide evidence supporting MNA. - MDEQ has preference for 4 rounds, 6 months apart, prior to selecting remedy. - MDEQ will evaluate whether they can support the 2-round approach, coupled with an MNA Decision Document that includes a strong monitoring and contingency plan to document that MNA is proceeding in line with expectations.

Date/Location: August 06, 2013/Teleconference Participants: USACE/CELRL (J. Van Bogaert, C. Coombs, G. Moore, K. Meier); MDEQ (C. Tracy, W. Harmon) Subject: Scoping Call Follow-up with MDEQ - All concurred on 2 rounds of monitoring, 6 months apart, spring and fall, for the RI. - Vertical Aquifer Profile (VAP) sampling does not need to begin at the water table. The initial sampling depth should be based on the 2009 results and the sinking plume Conceptual Site Model. - If MNA is the selected remedy, the Decision Document would require a contingency plan/remedy and monitoring plan to confirm MNA is occurring and trigger an alternative remedy if MNA is ineffective. - MDEQ believes 2 rounds of monitoring is unlikely to be sufficient to say with a high degree of confidence that MNA is viable, but would be amenable to using this approach for the RI/FS and confirming MNA with a strong monitoring and contingency plan during the Remedial Action/Long Term Monitoring Phase. - MDEQ suggested 5-foot well screens be considered based on historical comparison of VAP results to MW results, and field data from VAP borings during this RI.
Date/Location: August 14, 2013/CELRL offices Participants: USACE/CELRL and GEO Subject: Negotiation Meeting - USACE and GEO discussed GEO's initial proposal for the Raco trichloroethene (TCE) Plume RI/FS as well as USACE's discussions with MDEQ regarding the RI/FS scope. USACE/CELRL and GEO agreed on a path forward that would enable GEO to revise and finalize the RI/FS technical approach and cost proposal.
Date/Location: September 26, 2013/CELRL offices (MDEQ joined via teleconference) Participants USACE/CELRL (J. Van Bogaert, C. Coombs, G. Moore, Dr. D. Brancato); MDEQ (C. Tracy, W. Harmon); GEO (L. Copeland, N. Magill, O. West) Subject: Kick-off Meeting, RI/FS at Raco TCE Plume - Prior agreements between CELRL and MDEQ were confirmed. - The RI monitoring well sampling events will include one verification sampling event in Spring/Summer 2014 and two rounds of groundwater sampling (Fall 2014 and Spring 2015). If required, additional sampling will be performed as part of the Remedial Action and discussed in the Proposed Plan and Decision Document. - The results of the Verification Sampling Event will be used to determine the extent of potential changes in the plume since previous investigations and will provide a temporal trend point. - MDEQ requested 5-foot screens for the VAP sampler and new monitoring wells; all current monitoring wells have 10-foot screens. MDEQ indicated that screen length should depend on thickness of the plume at that location and should be a field decision (Note: A decision on VAP sampler screen length and monitoring well screen length was made during conference call on December 16, 2013). - MDEQ confirmed that two weeks between well installation and sampling was sufficient.

Date/Location: November 20, 2013/MDEQ offices
Participants USACE/CELRL (J. Van Bogaert, G. Moore); MDEQ (C. Tracy, W. Harmon); GEO (L. Copeland, N. Magill, T. Early, O. West)
Subject: Technical Project Planning Meeting; Raco Missile Battery Area (MBA) TCE Plume

- GEO presented a summary of previous investigations, conceptual site model, and RI Data Quality Objectives.

- Major discussion/decision points:
  - MDEQ suggested reducing the number of compound-specific isotope analysis and CENSUS DNA analysis, and re-directing resources to more groundwater samples during the verification round. *(Post-meeting follow up: Additional wells are being sampled during the verification event in exchange for a smaller number (4) of CENSUS DNA analyses.)*
  - A target risk of 10^{-4} (the upper limit of the target range in the National Contingency Plan) was proposed however the state of Michigan uses 10^{-5}. *(Post-meeting follow-up: USACE concurred with the target risk of 10^{-5}.)*
  - CELRL suggested MW-08 and MW-19 be included in the verification sampling event because these wells have been sampled multiple times previously. *(Post-meeting follow up: MW-08 and MW-19 have been added to the verification sampling event.)*
  - During VAP sampling, the bottom of the plume has been reached if one of the following conditions are met: (1) 2 consecutive non-detects of TCE, or (2) 1 sample < 5 µg/L and 1 non-detect.
  - The VAP screen length was discussed. MDEQ prefers 5-foot screens however previous (2009) sampling used a shorter screen (1.5 to 2 feet). *(Post-meeting follow up: a consensus was reached to use 1.5 to 2-foot VAP screens and 10-foot monitoring well screen lengths.)*
  - Two methods were used for VAP sampling in 2009: (1) push-ahead sampling while drilling, and (2) blind drilling to bottom then taking samples. A consistent method needs to be used during the RI field work. *(Post-meeting follow up: push-ahead VAP sampling will be used, with a 1.5 to 2 foot VAP screen. The 1.5 to 2-foot screen was able to capture the TCE depth profile in 2009.)*
  - There were discussions about partial versus year-round residents with respect to setting exposure parameters for residential users in the RI risk assessment. *(Post-meeting follow up: U.S. Forest Service (USFS) ownership of land precludes likelihood of water supply wells being installed down-gradient/east and southeast of the TCE plume. See scoping meeting notes for January 28, 2014 for further decisions on site receptors in risk assessment.)*

Date/Location: December 09, 2013/Teleconference
Participants USACE/CELRL (J. Van Bogaert, G. Moore, Dr. D. Brancato); MDEQ (W. Harmon, E. Wildfang); GEO (L. Copeland, N. Magill, O. West)
Subject: Risk Assessment, RI/FS at the Raco MBA TCE Plume

- Preliminary conceptual site model and exposure parameters for RI risk assessment were presented by CELRL/GEO to MDEQ.
- MDEQ concurred with the exposure parameters except for the potential resident. A decision was made to set a conference call with USFS to discuss current and future land use of the public land surrounding the Raco MBA TCE Plume.
- CELRL concurred with MDEQ target risk of 10^{-5}.

Date/Location: December 16, 2013/Teleconference Participants USACE/CELRL (J. Van Bogaert, G. Moore, Dr. D. Brancato); MDEQ (W. Harmon, C. Tracy); GEO (N. Magill, T. Early, O. West) Subject: Field Work Discussion, RI/FS at the Raco MBA TCE Plume - GEO presented TCE vs depth profiles from the VAP sampling in 2009. The profiles show symmetry of the TCE concentrations with depth, and indicate that the field crew was able to locate the peak of the plume using the 2-foot push-ahead sampler at 10-foot intervals. - Consensus was reached to use 2-foot VAP sampler screen and 10-foot monitoring well screens for wells to be installed in selected VAP soil borings (VSBs) during RI field work.
Date/Location: December 17, 2013/Teleconference Participants USACE/CELRL (J. Van Bogaert, G. Moore, Dr. D. Brancato); MDEQ (W. Harmon, C. Tracy, E. Wildfang); USFS (J. Stuntebeck, S. Christiansen, J. Ozenberger); GEO (N. Magill, O. West, L. Copeland) Subject: Land Use East and Southeast of Raco Army Airfield and Missile Site - GEO presented the area of interest east and southeast of the Raco TCE Plume. The plume configuration based on 2009 data shows an eastward migration direction. The regional groundwater flow is southeast. - USFS believe they have the authority to modify existing or future permits to restrict water supply wells to non-potable use. Smithers is currently restricted to withdrawing 14 million gallons per year. - There are no known existing recreational residences/cabins in the area of interest and it is extremely unlikely new recreational residences/cabins will be built on Hiawatha National Forest Land. USFS is no longer accepting applications for new recreational residence use permits (Reference: Hiawatha National Forest 2006 Forest Plan). - There is no chance of Hiawatha National Forest public land being sold to a private entity in the future. - USFS has no legal authority to restrict activities on private land within the Hiawatha National Forest. - USFS has no plans to install any new water supply wells in the area of interest in the immediate future. - A water supply well on the Raco property was acquired by USFS with the property that needs to be abandoned per MDEQ guidelines. USACE indicated it is the landowner's responsibility to abandon the well.

Date/Location: January 28, 2014/Teleconference
Participants USACE/CELRL (J. Van Bogaert, G. Moore, Dr. D. Brancato); MDEQ (W. Harmon, C. Tracy, E. Wildfang); GEO (N. Magill, K. Morris, O. West)
Subject: Conceptual Site Model/Viability of the Residential Pathway

- This teleconference was a follow-up to the December 17, 2013 teleconference regarding land use. USFS indicated that residential water supply wells are unlikely to be installed in the future within public land along the presumed pathway of the Raco TCE plume. The purpose of the call was to determine whether the residential pathway can be considered as an incomplete pathway.
- MDEQ stated that it was premature to make decisions on completed pathways if the plume had not yet been delineated.
- USACE and MDEQ agreed that all decisions on the completed pathways (i.e., those to be evaluated in the risk assessment) will be made after the extent and stability of the plume is defined.
- USACE and MDEQ agreed to include a "potential" residential receptor in the Conceptual Site Model to be presented in the RI/FS Work Plan. The hypothesis regarding the completeness of the residential receptor pathway will be framed as a Data Quality Objective to be included in the Work Plan (e.g., if the extent of the plume is found to be within the boundaries of the National Forest and the plume is shrinking/stable [i.e., not growing], then the residential pathway will be considered to be incomplete).
- If during the field work it is determined that the plume is impacting or may be impacting existing residential receptors, then USACE will conduct sampling of the residential wells.
- If the RI data does not allow for a definitive characterization of a stable/shrinking plume, or indicates that the plume may eventually reach a residential receptor, a remedy or contingent remedy would be accounted for in future documents (Decision Document) based on the extent of the plume, the dynamics of the plume, and the long-term potential impact of the plume.

QAPP Worksheet #10 – Conceptual Site Model

The following is a brief synopsis of information known about the project site. More details can be found in Section 2 (Site Description and Physical Setting) and Section 3 (Previous Investigations and Remedial Investigation Approach) of the RI/FS Work Plan (USACE 2014b). A graphical representation of the Conceptual Site Model is shown in Figure B-1.

Site Location, History and Land Use

The former Raco Army Airfield (AAF) and Missile Site (Raco Site) is located in Chippewa County, Michigan, in the Hiawatha National Forest 18 miles southwest of Sault Ste. Marie. The Department of Defense (DoD) used the site as an airfield for 21 years and as a missile base for approximately 13 years, ending in 1972. The site historically consisted of three 5000-foot runways oriented in a triangular configuration, the Fuel Depot east of the airfield, and the Missile Battery Area (MBA) located southeast of the airfield (see inset map, Figure B-1). The MBA included 28 Bomarc missile silos and associated support facilities. The focus of the RI/FS is in the northeastern portion of the former Raco MBA in the vicinity and east of the former wastewater lagoon where previous investigations have identified a trichloroethene (TCE) plume (Figure B-1 and B-2).

The former Raco AAF and Missile Site property consisted of 1,825.94 acres acquired between 1942 and 1945 via various transfer permits, licenses, leaseholds, easements, and fee purchases. Part of this acreage, a 600-acre parcel, was transferred from the Fort Brady Target Range [now Formerly Used Defense Sites (FUDS) Property E05MI0005]. Therefore, the 600-acre parcel is included with the Raco AAF and Missile Site (FUDS Property E05MI0026) and excluded from E05MI0005 as duplicate acreage. The Raco AAF was constructed between 1942 and 1943 east of the current FUDS Property E05MI0005.

Around 1960, the missile base was constructed southeast of the airfield. Between 1962 and 1964, the Air Force released all property interests to the United States Forest Service (USFS) except for the 152.54-acre missile area and an additional 5-acre area. On 30 June 1973 and 24 March 1976, respectively, these 152.54-acre and 5-acre areas were released to the USFS. Since that time, the property has remained under USFS jurisdiction. With the exception of the runways and some associated tarmac/hardstands, the original structures have all been removed, and the silos have been filled in and covered. The airfield runways and other portions of the site are currently used during the winter months for automobile tire testing by Smithers Scientific Services, Inc. (Smithers). The remainder of the site is vacant.

The Raco Site, specifically the airfield runways and the MBA, is leased by Smithers for industrial purposes. However the surrounding area is managed by the USFS to provide wildlife habitat for various avian species, conifer timber products, and public recreation areas. Because of its location within the National Forest System, the Raco Site is likely to remain publicly owned and part of the Hiawatha National Forest in the future. It should be noted that there are privately owned tracts of land within the Hiawatha National Forest, one of which is located approximately one mile east and a second is about 1.5 miles southeast of the Raco Site (see inset maps in Figures B-1 and B-2). According to the Chippewa County on-line parcel records database, the tracts to the east consist of residential parcels while the tracts to the southeast consist of residential and commercial forest properties.

Geology

The Raco Site lies in an extensive region covered by Quaternary post glacial outwash. The sediments underlying the site have been described by boring logs from previous investigations (generally less than 100 feet deep) as consisting of homogeneous fine to very fine sands with traces of silt and gravel. However, drilling logs for water supply wells approximately one mile north of the former Raco MBA indicate the increasing presence of sandy-silty clay lithologies at depths within the range of 70-140 feet below ground

surface (bgs). This observation suggests that finer grained sediments may also be present at similar depths at the former Raco MBA. This observation also is consistent with a transition to lacustrine sediments to the east of the Raco Site, where there is a thinning and disappearance of the surficial sands within 4-8 miles and the growing importance of clay-dominant lithologies (Farrand and Bell 1982).

Hydrogeology

The water table at the Raco Site occurs at a depth of 35 to 55 feet bgs at an elevation of approximately 850 – 860 feet above mean sea level (amsl). Monitoring wells are present with depths ranging from 35 to 130 feet bgs and are constructed with 10-foot screens. Potentiometric maps from previous investigations dating back to 1987 consistently show groundwater flowing in an easterly to southeasterly direction with a lateral gradient of approximately 0.002 feet/feet.

The Raco Site is at an elevation of about 900 ft amsl. However, in a direction consistent with the inferred groundwater flow direction to the east-southeast of the MBA the ground surface elevation drops steadily (Figure B-1).Within one mile from the former Raco MBA in this direction the ground surface is at an elevation of 850 feet; within an additional 0.5 mile surface streams draining to the southeast as well as associated wetlands are encountered. These surface drainage features suggest that this is a regional discharge area for groundwater originating in the upland region located to the west that also includes the Raco Site.

Measurement of hydraulic conductivity values for sediments underlying the Raco Site have been performed in 11 wells by slug testing in prior investigations. However, the testing performed in all but one well (MW-08) appears to have yielded results of limited reliability. The hydraulic conductivities measured at MW-08 ranged from 1.3 - 1.5 x 10^{-3} cm/sec (IT 1991). Using the upper bound of the hydraulic conductivity measured in MW-08, the estimated hydraulic gradient (0.002 feet/feet) and porosity of 30%, the estimated groundwater velocity is 10.4 feet/year. There is uncertainty in this estimate because this is based on only one reliable measurement of hydraulic conductivity for the Raco Site.

Contaminant Source(s)

Previous investigations have established the presence of a TCE groundwater plume that emanates from the Raco MBA (Figure B-1 and B-2). Soil borings at multiple locations have been drilled to find the source(s) for the groundwater plume. However, TCE has only been detected in one boring location, SB-08 (see Figure 7 in RI/FS Work Plan for borehole location), at a depth of 20 feet and at a very low concentration [0.55 micrograms per kilogram (µg/kg)]. Active TCE sources, including dense non-aqueous phase liquids, were not found at the former Raco MBA during any of the previous investigations. Although TCE contaminant source(s) have not been identified, groundwater monitoring results indicate that the source(s) most likely lie within the general area between the former Assembly Maintenance Building and the former wastewater lagoon (Figure B-1 and B-2, refer to Figure 3 in RI/FS Work Plan for a more detailed site layout). It is possible that the original source(s) are now exhausted of TCE through gradual dissolution by infiltrating precipitation over the past 40 to 50 years. If so, then leaching of TCE from sources in the vadose zone may no longer occur and the plume will gradually evolve from an initial growth phase through stabilization and eventually begin to shrink in size. Currently, there is insufficient concentration versus time data from site monitoring wells to determine the evolutionary phase of the TCE plume.

Contaminant Distribution, Fate and Transport

Groundwater TCE data obtained from previous investigations partially defines the lateral and vertical extent of the TCE plume at the former Raco MBA. A TCE concentration of 5 µg/L, the maximum contaminant level (MCL), is used to define the plume boundary. Current information bounds the western, northern and southern extent of the plume, which extends eastward for a distance of approximately 400 to

500 feet with no data to delineate the TCE plume east of MW-27 (Figure B-2). The width of the defined portion of the plume is approximately 225 feet.

Although the groundwater flow direction at the Raco Site is east-southeast, recent investigations as part of the Michigan Groundwater Inventory Mapping Project (2005) suggest that groundwater flow within a distance of one mile to the east of the former Raco MBA is more southeasterly and may steer plume transport in that direction. Thus, sampling efforts to delineate the eastern end of the TCE plume must be versatile enough to address this possible change in plume migration pathway.

The Vertical Aquifer Profile (VAP) investigation performed in 2009 (GEO 2010) provided evidence for a downward component to TCE transport at the site. During this investigation, VAP boreholes were drilled from which groundwater samples were collected at discrete depth intervals and analyzed on-site in a mobile laboratory. The highest TCE concentrations were measured in VAP locations VSB-08, VSB-03, and VSB-10, which appear to lie along the plume axis (Figure B-2). The TCE versus depth profiles from these VAP locations (Figure B-3) define a 40-foot thick plume that is descending linearly to the east at a rate of approximately 1 foot for every 10 feet of lateral distance. This descending transport pattern needs to be considered when delineating the plume to the east of VSB-10/MW-27. The Raco Site is located on a plateau of glacial outwash at an elevation of 900 feet amsl. The ground elevation drops off relatively quickly to the east and within about one mile at an elevation of approximately 850 feet amsl discharge of groundwater occurs and feeds streams draining to the east as well as some wetlands (see Figure 5 of the RI/FS Work Plan). These characteristics suggest a downward groundwater flow in the upland area where the TCE plume at the former Raco MBA is located.

As noted earlier, groundwater velocity was estimated at ~10.4 feet/year using the only reliable measurement of hydraulic conductivity at the former Raco MBA. In addition to groundwater velocity, contaminant transport for TCE is strongly influenced by sorption to natural organic matter. Currently, there are no measurements of natural organic carbon for aquifer materials at the Raco Site. Such measurements are needed to estimate TCE sorption and how it may impact contaminant transport rates for the TCE plume. TCE is also known to degrade, most commonly observed as occurring through microbial reductive dechlorination under anaerobic conditions although abiotic degradation has also been reported. Dissolved oxygen levels and oxidation-reduction potentials measured to date suggest aerobic conditions are prevalent in groundwater at the former Raco MBA. Furthermore, TCE reductive dechlorination products, cis- and trans-1,2-dichloroethene (DCE) as well as vinyl chloride, have never been detected at the site. However, as the plume moves deeper (Figure B-1 and B-3), geochemical conditions may be more anaerobic and favorable for TCE degradation by reductive dechlorination.

Potential Receptors

It was previously noted that publicly owned land within the Hiawatha National Forest east and southeast of the Raco Site (along the groundwater flow direction) is unlikely to be transferred to private ownership. The only potential residential receptors down-gradient of the Raco MBA TCE plume are current and future residents in privately owned properties located one to 1.5 miles east and southeast of the site (see inset maps in Figure B-1 and B-2). Residential water wells are known to be present in the properties southeast of the site (see inset map in Figure B-1). Based on currently available information, the TCE groundwater plume at the former Raco MBA appears to be oriented in a direction towards the residential properties to the east (Figure B-1); there are currently no residential water wells known to be present in this area although residential wells may be installed in the future. The potential exposure of these residents to contaminated groundwater only can be evaluated when the plume is fully delineated and temporal data are available for assessing the state of the plume (i.e. growing, shrinking, or stable). Thus, obtaining both kinds of information is essential in order to assess the extent and stability of the plume and to fully characterize risks associated with it.

Data Needs

Based on the current information about the Raco Site and the TCE groundwater plume at the former Raco MBA, the following is a list of data needed to fulfill the overall purpose of the RI/FS.

- Horizontal delineation east of the defined TCE plume (i.e., east of MW-27, see Figure B-2) and vertical delineation to a concentration of 5 µg/L
- TCE concentration versus time from multiple monitoring wells within the plume that can be used to evaluate the evolutionary phase of the TCE plume (i.e., growing, shrinking, stable)
- The status of natural attenuation at the site and whether such mechanisms can potentially be relied on for clean-up of the TCE groundwater plume
- Aquifer properties which are needed to predict TCE transport as well as to select and evaluate the feasibility of remedial alternatives.

QAPP Worksheet #11 – Project/Data Quality Objectives

This worksheet is used to develop and document Data Quality Objectives (DQOs) following guidelines based on U.S. Environmental Protection Agency's (USEPA's) 7-step DQO process.

1. State the Problem.

A trichloroethene (TCE) groundwater plume is present at the former Raco Missile Battery Area (MBA). Additional data are needed to achieve the overall purpose of the Remedial Investigation (RI)/Feasibility Study (FS) which is to characterize the nature and extent of risks posed by the TCE groundwater plume and to evaluate remedial options. An active source for this plume has not been found despite multiple investigations. It is possible that the original source(s) are now exhausted of TCE through gradual dissolution by infiltrating precipitation over the past 40 to 50 years. Currently, there is insufficient concentration versus time data from site monitoring wells to determine the evolutionary phase of the TCE plume which would help confirm that active source(s) are no longer present. The western, northern and southern boundaries of the plume have been delineated to a concentration of 5 µg/L, however the leading eastern edge of the plume needs to be horizontally and vertically delineated. Plume delineation and stability are needed to determine the completeness of the exposure pathway to the closest residential receptors that are more than one mile down gradient from the Raco MBA. Data are needed to adequately assess the status of natural attenuation. Aquifer properties are required for TCE fate and transport calculations as well as to facilitate the identification of remedial alternatives.

2. Identify the Goals of the Study.

As noted in the Introduction to this Quality Assurance Project Plan (QAPP), the goals of the RI field activities are (1) to horizontally and vertically delineate the boundary of the TCE groundwater plume to a concentration of 5 µg/L, (2) to perform an initial evaluation of the temporal stability of the TCE groundwater plume and the potential for natural attenuation, (3) to conduct a Baseline Risk Assessment (BLRA) to quantify risks from exposure to TCE-impacted groundwater, (4) to identify and evaluate potential remedial alternatives that may be implemented if there are unacceptable risks, and (5) to collect a sufficient quantity of hydrogeologic information and engineering data during the RI field work that will allow an evaluation of remedial alternatives in the FS.

3. Identify Information Inputs.

Data inputs include:

- Groundwater contaminant concentration data from a sufficiently dense sampling network on the eastern/leading edge of the plume that can be used to establish current extent relative to a target concentration of 5 µg/L.
- Groundwater concentration versus time data for the most highly contaminated portions of the plume to assess the current status of the plume (i.e., growing, stable, diminishing in size).
- Groundwater concentration data that most closely represents concentrations in drinking water for quantitative risk assessment.
- Standard set of geochemical parameters to screen for Monitored Natural Attenuation (MNA). These include: pH, temperature, dissolved oxygen, oxygen-reduction potential, anions (chloride, nitrite, nitrate, sulfate), ferrous iron, dissolved gases (methane, ethene, ethane, carbon dioxide), alkalinity, sulfide, and dissolved organic carbon. TCE dechlorination products will also being analyzed.

- Carbon isotope ratios (expressed as $\delta^{13}C$) for TCE to help determine whether abiotic or microbiological degradation is occurring. A limited number of analyses (6) are planned based on cost and because this is a screening evaluation.
- Microbiological data to determine the presence of microorganisms known to degrade TCE and its dechlorination products. A limited number of analyses (4) are planned based on cost and because this is a screening evaluation.
- Measurement of aquifer properties and data relevant to groundwater flow and contaminant transport including: hydraulic conductivity, groundwater water levels, and soil total organic carbon content (to estimate contaminant sorption coefficients).
- Visual logging of soils as well as soil grain size distribution analysis to detect any changes in subsurface lithology with depth that can influence TCE migration and biogeochemical conditions. Finer grained soil will result in lower hydraulic conductivities that will slow contaminant transport but also will make active remediation more challenging. Existing geochemical data which are mostly from depths less than 100 feet suggest oxidizing conditions; however reducing conditions suitable for dechlorination may become more prevalent with lower hydraulic conductivities if clay content increases with depth.

4. Define the Boundaries of the Study.

The study will focus on the TCE plume area and the area to the east of the defined portion of the plume. Groundwater monitoring will focus on wells within the TCE plume area. Existing monitoring wells on the periphery of the plume that have been sampled multiple times with TCE concentrations below 5 µg/L will not be sampled during the RI. Existing monitoring wells selected for sampling are listed in Worksheet #17 and shown in Figure B-2. Multiple investigations have been conducted at the Raco Site and only TCE has been detected above screening criteria and only in groundwater. As such, the target analytes are TCE and its dechlorination products: cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-DCE and vinyl chloride. No soil sample analyses for TCE are planned because multiple investigations have already been performed towards locating source(s) for the TCE plume and revealed no evidence of the presence of active TCE sources.

5. Develop the Analytic Approach.

The primary parameters of interest in this investigation are TCE and its dechlorination products (cis-1,2-DCE, trans-1,2-DCE and vinyl chloride) in groundwater. It should be noted that none of the dechlorination products have ever been detected at the Raco Site, although these are retained as parameters of primary interest because their presence is an indicator of natural degradation mechanisms. For plume delineation, concentration data obtained from the analysis of groundwater point-in-time samples such as the Vertical Aquifer Profile (VAP) groundwater sampling system will be used. Given the depth of the plume (greater than 100 feet on the eastern end), groundwater sampling from boreholes rather than permanent monitoring wells is a cost effective means for obtaining groundwater concentration data at a spatial density that will allow for reasonable confidence in plume delineation. Groundwater concentration data from monitoring wells along the plume axis (i.e., the most highly contaminated zone) will be used for plume stability and quantitative risk assessment. Groundwater samples from monitoring wells will be used for quantitative risk assessment since these more likely represent drinking water, when compared to groundwater point-in-time samples which may have very high turbidity based on previous investigation (GEO 2010). TCE groundwater concentrations will be used in making decisions relevant to the RI/FS as shown in the table of DQOs listed at the end of this Worksheet. Other parameters of interest in this study and used for decisions are: (1) the standard set of MNA screening parameters, (2) population estimates for TCE-degrading microbes (if present), and (3) $\delta^{13}C$ for TCE in selected monitoring wells. Water levels, hydraulic conductivity, groundwater velocity, and soil organic carbon content will be measured but will not

be directly used in any decision process. DQOs and decision statements are listed in the table at the end of this Worksheet.

6. Specify Performance or Acceptance Criteria

- Plume delineation will be based on groundwater samples collected from VAP boreholes to be located using a drilling strategy outlined in Worksheet #17 that integrates available historical data and information regarding the site to predict the likely horizontal and vertical trajectory of the TCE plume. Plume delineation will be based on the maximum contaminant level (MCL) for TCE (5 µg/L). If any of the TCE dechlorination products are detected, the target delineation concentration will be the MCLs for these constituents (see Worksheet #15 for reference limits).
- Analytical results for groundwater samples [excluding the compound specific isotope analysis (CSIA) and CENSUS analyses] from the off-site fixed-base laboratory will undergo third party data validation. Analytical results that are rejected by the third-party data validator will be reported as such and not used for any decisions, trend analyses, or risk calculations.
- The completeness of the analytical data package (to be calculated as detailed in Worksheet #37) shall be greater than 95%.
- If statistical analyses of data require the selection of significance levels, a 5% significant level will be used.

7. Develop the detailed plan for obtaining data.

The following RI field activities are planned (also listed in the RI/FS Work Plan, USACE 2014b):

- A Verification Sampling Event of selected existing monitoring wells to determine the potential for plume movement since prior sampling events (2009), and to evaluate whether the VAP drilling strategy [described in the Field Sampling Plan (FSP)] needs to be modified. Data also will be used for future trend analysis. Groundwater samples will be collected from eight existing wells within and on the margin of the TCE Plume at the Raco Site (see Worksheet #17). Water levels will be measured to develop a potentiometric surface map. Field water quality parameters will be measured in groundwater and used to document compositional stability before samples for VOC analysis are collected. Groundwater samples will be sent to an off-site fixed-based laboratory for analysis of TCE and dechlorination products (cis-1,2-DCE, trans-1,2-DCE and vinyl chloride). An Abbreviated Work Plan (USACE 2014a) was prepared separately from the RI/FS Work Plan in order to expedite the review process and enable sampling in Spring 2014.
- VAP and monitoring well installation (Summer 2014)
  - VAP borehole drilling and groundwater sampling using sonic drilling methods and a push-ahead groundwater sampling tool for TCE plume delineation. VAP boreholes will be advanced every 10 feet by rotosonic drilling; a 2-foot push-ahead sampler will be advanced for VAP groundwater sampling. Groundwater samples will be collected and analyzed for TCE and dechlorination products at an on-site mobile laboratory. The VAP boreholes will be located east of the existing monitoring wells in the previously un-delineated portions of the TCE plume (Figure B-1). VAP boreholes will be drilled and groundwater samples for on-site analysis will be collected until the TCE plume is delineated to 5 µg/L (refer to Worksheet #17 for drilling strategy and decision process to be used in plume delineation). Continuous soil cores will be collected from the VAP boreholes and logged. In addition soil samples will be collected and analyzed for grain size distribution and total organic carbon by off-site fixed-base laboratories.

  - Installation and development of up to six monitoring wells in selected VAP boreholes. Well construction details (e.g., the depth of the 10-foot well screens) will be based on VAP groundwater data obtained from the boreholes. The new monitoring wells will be developed and surveyed.
  - If there is excess rotosonic drilling capacity after the plume has been delineated (i.e. if less than the project drilling capacity, total of 2400 lineal feet of drilling, has occurred), nested piezometers may be installed to provide vertical groundwater gradient information that may be useful in the FS.
  - An ecological reconnaissance will also be conducted to evaluate the presence of ecological resources at the site.

- Two rounds of groundwater sampling (approximately six months apart) in a combination of existing and newly installed monitoring wells. Field water quality parameters and water levels will be measured during each event. Groundwater samples during both events will be sent to an off-site laboratory for analysis of TCE and dechlorination products. During both events, a subset of monitoring wells will be sampled for analysis of the standard MNA parameters by field methods and in an off-site laboratory. In addition to sampling for TCE, dechlorination products and MNA parameters, the following additional activities are planned.
  - During the Fall 2014 sampling event, slug tests will be performed in five monitoring wells to measure hydraulic conductivity.
  - During the Spring 2015 sampling event, a subset of monitoring wells will be sampled for CSIA to measure $\delta^{13}C$ for TCE, and CENSUS analysis to quantify populations for known TCE-degrading microbes. CENSUS analysis is a recently developed Molecular Biological Tool (MBT) for quantifying microbial populations based on deoxyribonucleic acid (DNA) analysis.

The following DQOs/decision statements have been proposed:

Area	DQO/Decision Statement
TCE Plume Delineation and Stability	1. If TCE concentrations in groundwater samples from VAP boreholes at the plume's leading edge are below 5 µg/L, then plume delineation has been completed. Within a VAP borehole where TCE is detected at greater than 5 µg/L, the depth of contamination will be considered delineated when TCE is not detected [< 0.25 µg/L; mobile laboratory's Limit of Detection (LOD)] in VAP groundwater samples from two successive depth intervals, or if TCE is < 5 µg/L and not detected in VAP groundwater samples from two successive depth intervals. If TCE is not detected in any groundwater sample from a VAP borehole to a depth as much as 30 feet below the extrapolated maximum depths (see Worksheet #17 for maximum depth calculation), drilling will be terminated. Worksheet #17 also contains a flow chart that graphically illustrates the VAP drilling strategy and the decision process for horizontal and vertical plume delineation. 2. If TCE concentrations in monitoring wells associated with VAP boreholes installed in 2009 have changed (< 50% relative percent difference[2]) between 2009 and 2014-2015, then the VAP groundwater sample data from 2009 field work can be combined with 2014-2015 field data to develop a 3-dimensional

[2] The data set, which consists of sampling results from 4 monitoring wells, will be too small to conduct reliable statistical comparisons between the 2009 and 2014/2015 data. Agreement will be evaluated in a judgmental manner using a criterion of 50%.

Area	DQO/Decision Statement
	configuration of the TCE plume. An exception to this rule will be made for VSB-10/MW-27. The October 2009 groundwater sample collected from MW-27 was much lower (16 µg/L) than the maximum concentration measured in VSB-10 (61 µg/L in the mobile laboratory, 55 µg/L confirmed by the off-site fixed-based laboratory) (see Table 6 in the RI/FS Work Plan for analytical data from these VAP boreholes). Because the TCE profile in VSB-10 matched profiles from upgradient boreholes (see Figure B-3), the VSB-10 TCE concentrations are considered a more reliable measure of actual contaminant conditions in the aquifer than the October 2009 result from MW-27. Thus, if the TCE concentration is higher in MW-27 when sampled in 2014-2015, this will not be considered indicative of a change in plume configuration. 3. An initial temporal statistical trend analysis will be completed on monitoring wells with 4 or more sampling data points. a. If there is no statistically significant negative or positive trend, then plume appears to be stable. b. If there is a statistically significant negative trend in monitoring wells closest to the suspected source of the plume, then there is no ongoing source. c. If there is a statistically significant positive trend in monitoring wells closest to the suspected source of the plume, then this suggests the presence of a sustained plume source to be further evaluated (e.g. during a pre-design investigation). d. If there is no statistically significant trend and concentrations have been <5 µg/L, removing the monitoring well from future monitoring will be discussed. Further trend analysis will be performed as more data are collected during remedy implementation and/or long-term monitoring.
Monitored Natural Attenuation	1. If TCE degradation products are present, then it will be considered evidence for TCE degradation. 2. If screening criteria for MNA are met in accordance with the USEPA protocol (Wiedemeier et al. 1998), MNA will be considered as a potentially viable remedial alternative. 3. If there is an overall increase in $\delta^{13}C$ greater than 2 per mil for TCE in groundwater for monitoring wells along the plume axis/flow path, this will be considered qualitative line of evidence for TCE degradation (USEPA 2008). 4. If CENSUS/MBT analysis of groundwater obtained from monitoring wells within the TCE plume indicates the presence of TCE-dechlorinating microbial species, then it will be considered a qualitative line of evidence for potential TCE degradation. 5. If there is no evidence for TCE degradation, physical processes such as sorption, diffusion, dilution, and dispersion are the primary forms of natural attenuation occurring at the site.
Risk Assessment	1. Target analytes will include: TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride.

Area	DQO/Decision Statement
	2. If the TCE plume is found to be within the boundaries of the National Forest, does not extend to the residential properties east and southeast of the former Raco MBA (inset map in Figure B-1), and is shrinking/stable, the residential exposure pathway will be considered incomplete. 3. USEPA Regional Screening Levels (RSLs) for Residential Tap water will be used for screening to identify Chemicals of Potential Concern. If an analyte concentration exceeds the USEPA RSL in a monitoring well sample, it will be carried forward into the quantitative risk assessment, with the exception of vinyl chloride which has an RSL of 0.015 µg/L. Vinyl chloride will be carried forward into the quantitative risk assessment if it is detected above the off-site fixed-based detection limit of 0.5 µg/L. For reference, the MCL for vinyl chloride is 2 µg/L. 4. Exposure Point Concentrations will be estimated from 2009-2015 monitoring well data.
Determination of Need for Remedial Action and Identifying Remedial Alternatives	1. If trend analysis of TCE monitoring well data within the TCE plume indicates that the plume is growing, and the source shows no sign of becoming exhausted, then remedial action may be appropriate for the source/plume. 2. If there is a currently complete exposure pathway to receptors, and the Incremental Lifetime Cancer Risk from exposure exceeds 10^{-5} and/or the Hazard Index is greater than 1, then remedial action is warranted. 3. If evidence does not show the plume to be expanding, or it is expanding but not anticipated to reach a receptor within 50 years[3], and there are no unacceptable risks to current receptors, then MNA (with a contingency active remedy) will be evaluated as a viable remedy.
Management of Decision Errors	Decision errors and how these will be managed are described below: 1. *The TCE plume axis is used to design the plume delineation sampling strategy (described in Worksheet #17 and the FSP, Appendix A of the RI/FS Work Plan); this axis may have potentially shifted since the last sampling in 2009 (GEO 2010).* To address this potential source of error, verification sampling of selected wells (see Worksheet #17 for wells to be sampled) will be completed (currently planned for April 2014) as far in advance of the main RI field work as possible (currently scheduled for Summer 2014) such that potential plume axis shifts can be considered in the drilling strategy of the RI. Verification samples will be analyzed by a fixed-base laboratory certified by the Environmental Laboratory Accreditation Program (ELAP). A Verification Sampling Event Work Plan has been prepared separately (USACE 2014a). 2. *Spatial density of groundwater data may not sufficiently capture the horizontal and vertical extent of the TCE plume.* This decision error will be managed by groundwater sampling from VAP boreholes (up to 2400 lineal feet total drilling depth) at successive 10 foot depth increments and analyzed by an on-site mobile-laboratory, with appropriate Quality Assurance/Quality Control (QA/QC) controls in place (field duplicates, matrix spike/matrix spike duplicates). Assuming an average drilling depth for each VAP borehole of 200 feet, the 2400 lineal feet of drilling capacity will result in 12 VAP boreholes.

[3] If the plume is not shrinking, a waiver will be required from MDEQ to approve an MNA approach.

Area	DQO/Decision Statement
	3. *In analysis of VAP groundwater samples and monitoring well samples, TCE and the dechlorination products are reported as being below their respective MCLs when the true concentrations exceed the standards.* This decision error is addressed as follows: a. Analysis for TCE and its dechlorination products in groundwater samples from both VAP boreholes and monitoring wells will be performed using USEPA Method 8260. Both the off-site fixed-base and on-site mobile laboratories are ELAP-accredited and perform analyses in accordance with the Department of Defense (DoD) *Quality Systems Manual for Environmental Laboratories* (QSM, DoD 2010). The off-site fixed based laboratory (CT Laboratories) that will be analyzing the groundwater monitoring well samples will be in compliance with the updated DoD QSM (DoD 2013) in June 2014. b. The Method Limit of Quantitation (LOQ) is 10 times lower than the target delineation concentration of 5 µg/L for TCE (see Worksheet #15 for reference concentrations for dechlorination products of TCE).
	4. *Sampling locations for groundwater to evaluate plume stability may not be located within the most contaminated zone of the TCE plume.* To manage this decision error, monitoring wells (up to 6) to be installed as part of the RI will be located based on the on-site analyses of groundwater samples from VAP boreholes. The 10-foot screened interval will be set to intercept the highest TCE concentrations in the VAP borehole. The 10-foot screen for the new monitoring wells is consistent with existing monitoring wells.
	5. *Temporal data from monitoring wells located along the plume axis with the highest TCE concentrations are currently not adequate for trend analysis.* To date, the monitoring wells with the highest TCE concentrations are MW-19, MW-26 and MW-23 (see Figure B-2 for well locations). These wells will be sampled during the Verification Sampling Event and two rounds of groundwater sampling to be conducted as part of the RI. USACE and Michigan Department of Environmental Quality (MDEQ) concurred on two rounds of groundwater sampling (spaced 6 months apart) for the RI during a scoping session on August 6, 2013 (see Worksheet #9). The monitoring wells selected for sampling are listed in Worksheet #17. Groundwater samples will be analyzed by a fixed-base laboratory with appropriate QA/QC controls in place (field duplicates, matrix spike/matrix spike duplicates).
	6. *Exposure point concentrations used in the risk assessment underestimate true exposure.* To address this error, the exposure point concentration will be set to the 95% upper confidence limit of the mean concentration calculated from 2009-2015 monitoring well groundwater data within designated groundwater exposure units. The latter will be defined based on data to be collected during the RI (see Section 4.4: Baseline Risk Assessment Methods) of the RI/FS Work Plan).
	7. *The TCE plume is inferred to be stable or shrinking at the conclusion of the RI/FS when it is actually growing.* This decision error will be managed as follows:

Area	DQO/Decision Statement
	a. Non-parametric (e.g., Mann Kendall) and parametric (e.g., linear regression) trend analysis will only be applied to monitoring wells with at least four sampling events. The Verification Sampling Event and first and second groundwater sampling events will be conducted as far apart in time as possible while still meeting the target schedule for the RI/FS project (see Worksheet #16). The trend analysis will include all available historical data from monitoring wells located within the TCE plume (see Figure B-1 for well locations). b. The uncertainty in the trend analysis will be discussed in the RI report, considered in the FS, and discussed in the FS report. c. Additional sampling may be performed as part of the Remedial Design phase and/or Remedial Action; this will be discussed in the Proposed Plan and Decision Document (see scoping session notes for September 26, 2013 in Worksheet #9). 8. *MNA is the selected remedy for the site, however subsequent monitoring during remedy implementation suggests it is not occurring.* This decision error will be managed by a strong long-term monitoring program and contingency plan to be described in the Decision Document (see scoping meeting notes for August 6, 2013, Worksheet #9).

QAPP Worksheet #12 – Measurement Performance Criteria

Matrix: Water
Analytical Group/Method: Target VOCs/8260B or 8260C/apply to both off-site fixed-base and on-site laboratory

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Precision – Overall	Field Duplicates	RPD ≤ 30%
Accuracy	Equipment blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater. Common contaminants must not be detected greater than the LOQ.
Accuracy	Method blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater. Common contaminants must not be detected greater than the LOQ.
Accuracy	Trip blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater. Common contaminants must not be detected greater than the LOQ.
Accuracy	Split samples to be analyzed by USACE-selected independent laboratory*	RPD ≤ 30%
Accuracy	LCSs MSs	TCE: %Recovery 79 – 123% Cis-1,2-DCE %Recovery 78 – 123% Trans-1,2-DCE %Recovery 75 – 124 % Vinyl chloride 58 – 137% (DoD 2013 Table 24)
Sensitivity	MDL studies conducted at initial method set-up and verified annually	Method LOQ < 10-20% of the MCL (see Worksheet #15)
Precision – Laboratory	Matrix spike duplicates	RPD ≤ 30%

MCL – maximum contaminant level; MDL – Method Detection Limit; MS – matrix spike; LCS – laboratory control sample; LOQ – Limit of Quantitation; RL – Reporting Limit; RPD – Relative percent difference; RSL – Regional Screening Level; TCE – trichloroethene (USEPA 2013, also in Worksheet #15)
Target VOCs (volatile organic compounds): Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride

QAPP Worksheet #12 – Measurement Performance Criteria (continued)

Matrix: Water
Analytical Group/Method: Anions/9056A

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Accuracy	Method blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample
Accuracy	LCSs	Chloride: %Recovery 87 – 111% Nitrite: %Recovery 87 – 111% Nitrate: %Recovery 88 -111% Sulfate: 87 – 112% (DoD 2013, Table 41)
Sensitivity	MDL studies conducted at initial method set-up and verified annually	LOQs comparable to or less than the minimum limit of quantitation provided in Table 2.2 of the USEPA MNA screening protocol (Weidemeier et al. 1998) (see Worksheet #15)

DoD – Department of Defense; LCS – laboratory control sample; LOQ – Limit of Quantitation; MDL – Method Detection Limit; MNA – Monitored Natural Attenuation; RL – Reporting Limit; USEPA – U.S. Environmental Protection Agency
Anions: Chloride, nitrite, nitrate, sulfate

QAPP Worksheet #12 – Measurement Performance Criteria (continued)

Matrix: Water
Analytical Group/Method: Dissolved Organic Carbon/9060, Sulfide/9034

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Accuracy	Method blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample.
Accuracy	LCSs	%Recovery 80 – 120%
Sensitivity	MDL studies conducted at initial method set-up and verified annually	LOQs comparable to or less than the minimum limit of quantitation provided in Table 2.2 of the USEPA MNA screening protocol (Weidemeier et al. 1998) (see Worksheet #15)

LCS – laboratory control sample; LOQ – Limit of Quantitation; MDL – Method Detection Limit; MNA – Monitored Natural Attenuation; RL – Reporting Limit; USEPA – U.S. Environmental Protection Agency

Matrix: Water
Analytical Group/Method: Alkalinity/310.2

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Accuracy	Method blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample.
Accuracy	LCSs	%Recovery 90 - 110%
Sensitivity	MDL studies conducted at initial method set-up and verified annually	LOQs comparable to or less than the minimum limit of quantitation provided in Table 2.2 of the USEPA MNA screening protocol (Weidemeier et al. 1998) (see Worksheet #15)

LCS – laboratory control sample; LOQ – Limit of Quantitation; MDL – Method Detection Limit; MNA – Monitored Natural Attenuation; RL – Reporting Limit; USEPA – U.S. Environmental Protection Agency

QAPP Worksheet #12 – Measurement Performance Criteria (continued)

Matrix: Water
Analytical Group/Method: Dissolved Gases/RSK 175

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Accuracy	Method blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample.
Accuracy	LCSs	Methane : %Recover 73 – 125% Ethane: %Recovery 74 – 131% Ethene: %Recovery 72 – 133% Carbon dioxide: %Recovery 8- - 122% (DoD QSM 2013, Table 42)
Sensitivity	MDL studies conducted at initial method set-up and verified annually	LOQs comparable to or less than the limit of quantitation provided in Table 2.2 of the USEPA MNA screening protocol (Weidemeier et al. 1998) (see Worksheet #15)

DoD – Department of Defense; LCS – laboratory control sample; LOQ – Limit of Quantitation; MDL – Method Detection Limit; MNA – Monitored Natural Attenuation; RL – Reporting Limit; USEPA – U.S. Environmental Protection Agency
Dissolved gases: Methane, ethane, ethene, carbon dioxide

Matrix: Water
Analytical Group/Method: Ferrous Iron/Hach 8008

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Sensitivity	Measurement range provided by test kit manufacturer (Hach)	Lower limit of measurement range must be less than the minimum limit of quantitation provided in Table 2.2 of the USEPA MNA screening protocol (Weidemeier et al. 1998) (see Worksheet #15)

USEPA – U.S. Environmental Protection Agency

QAPP Worksheet #12 – Measurement Performance Criteria (continued)

Matrix: Water
Analytical Group/Method: Water quality parameters

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Accuracy	Daily calibration prior to field use	Satisfy instrument manufacturer calibration criteria
Accuracy	Response verification check at the end of the day	Response must be within instrument specifications
Sensitivity	Instrument measurement range	Lower limit of measurement range must be less than the minimum limit of quantitation provided in Table 2.2 of USEPA MNA screening protocol (Weidemeier et al. 1998) (see Worksheet #15)

MNA – Monitored Natural Attenuation; USEPA – U.S. Environmental Protection Agency
Water quality parameters: pH, Dissolved Oxygen, Oxidation-Reduction Potential, Temperature, Turbidity

Matrix: Water
Analytical Group/Method: Carbon isotope ratio for TCE (δ^{13}C-TCE)/ Compound Specific Isotope Analysis

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Precision – Analytical	Duplicate analysis of field sample	δ^{13}C-TCE of duplicate must be within 1.0 per mil of original field sample
Accuracy	Method blanks	No detections greater than practical quantitation limit*
Accuracy	Laboratory control samples (LCSs)	Per in-house laboratory control limits

*The practical quantitation limit is defined in the laboratory's analytical SOP for CSIA (available upon request); it is the lowest concentration of TCE for which the range of three replicate δ^{13}C values is less than or equal to 1 per mil.

QAPP Worksheet #12 – Measurement Performance Criteria (continued)

Matrix: Water
Analytical Group/Method: TCE-degrading microbial populations (CENSUS)/Compound Specific Isotope Analysis

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Precision – Analytical	Duplicate analysis of field sample	Duplicate analysis within+/-20% of original sample analysis
Accuracy	Method blanks/Negative controls	Count values for positive samples are set above the negative control
Accuracy	Positive control	Count value within +/-20% of the known value

Matrix: Soil
Analytical Group/Method: Total organic carbon/9060

Data Quality Indicators	Quality Control Sample Used to Assess Measurement Performance	Measurement Performance Criteria
Accuracy	Method blanks	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample
Accuracy	LCSs	%Recovery 80 – 120%

LCS – laboratory control sample; LOQ – Limit of Quantitation; RL – Reporting Limit

QAPP Worksheet #13 – Secondary Data Criteria and Limitations

The table below describes historical data, how it will be used, and any limitations.

Secondary Data	Data Source	Collection Dates	How Data Will Be Used	Limitations on Data Use
Groundwater and soil analytical data	Envirodyne (1987)	1986-1987	Site background	Groundwater samples not collected by low-flow methods.
Groundwater and soil analytical data	IT Corp (1991)	1990-1991	Site background, monitoring well data will be included in future trend analysis for TCE in groundwater	Groundwater samples not collected by low-flow methods.
Groundwater analytical data	Sverdrup (1997)	1996	Site background	Groundwater samples not collected by low-flow methods.
Groundwater analytical data	USACE (2003)	2002	Site background, future trend analysis for TCE in groundwater	None
Groundwater and soil analytical data	Earth Tech (2005)	2003, 2004	Site background, monitoring well data will be included in future trend analysis for TCE in groundwater	None
Groundwater analytical data	GEO (2008) GEO (2010)	June 2007 August 2007 September-October 2009	Plan locations of Vertical Aquifer Profile soil boring locations to delineate the TCE plume. Data will be included in future trend analysis 2009 data to be included in risk assessment	None
Groundwater analytical data	Verification Sampling Event	May 2014	Potentially revising drilling strategy for Vertical Aquifer Profile soil borings; Future trend analysis	None

QAPP Worksheet #14 – Summary of Project Tasks

Sampling and Analysis Tasks:

Refer to Worksheet #11.

Quality Control Tasks: The following Quality Control (QC) samples will be analyzed: method blanks, trip blanks [for volatile organic compounds (VOCs], equipment blanks, field duplicates, and matrix spikes (including a matrix spike duplicate). All analyses will include the required initial calibrations and continuing calibration verifications, as well as instrument blanks, laboratory control samples (LCSs), and all other applicable QC samples defined in the method.

Data Management Tasks: Electronic data deliverables in U.S. Army Corps of Engineers (USACE) Automated Data Review (ADR) format will be submitted by the laboratory; the analytical results will be entered into a Microsoft Access database maintained by GEO Consultants, LLC (GEO), which will then be used to prepare tables of analytical results for inclusion in the Remedial Investigation (RI) report.

Documentation and Records: All samples collected will have global positioning system locations and depth documented in the field logbook. Groundwater monitoring wells will be surveyed. Other sample documentation will include Chain-of-Custody forms, airbills, drilling logs, and groundwater sampling logs.

Data Packages: Data packages will be provided in Contract Laboratory Program format, and will include, but will not be limited to, the following:

- Summary of field sample identifications, laboratory identifications, re-analyses, and dilutions, as well as collection, extraction/preparation, and analysis dates;
- Table of contents;
- The original Chain-of-Custody Record(s);
- Case narrative summarizing any problems with the analysis or the laboratory QC and the corrective action taken;
- Laboratory Certification Statement authorizing release of the sample results signed by the appropriate laboratory designee;
- Definitions of laboratory qualifiers;
- Sample condition upon receipt information;
- Summary of results;
- Summary Forms I through VIII, as specified in the National Functional Guidelines for Organic and Inorganic Data Review;
- Form Is or the summary of results should indicate Method Detection Limit and Method Quantitation Limit; and
- Raw analytical data, as required.

Assessment/Audit Tasks: Daily QC reports documenting compliance with QC procedures, or any problems encountered, will be prepared during the field activities. These reports will be submitted daily to USACE Louisville District (CELRL).

Data Review Tasks: The laboratory will perform a QC review of the data to ensure the validity of the data prior to submittal. The laboratory will perform a minimum of three levels of review to evaluate data generation and reduction. Each level of review requires an evaluation of the data quality based on the results of the QC data and the professional judgment of the data reviewer. Each review will be documented using an appropriate checklist signed and dated by the reviewer. The checklist will specify the items required for review. The minimum required levels of review and the items to be checked for each review are described below.

Level I – Consists of a review of the quality of the analytical work. The analyst who performed the test and has documented training in the method and the laboratory standard analytical requirements performs the Level I review. At a minimum, this review ensures that:

- Sample preparation and analytical results information are correct;
- Appropriate Standard Operating Procedures were followed;
- QC samples are within established limits;
- Data transfers were verified; and
- Documentation is correct and complete.

Level II – Consists of a technical review of the quality of the analytical work. It is reviewed by personnel who did not perform the test and have documented training for the method and laboratory standard analytical requirements. The purpose of this review is to provide an independent, complete peer review of the analytical data package. Level II review requires the review of all calibration data, QC sample results, and analytical results, including the raw data.

Level III – Consists of a total overview of the data package by a laboratory QC officer, supervisor, or other laboratory designee, with documented training on Level III review. Level III review includes the following:

- Spot check of raw data;
- Review of manual integrations and calculations;
- Review of the sample receipt information; and
- Final report verification to ensure compliance with project-specific requirements.

Any errors will be corrected and documented. The Level III reviewer is responsible for final approval of the applicable Laboratory Information Management System. Each level of review will be performed by a different individual. The percentage of data reviewed for each of the three levels will be specified by standard laboratory procedures. In addition to the three levels of

review, the laboratory Quality Assurance (QA) department will review the reporting process for at least 10% of the data produced by the laboratory.

The GEO Technical Manager (or designee) will conduct a review of the analytical data to determine if project Data Quality Objectives have been met and data are usable. In addition, the entire groundwater data package [excluding the compound specific isotope analysis (CSIA) and CENSUS analyses] will be subjected to a full data validation by a third party (i.e., an individual from a laboratory or data validation company not involved in the sample analyses). The data validation report will be submitted to CELRL.

Laboratory Documents and Certifications: Certifications for the contract laboratories can be found in Appendix C of the Work Plan.

QAPP Worksheet #15 – Reference Limits and Evaluation Table

This worksheet presents a comparison of analytical limits against reference concentrations for parameters to be measured in groundwater and compared against standards and screening criteria. Soil samples will be collected for total organic carbon and grain size analyses. The results for these soil analyses will not be compared to criteria and are therefore excluded from this worksheet.

Matrix: Water
Analytical Group/Method: Volatile Organic Compounds/8260B or 8260C

		Fixed-Base Lab (CT Laboratories)			On-site Mobile Lab (ECCS)				
Analyte	**CAS #**	**MDL [µg/L]**	**LOD [µg/L]**	**LOQ [µg/L]**	**LOD [µg/L]**	**LOQ [µg/L]**	**USEPA Tap water RSL[1] [µg/L]**	**USEPA MCL[1] [µg/L]**	**LOQ Acceptable**
cis-1,2-Dichloroethene	156-59-2	0.25	0.25	0.5	0.25	0.5	28	70	Yes
trans-1,2-Dichloroethene	156-60-5	0..25	0.25	0.5	0.25	0.5	86	100	Yes
Trichloroethene	79-01-6	0.21	0.25	0.5	0.25	0.5	0.44	5	Yes
Vinyl chloride	75-01-4	0.18	0.25	0.5	0.25	0.5	0.015	2	Yes [2]

[1] USEPA 2013
[2]The RSL for vinyl chloride is not analytically achievable. The decision limit for this study will be the MCL not the RSL. The sensitivity of the method for VC is adequate because the LOQ is < MCL.
CAS: Chemical Abstract Service; DL: detection limit; ECCS; Environmental Chemistry Consulting Services, Inc. LOD: Limit of Detection; LOQ: Limit of Quantitation; MCL: maximum contaminatent level; MDL: Method Detection Limit; RSL: Regional Screening Level; USEPA: U.S. Environmental Protection Agency; µg/L: micrograms per liter

QAPP Worksheet #15 – Reference Limits and Evaluation Table (continued)

Matrix: Water
Analytical Group: Monitored Natural Attenuation Parameters

Analyte/Method	CAS #	MDL [µg/L]	LOD [µg/L]	LOQ [µg/L]	USEPA MCL[1] [µg/L]	Minimum Limit of Quantification [2] [µg/L]	Method Sensitivity and Range Acceptable
pH/Field water quality meter	None	NA	2-12 SU [3]	NA	None	0.1 SU	Yes
Dissolved oxygen/Field water quality meter	None	NA	0 – 50 mg/L [3]	0.01 mg/L	None	0.2 mg/L	Yes
Oxidation-reduction potential/Field water quality meter	None	NA	-999 to 999 mV [3]	NA	None	-300 to 300 mV	Yes
Ferrous Iron/Hach 8146	None	NA	20	20	None	500	Yes
Nitrate-Nitrogen/9056A	14797-55-8	80	150	400	10000	100	Yes
Dissolved organic carbon/9060	None	NA	100	500	None	100	Yes
Nitrite-Nitrogen/9056A	14797-65-0	100	200	400	1000	None	Yes
Sulfate/9056A	14808-79-8	800	2000	4000	None	5000	Yes
Sulfide/9034	18496-25-8	1000	1000	1000	None	None	Yes
Alkalinity/310.2	None	1070	2000	5000	None	50000	Yes
Carbon dioxide(dissolved)/ RSK 175	124-39-9	220	220	735	None	None	Yes
Methane (dissolved)/RSK 175	74-82-8	0.8	0.8	2.7	None	1	Yes
Ethane (dissolved)/RSK 175	74-84-0	1.1	1.1	3.8	None	1	Yes
Ethene (dissolved)/RSK 175	74-85-1	0.4	0.4	1.3	None	1	Yes

[1] USEPA, 2013; [2]Weidemeier et al. 1998, Table 2.2; [3] Values correspond to instrument range
SU: Standard units; NA: Not applicable
CAS: Chemical Abstract Service; DL: detection limit; LOD: Limit of Detection; LOQ: Limit of Quantitation; MCL: maximum contaminatent level; MDL: Method Detection Limit; mg/L: milligrams per liter; USEPA: U.S. Environmental Protection Agency

QAPP Worksheet #16 – Project Schedule / Timeline Table

The following shows the overall schedule for the Remedial Investigation/Feasibility Study Tasks and is identical to Table 9 of the RI/FS Work Plan. A more detailed schedule that includes document reviews can be found in Appendix E of the RI/FS Work Plan (USACE 2014b).

Task	Approximate Dates
Task 1: Project Management	Throughout project
Task 2: Community Relations	Throughout project
Task 3: RI Field Activities/Data Management/Reporting	April 2014 - March 2016
Verification Sampling Event	May 2014
Vertical Aquifer Profiling and Monitoring Well Installation	Summer (August-September) 2014
First Round , Groundwater Sampling	Fall (September-October) 2014
Second Round, Groundwater Sampling	Spring (April) 2015
RI Report Preparation, Review, Revisions	April 2015-March 2016
Task 4: Baseline Risk Assessment*	April 2015 -March 2016
Task 5: Feasibility Study	March 2016-October 2016
Task 6: Proposed Plan	October 2016-April 2017
Task 7: Decision Document	April 2017-October 2017

*Results will be incorporated into RI Report

.

QAPP Worksheet #17 – Sampling Design and Rationale

This worksheet describes the sampling design for the Vertical Aquifer Profile (VAP) investigation for plume delineation, monitoring well installation, and the subsequent two rounds of groundwater sampling. The sampling design for the Verification Sampling Event was presented in the Abbreviated Work Plan (USACE 2014a) that was prepared separately so that sampling can occur before the Remedial Investigation (RI)/Feasibility Study (FS) Work Plan is finalized.

Groundwater samples from the VAP investigation will be analyzed in an on-site laboratory for trichloroethene (TCE), 1,2-cis-DCE, 1,2-trans-DCE, and vinyl chloride. Groundwater samples to be collected from monitoring wells will be analyzed in an off-site, fixed-based laboratory. A summary of monitoring well sampling locations is presented at the end of this Worksheet.

Drilling Strategy and Rationale for Vertical Aquifer Profile Borehole Locations

The following is an abbreviated discussion of the drilling strategy that is presented in Section 3.2 of the Field Sampling Plan (FSP) (Appendix A of the RI/FS Work Plan).

Figure B-2 illustrates the estimated plume axis, which is a linear fit through the locations of VSB-08/MW-26, VSB-03/MW-23, and VSB-10/MW-27; these were the locations where the highest TCE concentrations were measured during the 2009 investigation (GEO 2010). Figure B-2 also shows the extension of the plume axis for a distance of 600 feet to the east of VSB10/MW-27 and three potential drilling locations (A, B, and C) are identified. The extrapolation of this plume axis beyond the location of VSB10/MW-27 corresponds to an estimate of the plume axis that will persist as long as no deviation of plume migration direction occurs. Each of these locations is progressively 200 feet further to the east.

The 2009 investigation (GEO 2010) also provided information regarding the TCE plume's vertical configuration (Figure B-3). The TCE profile in VSB-08, VSB-03, and VSB-10 descends at a rate of approximately 1 foot per 10 feet of lateral distance. This approximate rate of descent is relative to absolute elevation rather than relative to the ground surface (which generally slopes eastward). Assuming that this approximate rate of descent applies beyond VSB-10, installing a borehole at location A will involve a total drill depth of approximately 170 feet with the TCE profile anticipated to be captured over a depth range of about 130 to 170 feet below ground surface (bgs). If the plume extends beyond location A and the plume axis is assumed to continue on the same trajectory, a VAP borehole at location B will require a total drill depth of nearly 200 feet bgs with an estimated TCE profile depth range of approximately 155 to 195 feet bgs. For location C (not shown in Figure B-2) the estimated total drill depth is projected to be approximately 220 feet bgs with a TCE profile anticipated to be captured between approximately180 to 220 feet bgs.

The first VAP borehole will be placed at location A, 200 feet to the east of VSB-10/MW-27 (Figure B-1). VAP groundwater sampling will commence at a depth of 120 feet bgs (10 feet above the top of the projected profile, see Figure B-3), and will continue at 10-foot intervals (i.e., the drill rod will be advanced 10 feet, then a 2-foot push-ahead VAP groundwater sampler will be advanced 5 feet and a groundwater sample is collected. Figure B-4 presents a flow chart that illustrates the possible outcomes and subsequent steps based on the VAP results at location A, as well as the decision process in selecting subsequent drilling locations. The drilling strategy illustrated in Figure B-4 relies on estimating the plume axis orientation from completed VAPs. The strategy was designed to make use of VAP data collected in the field, and to be flexible enough to capture changes in plume trajectory.

Monitoring Well Installation

The decision to complete a VAP borehole as a monitoring well will be based on the VAP groundwater data obtained from the borehole. The initial approach is to install monitoring wells in those VAP boreholes

where the maximum TCE concentrations exceed 5 µg/L, and to set the 10-foot screens at the depth where the peak in the TCE vertical profile is observed. For VAP boreholes with detectable TCE but with all concentrations less than 5 µg/L, the decision to complete these boreholes with monitoring wells will be made in the field based on their location and relationship to data from surrounding VAP boreholes.Boreholes with TCE concentrations that are either all non-detects or are all well below 5µg/L (e.g. less than 1µg/L) generally will not be completed as monitoring wells.

Groundwater Sampling

The following table provides a summary of the samples to be collected from monitoring wells during each sampling event (including the Verification Sampling Event scheduled for Spring 2014 and described in the Abbreviated Work Plan, USACE (2014a)). The wells selected for inclusion in the RI field work are those closest to the TCE plume (Figure B-2). Furthermore, wells which are on the periphery of the plume and have historically had non-detectable TCE or TCE below 5 µg/L are excluded from sampling (see Table 5 of the RI/FS Work Plan for historical TCE data from all Raco MBA monitoring wells).

Monitoring well sampling events and rationale

Well ID	Number of prior sampling events through 2009	TCE range of concentrations (ug/L)	Water Quality Parameters [1]	TCE and dechlorination products [2]	Monitored Natural Attenuation Parameters [3]	Compound Specific Isotope Analysis	CENSUS Molecular Biological Tool	Rationale for Sampling
MW-08	9	3J to 19	V, 1, 2	V, 1, 2	--	--	--	TCE > 5 ug/L, multiple samplings since 1990
MW-19	4	4 to 33	V, 1, 2	V, 1, 2	--	--	--	TCE > 5 ug/L, multiple samplings since 2004
MW-20	4	1U to 0.59	V, 1, 2**	V, 1, 2**	--	--	--	Defines the southern plume boundary
MW-23	1	48	V, 1, 2	V, 1, 2	1,2*	2*	2*	Located along plume axis based on 2009 data
MW-24	1	12	V, 1, 2	V, 1, 2	--	--	--	Near the southern plume boundary
MW-25	1	5.7	V, 1, 2	V, 1, 2	--	--	--	Near the northern plume boundary
MW-26	1	51	V, 1, 2	V, 1, 2	1,2*	2*	2*	Located along plume axis based on 2009 data
MW-27	1	16	V, 1, 2	V, 1, 2	1,2*	2*	2*	Located along plume axis based on VSB10 2009 data
MW-28 (To be installed)	--	--	1, 2	1, 2	1,2*	2*	2*	New well
MW-29 (To be installed)	--	--	1, 2	1, 2	1,2*	2*	--	New well
MW-30 (To be installed)	--	--	1, 2	1, 2	1,2*	2*	--	New well
MW-31 (To be installed)	--	--	1, 2	1, 2	--	--	--	New well
MW-32 (To be installed)	--	--	1, 2	1, 2	--	--	--	New well
MW-33 (To be installed)	--	--	1, 2	1, 2	--	--	--	New well

[1] pH, temperature, specific conductance, dissolved oxygen, oxidation-reduction potential, turbidity

[2] To be measured in an off-site, fixed-base lab by Method 8260C.

[3] Ferrous iron, chloride, nitrite, nitrate, sulfate, sulfide, methane, ethane, ethene, carbon dioxide, alkalinity, dissolved organic carbon, in addition to water quality parameters

*Selected wells will be located along the plume axis; list of wells may change based on groundwater monitoring data to be collected during the Verification and First sampling events.

**MW-20 may be excluded from further sampling after the Verification Sampling Event if TCE is detected at less than 1 ug/L (i.e., comparable to previous results)

TCE: Trichloroethene

Note: The sampling plans shown above are subject to change based on field data and coordination with stakeholders.

V: Verification Sampling Event (Spring 2014); 1: First monitoring well sampling event (Fall 2014); 2: Second monitoring well sampling event (Summer 2015)

QAPP Worksheet #18 – Sampling Locations and Methods/Standard Operating Procedure Requirements

This worksheet lists the samples to be collected and can be used as a completeness check for field personnel. It facilitates checks to make sure all planned samples have been collected and appropriate methods have been used.

Verification Sampling Event (Spring 2014)

Sample Location	Matrix	Depth (ft bgs)	Sample Type	Analyte Group	Sampling SOP	Comments
MW-08	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
MW-19	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
MW-20	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
			MW, MS/MSD	Target VOCs	GEO-TEC-012	
MW-23	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
MW-24	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
MW-25	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
MW-26	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	
			Field duplicate	Target VOCs	GEO-TEC-012	
			Split sample for USACE QA lab	Target VOCs	GEO-TEC-012	
MW-27	Groundwater	Midpoint of screen	MW	Target VOCs	GEO-TEC-012	

bgs – below ground surface; MS – matrix spike; MSD – matrix spike duplicate; MW – monitoring well; SOP – Standard Operating Procedure; VOC – volatile organic compound; QA- Quality Assurance; USACE – U.S. Army Corps of Engineers

QAPP Worksheet #18 – Sampling Locations and Methods/Standard Operating Procedure Requirements (continued)

Vertical Aquifer Profile Investigation and Monitoring Well Installation (Summer 2014)

Sample Location(s)	Matrix	Depth (ft bgs)	Sample Type	Analyte Group	Sampling SOP	Comments
VSB11 – VSB22	Soil	TBD, from 2 depth intervals per VSB	Soil core	Total Organic Carbon	GEO-TEC-015	24 samples
			Soil core	Soil grain size distribution analysis	GEO-TEC-015	24 samples
VSB11 – VSB22	Ground water	TBD, sampling begins at 10 feet above projected depth of TCE profile (see Worksheet #17)	VAP/on-site analysis	Target VOCs	GEO-TEC-012	Estimated maximum of 120 samples.
		TBD, one for every other VSB	VAP, Split Sample for USACE QA lab	Target VOCs	GEO-TEC-012	Estimated maximum of 12 samples
		TBD, one per VSB	VAP/on-site analysis Field Duplicate	Target VOCs	GEO-TEC-012	Estimated maximum of 12 samples
		TBD, one pair for every other VSB	VAP/on-site analysis MS/MDS	Target VOCs	GEO-TEC-012	Estimated maximum of 6 pairs of samples

bgs – below ground surface; MS – matrix spike; MSD – matrix spike duplicate; TBD – to be determined; TCE – trichloroethene; VAP—Vertical Aquifer Profile; VSB –VAP Soil Boring; VOC – volatile organic compound; QA – Quality Assurance; USACE – U.S. Army Corps of Engineers

QAPP Worksheet #18 – Sampling Locations and Methods/Standard Operating Procedure Requirements (continued)

First Groundwater Sampling Event (Fall 2014)

Sample Location(s)	Matrix	Depth (ft bgs)	Sample Type	Analyte Group	Sampling SOP	Comments
MW-08	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
			MW, MS/MSD	Target VOCs [1]	GEO-TEC-012	
MW-19	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
MW-20	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
MW-23	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
			MW, FD	Target VOCs [1]	GEO-TEC-012	
			MW	Anions [3]*	GEO-TEC-012	
			MW	Dissolved gases [4]*	GEO-TEC-012	
			MW	Dissolved organic carbon*	GEO-TEC-012	
			MW	Alkalinity*	GEO-TEC-012	
			MW	Sulfide*	GEO-TEC-012	
			MW	Ferrous Iron[2]*	GEO-TEC-012	
MW-24	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron[2]	GEO-TEC-012	
MW-25	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
MW-26	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
			MW, FD	Target VOCs [1]	GEO-TEC-012	
			MW, Split Sample for USACE QA lab	Target VOCs [1]	GEO-TEC-012	
			MW	Anions [3]*	GEO-TEC-012	
			MW	Dissolved gases [4]*	GEO-TEC-012	
			MW	Dissolved organic carbon*	GEO-TEC-012	
			MW	Alkalinity*	GEO-TEC-012	
			MW	Sulfide*	GEO-TEC-012	
			MW	Ferrous Iron*	GEO-TEC-012	

bgs – below ground surface; FD – Field Duplicate; MS – matrix spike; MSD – matrix spike duplicate; MW – monitoring well; USACE – U.S. Army Corps of Engineers; VOC – volatile organic compound; QA – Quality Assurance; USACE – U.S. Army Corps of Engineers

[1] Target VOCs: Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride; [2] Ferrous Iron to be measured in the field; [3] Anions: Chloride, nitrite, nitrate, sulfate, [4] Dissolved gases: methane, ethane, ethane, carbon dioxide

QAPP Worksheet #18 – Sampling Locations and Methods/Standard Operating Procedure Requirements (continued)

First Groundwater Sampling Event (Fall 2014) (continued)

Sample Location(s)	Matrix	Depth (ft bgs)	Sample Type	Analyte Group	Sampling SOP	Comments
MW-27 – MW-33	Groundwater	Midpoint of screen	MW	Target VOCs [1]	GEO-TEC-012	New wells to be installed based on VAP results
			MW	Anions [3]*	GEO-TEC-012	
			MW	Dissolved gases [4]*	GEO-TEC-012	
			MW	Dissolved organic carbon*	GEO-TEC-012	
			MW	Alkalinity*	GEO-TEC-012	
			MW	Sulfide*	GEO-TEC-012	
			MW	Ferrous Iron[2]*	GEO-TEC-012	
Second Groundwater Sampling Event (Spring 2015)						
MW-08	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
			MW, MS/MSD	Target VOCs [1]	GEO-TEC-012	
MW-19	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]]	GEO-TEC-012	
MW-20	Groundwater	Midpoint of screen	MW	Target VOCs [1 Ferrous Iron [4]]	GEO-TEC-012	
MW-23	Groundwater	Midpoint of screen	MW	Target VOCs [1]	GEO-TEC-012	
			MW, FD	Target VOCs [1]	GEO-TEC-012	
			MW	Anions [3]*	GEO-TEC-012	
			MW	Dissolved gases [4]*	GEO-TEC-012	
			MW	Dissolved organic carbon*	GEO-TEC-012	
			MW	Alkalinity*	GEO-TEC-012	
			MW	Sulfide*	GEO-TEC-012	
			MW	Ferrous Iron[2]*	GEO-TEC-012	
			MW	CENSUS/MBT	GEO-TEC-012	
			MW	Compound specific Isotope Analysis*	GEO-TEC-012	

*MNA parameters. Monitoring wells selected for sampling may be changed depending on data collected in the field (i.e., VAP analyses).

FD – Field Duplicate; MW: Monitoring well; VAP: Vertical Aquifer Profile; VOCs: Volatile organic compounds; MBT: Molecular Biological Tool; bgs: below ground surface

[1] Target VOCs: Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride; [2] Anions: Chloride, nitrite, nitrate, sulfate; [3] Dissolved gases: methane, ethane, ethane, carbon dioxide; [4] Ferrous Iron to be measured in the field.

QAPP Worksheet #18 – Sampling Locations and Methods/Standard Operating Procedure Requirements (continued)

Second Groundwater Sampling Event (Spring 2015) (continued)

Sample Location(s)	Matrix	Depth (ft bgs)	Sample Type	Analyte Group	Sampling SOP	Comments
MW-24	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
MW-25	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
MW-26	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
			MW, FD	Target VOCs [1]	GEO-TEC-012	
			MW, Split Sample for USACE QA lab	Target VOCs [1]	GEO-TEC-012	
			MW	Anions [3]*	GEO-TEC-012	
			MW	Dissolved gases [4]*	GEO-TEC-012	
			MW	Dissolved organic carbon*	GEO-TEC-012	
			MW	Alkalinity*	GEO-TEC-012	
			MW	Sulfide*	GEO-TEC-012	
			MW	Ferrous Iron[2]*	GEO-TEC-012	
			MW	CENSUS/MBT*	GEO-TEC-012	
			MW	Compound specific Isotope Analysis*	GEO-TEC-012	
MW-27	Groundwater	Midpoint of screen	MW	Target VOCs [1] Ferrous Iron [2]	GEO-TEC-012	
MW-28 – MW-33	Groundwater	Midpoint of screen	MW	Target VOCs [1]	GEO-TEC-012	New wells to be installed based on VAP results
			MW	Target VOCs [1]	GEO-TEC-012	
			MW	Anions [3]*	GEO-TEC-012	
			MW	Dissolved gases [4]*	GEO-TEC-012	
			MW	Dissolved organic carbon*	GEO-TEC-012	
			MW	Alkalinity*	GEO-TEC-012	
			MW	Sulfide*	GEO-TEC-012	
			MW	Ferrous Iron[2]*	GEO-TEC-012	
			MW	CENSUS/MBT*	GEO-TEC-012	
			MW	Compound specific Isotope Analysis*	GEO-TEC-012	

*MNA parameters. Monitoring wells selected for sampling may be changed depending on data collected in the field (i.e., VAP analyses).
MW: Monitoring well; VAP: Vertical Aquifer Profile; VOCs: Volatile organic compounds; MBT: Molecular Biological Tool; bgs: below ground surface
[1] Target VOCs: Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride; [2] Ferrous Iron to be analyzed in the field; [3] Anions: Chloride, nitrite, nitrate, sulfate; [4] Dissolved gases: methane, ethane, ethane, carbon dioxide

QAPP Worksheet #19 – Sample Containers, Preservation and Holding Times

The following table is identical to Table A-5 of the Field Sampling Plan (Appendix A of the Work Plan)

Sample Medium	Analytes/Method	Container	Preservation	Holding Time
Groundwater	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	5 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, HCl, pH<2, no headspace	14 days
Groundwater	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260B (mobile lab)	3 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, no headspace	Analyzed in on-site mobile lab within 24 hours
Groundwater	Ferrous Iron/Hach 8146	[1]	[1]	[1]
Groundwater	Nitrate/9056A	125 mL HDPE bottle	Cooled to 4°C	48 hours
Groundwater	Chloride, Sulfate, Nitrite/9056A	125 HDPE bottle	Cooled to 4°C	48 hours
Groundwater	Sulfide/9034	500 mL HDPE botle	Cooled to 4°C NaOH, ZnAc	7 days
Groundwater	Dissolved Organic Carbon/9060	2 x 40 mL amber glass bottle	Cooled to 4°C, HCl, pH<2	28 days
Groundwater	Alkalinity/310.2	250 mL HDPE bottle	Cooled to 4°C	14 days
Groundwater	Methane, Ethane, Ethene, Carbon Dioxide/RSK 175	3 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, HCl, pH<2, no headspace	7 days
Groundwater	Compound Specific Isotope Analysis/Lab-specific	9 x 40 mL VOA vial, Teflon septum cap	Cooled to 4°C, HCl, pH<2, no headspace	14 days
Groundwater	CENSUS/Molecular Biological Tool	1 L HDPE bottle	Cooled to 4°C	24-48 hours
Soil	Total Organic Carbon/9060	4 ounce plastic cup	Cooled to 4°C	14 days
Soil	Grain size distribution/ASTM D4464	1 L HDPE bottle	None required	None

[1] Field analysis; will be analyzed immediately upon collection.
1,2-cis- and trans-DCE: Dichlroethene; HCl; hydrochloric acid; HDPE: high density polyethylene; NaOH: sodium hydroxide; TCE: Trichloroethene; VC: vinyl chloride; VOA: volatile organic analysis; ZnAc: zinc acetate

QAPP Worksheet #20 – Field Quality Control Sample Summary

The following table is identical to Table A-6 of the Field Sampling Plan (Appendix A of the Work Plan).

.

Sampling Procedure	Analytes/ Method	Laboratory* *All are off-site, fixed-base unless noted otherwise.	Number of field samples	Field duplicates	MS/MSD Pairs	QA Split Samples	Trip Blanks	Equipment blanks
Verification Sampling Event - Spring 2014	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	CT Laboratories	8	1	1	1	1/sample cooler	0
VAP Groundwater Sampling - Summer 2014	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260B	ECCS (on-site mobile) USACE QA Lab (TBD) for splits	120	12	6	12	1/sample cooler	1/day
Soil Sampling - Summer 2014	TOC/9060	CT Laboratories	24	2	0	0	0	0
	Grain size distribution/ASTM D422	PTS Laboratories	24	0	0	0	0	0
First Round - Groundwater Sampling - Fall 2014	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	CT Laboratories USACE QA Lab (TBD) for splits	14	2	1	2	1/sample cooler	0
	MNA: Chloride, Nitrite, Nitrate, Sulfate/9056A	CT Laboratories	6	0	0	0	0	0
	dioxide/RSK 175	CT Laboratories	6	0	0	0	0	0
	MNA: Dissolved Organic Carbon/9060	CT Laboratories	6	0	0	0	0	0
	MNA: Alkalinity/310.2	CT Laboratories	6	0	0	0	0	0
	MNA: Sulfide/9034	CT Laboratories	6	0	0	0	0	0
	MNA: Ferrous Iron/Hach 8146	GEO Consultants (on-site)	14	0	0	0	0	0
Second Round - Groundwater Sampling - Spring 2015	TCE,cis-1,2-DCE,trans-1,2-DCE,VC/8260C	CT Laboratories USACE QA Lab (TBD) for splits	14	2	1	2	1/sample cooler	0
	MNA: Chloride, Nitrite, Nitrate, Sulfate/9056A	CT Laboratories	6	0	0	0	0	0
	dioxide/RSK 175	CT Laboratories	6	0	0	0	0	0
	MNA: Dissolved Organic Carbon/9060	CT Laboratories	6	0	0	0	0	0
	MNA: Alkalinity/310.2	CT Laboratories	6	0	0	0	0	0
	MNA: Sulfide/9034	CT Laboratories	6	0	0	0	0	0
	MNA: Ferrous Iron/Hach 8146	GEO Consultants (on-site)	14	0	0	0	0	0
	Compound Specific Isotope Analysis	Microseeps, Inc.	6	0	0	0	0	0
	CENSUS/Molecular Biological Tool	Microbial Insights, Inc.	4	0	0	0	0	0

NOTES: Wells to be sampled in Round 1 and 2 are identified in Table A-5. USACE QA Lab To be determined.
DCE: dichloroethene; MNA: Monitored Natural Attenuation; MS/MSD: Matrix Spike/Matrix Spike Duplicate; NA: Not applicable; TCE: Trichloroethene; TOC: total organic carbon; QA: Quality Assurance; VAP: Vertical Acquifer Profiling; VC: vinyl chloride

QAPP Worksheet #21 – Project Sampling Standard Operating Procedure References

Note: All Standard Operating Procedures will be on-site during all field activities. Standard Operating Procedures are included in Appendix C.

Reference Number	Title, Revision Date and / or Number	Originating Organization	Equipment Type	Modified for Project Work? Yes/No (Y/N)	Comments
GEO-TEC-005	Logbooks, Revision 2	GEO Consultants, LLC (GEO)	Logbooks	N	
GEO-TEC-006	Sample Chain of Custody, Revision 3	GEO	Chain of Custody forms	N	
GEO-TEC-010	Equipment Cleaning and Decontamination, Revision 4	GEO	See Section 8.1 of GEO-TEC-010	N	
GEO-TEC-012	Groundwater Monitoring Well Sampling	GEO	See Section 6.2 of GEO-TEC-012	N	
GEO-TEC-014	Water Level Measurements (Well)	GEO	See Section 6.2 of GEO-TEC-014	N	
GEO-TEC-015	Subsurface Soil Sampling	GEO	See Section 8.1 of GEO-TEC-015	N	
Not Applicable	Standard Operating Procedure for Groundwater Low-Flow Purging, Version 1.3	U.S. Army Corps of Engineers (USACE)	See Section 3.2 of USACE 2002	N	

Note: There are no Standard Operating Procedures for slug testing or soil logging. The procedures for these activities are described in the Field Sampling Plan (Appendix A of the Work Plan).

QAPP Worksheet #22 – Field Equipment Calibration, Maintenance, Testing, and Inspection Table

Field equipment calibration is discussed in Section 3.12 of the Field Sampling Plan.

QAPP Worksheet #23 – Analytical Standard Operating Procedure References

U.S Environmental Protection Agency (USEPA) or Standard Method Number	Standard Operating Procedure Number	Title	Definitive or Screening Data	Analytical Group	Organization Performing Analysis	Modified for Project Work? Yes/No (Y/N)
310.2	CC-10	Alkalinity, Automated Colorimetric	Definitive	Alkalinity	CT Laboratories	N
9056	CC-IC	Ion Chromatography	Definitive	Chloride, Nitrate, Nitrite, Sulfate	CT Laboratories	N
Hach 8146	Hach 8146	Ferrous Iron	Screening	Ferrous Iron	GEO	N
RSK 175	Dissolved Gases	Dissolved Methane, Ethene, Ethane, and Carbon Dioxide in Water	Definitive	Methane, Ethene, Ethane, and Carbon Dioxide	CT Laboratories	N
9034	CC-32	Sulfide, Titrimetric Method	Definitive	Sulfide	CT Laboratories	N
9060A	TOC Solids	Total organic carbon in Solids	Definitive	TOC	CT Laboratories	N
9060	TOC Waters	Total organic carbon in Water	Definitive	Dissolved organic carbon	CT Laboratories	N
8260C	VOC 8260C	Analysis of VOCs by GC/MS	Definitive	Target VOCs [1]	CT Laboratories	N
8260B	VOC 8260B	Analysis of VOCs by GC/MS	Definitive	Target VOCs [1]	Environmental Chemistry Consulting Services, Inc.	N
NA		CENSUS, Quantitative polymerase chain reaction analysis of *Dehalococcoides* and target functional genes	Screening	Molecular Biological Tool/TCE-degrading microbes	Microbial Insights	N
NA	Revision 1	Standard Operating Procedure for the measurement of Compound Specific Isotopic Ratios with Gas Chromatography	Screening	$\delta(^{13}C)$-TCE	Microseeps	N
ASTM D4464		Standard Test Method for Particle-Size Analysis of Soils	Definitive	Soil property	PTS Laboratories	N

GC/MS – gas chromatograph/mass spectrometer, MS – matrix spike, NA – not applicable, TOC – total organic carbon, VOCs – volatile organic compounds
Target VOCs: Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride

QAPP Worksheet #24 – Analytical Instrument Calibration

CT Laboratories and ECCS have been certified under the Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) as being capable of performing the analyses in conformance with the Quality Control (QC) requirements of the DoD's Quality Systems Manual (QSM) version 4.2 (DoD 2010). CT Laboratories anticipates compliance with DoD QSM version 5.0 (DoD 2013) by June 30, 2014. As such, the laboratories will be following the requirements in the applicable DoD QSM for analytical instrument calibration.

QAPP Worksheet #25 – Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table

Both CT Laboratories (primary off-site fixed-base laboratory) and ECCS (mobile laboratory) operate under a quality system that conforms to International Organization for Standardization (ISO) 17025:2005. The activities normally documented in this worksheet are documented in the laboratory's quality manual (USEPA 2012). These laboratories are ELAP-accredited; their certificates document compliance with the requirements of ISO 17025:2005.

It should be noted that CSIA and CENSUS analysis are not ELAP-accreditable methods.

QAPP Worksheet #26 – Sample Handling System

SAMPLE COLLECTION, PACKAGING, AND SHIPMENT

Sample Collection (Personnel/Organization): *Paul Lewers/GEO Consultants, LLC (GEO) and field crew (to be determined)*

Sample Packaging (Personnel/Organization): *Paul Lewers/GEO and field crew (to be determined)*

Coordination of Shipment (Personnel/Organization): *Paul Lewers/GEO and field crew (to be determined); Pat Letterer/CT Laboratories*

Type of Shipment/Carrier: *All samples to be shipped in coolers/Federal Express*

SAMPLE RECEIPT AND ANALYSIS

Sample Receipt (Personnel/Organization): *To be assigned by Laboratory Project Manager (PM) at CT Laboratories*

Sample Custody and Storage (Personnel/Organization): *To be assigned by Laboratory PM at CT Laboratories*

Sample Preparation (Personnel/Organization): *To be assigned by Laboratory PM at CT Laboratories*

Sample Determinative Analysis (Personnel/Organization): *To be assigned by Laboratory PM at CT Laboratories*

SAMPLE ARCHIVING

Field Sample Storage (Number of days from sample collection): *minimum hold time, Nitrate, 48 hours.*

Sample Extract/Digestate Storage (Number of days from extraction/digestion): *Not applicable*

Biological Sample Storage (Number of days from sample collection): *Not applicable*

SAMPLE DISPOSAL

Personnel/Organization: *To be assigned by Laboratory PMs at CT Laboratories*

Number of Days from Analysis: *Up to six weeks*

QAPP Worksheet #27 – Sample Custody

Sample custody procedures are described in Section 4 of the Field Sampling Plan (Appendix A of the Remedial Investigation/Feasibility Study Work Plan) and GEO-TEC-006 Revision 3 *Sample Chain of Custody* (included in Appendix C).

QAPP Worksheet #28 – Quality Control Samples

Matrix: Water
Analytical Group: Target Volatile organic compounds (Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride)
Analytical Method / Standard Operating Procedure Reference: Method 8260 (for both on-site mobile and off-site fixed-base laboratory)

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater. Common contaminants must not be detected greater than the LOQ. (DoD 2013)	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	Use LCS control limits for Method 8260 Water Matrix in DoD QSM, Version 5.0 (DoD 2013), Table 24 (also in Worksheet #12)	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias
Matrix spike (MS)	1/20 field samples	Use LCS control limits for Method 8260 Water Matrix in Department of Defense (DoD) Quality Systems Manual (QSM), Version 5.0 (DoD 2013), Table 24 (also in Worksheet #12)	Evaluate data to determine if outage is related to analytical error or matrix effect. For the specific analyte(s) in the parent sample, apply data qualifiers to the results.	Analyst/Section Supervisor	Accuracy/Bias
Matrix spike duplicate (MSD)	1/20 field samples	Use LCS control limits for Method 8260 Water Matrix in DoD QSM, Version 5.0 (DoD 2013), Table 24 (also in Worksheet #12) Relative percent difference between MS and MSD ≤ 30%	Evaluate data to determine if outage is related to analytical error or matrix effect. For the specific analyte(s) in the parent sample, apply data qualifiers to the results.	Analyst/Section Supervisor	Accuracy/Bias – Precision
Surrogate spike	All field and QC samples	Use surrogate control limits for Method 8260 Solid and Water Matrix in DoD QSM Version 5.0 (DoD, 2013), Table 24	Correct problem then re-prepare and reanalyze all failed samples for failed surrogates in the associated preparatory batch, if sufficient sample material is available. Apply data qualifiers if control limits are not met and sufficient sample is unavailable.	Analyst/Section Supervisor	Accuracy/Bias
Field duplicate	1/10 field samples	Relative percent difference ≤ 30%	Evaluate data to determine source of difference between results	Analyst/Section Supervisor	Precision

[1] Additional QC requirements (e.g., calibration checks) for Method 8260B/C, as specified in DoD QSM, Version 4.2 (DoD 2010) or DoD QSM, Version 5.0 (DoD 2013), will be followed.

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Anions
Analytical Method / Standard Operating Procedure Reference: 9056A

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample. (DoD 2013).	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	Use LCS control limits for Method 9056 Water Matrix in DoD QSM, (DoD 2013), Table 41 (see Worksheet #12)	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Dissolved Organic Carbon
Analytical Method / Standard Operating Procedure Reference: 9060

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample. (DoD 2013).	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	See Worksheet #12	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Dissolved Gases (Methane, ethane, ethene, carbon dioxide)
Analytical Method / Standard Operating Procedure Reference: RSK 175

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample. (DoD 2013).	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	Use LCS control limits for Method RSK 175 Water Matrix in DoD QSM, (DoD 2013), Table 42 (see Worksheet #12)	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Alkalinity
Analytical Method / Standard Operating Procedure Reference: 310.2

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample. (DoD 2013).	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	See Worksheet #12	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Sulfide
Analytical Method / Standard Operating Procedure Reference: 9034

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > ½ LOQ and greater than 1/10 the amount measured in any sample. (DoD 2013).	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	See Worksheet #12	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Molecular Biological Tool/TCE-degrading microbial populations
Analytical Method / Standard Operating Procedure Reference: CENSUS/MBT

Method	Quality Control Check	Minimum Frequency	Acceptance Criteria	Corrective Action
CENSUS	Assay Calibration (Standard Curve)	Primary – initial	Standard curve R^2 >0.95	Rerun assay / check reagents.
	Laboratory (sample) Duplicate	All field samples	Count value within +/- 20%	Rerun assay; if still not within 20%, flag J (estimate)
	Assay Negative Control (Blank)	1 per analytical assay plate in duplicate	Count values for positive samples are set above the negative control	Rerun assay; may have to re-optimize assay
	DNA extraction negative control	1 per analytical batch	Count value < or = Assay Negative Control	Rerun assay or re-extract samples if problem persists
	Positive Control	1 per analytical assay plate in duplicate	Count value within +/- 20% of known value	Rerun assay / check reagents

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Water
Analytical Group: Carbon isotope ratio for TCE **(δ^{13}C-TCE)**
Analytical Method / Standard Operating Procedure Reference: Compound specific isotope analysis

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 10 samples	No chromatographic area greater than the practical quantitation limit.	If there is any possibility that the problems that caused the out-of-control QC also compromised field sample results, then all samples associated with the out-of-control quality control samples must be reanalyzed (with the exception of matrix interference seen in surrogate measurements). If examination of the analytical records reveals that the problems are identifiable and that either those problems were due to interference from the field samples or to analytical problems which did not affect the field samples, the results can be reported along with a detailed case narrative explaining the problem.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Field Sample Duplicate	1/5 field samples	If the chromatographic area is greater than the practical quantitation limit, carbon isotopic ratio of the duplicate analysis must be within 1.0 per mil of the original sample.		Analyst/Section Supervisor	Precision
Laboratory control samples (LCS)	1/Preparatory batch of at most 10 samples	Use LCS control limits as described in the laboratory's Standard Operating Procedure.		Analyst/Section Supervisor	Accuracy/Bias

QAPP Worksheet #28 – Quality Control Samples (continued)

Matrix: Soil
Analytical Group: Total organic carbon
Analytical Method / Standard Operating Procedure Reference: 9060

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Method Blank	1/Preparatory Batch of at most 20 samples	No analytes detected > 1/2 Reporting Limit (RL) and > 1/10 the amount measured in any sample.	Correct problem. If sample results are above detection limit, re-prepare and reanalyze method blank and all samples processed with the contaminated blank. If there is insufficient sample for re-analysis, report results with data qualifiers.	Analyst/Section Supervisor	Accuracy/Bias – Contamination
Laboratory control samples (LCS)	1/Preparatory batch of at most 20 samples	See Worksheet #12	Correct problem, then re-prepare and reanalyze the LCS and all samples in the associated preparatory batch, if sufficient sample material is available. If sufficient sample volume is unavailable, apply data qualifiers to results.	Analyst/Section Supervisor	Accuracy/Bias

Matrix: Soil
Analytical Group: Soil grain distribution
Analytical Method / Standard Operating Procedure Reference: ASTM D4464

QC Sample	Frequency / Number	Method / Standard Operating Procedure (SOP) Quality Control (QC) Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator
Laboratory will provide quality control data if required by ASTM D4464.					

QAPP Worksheet #29 – Project Documents and Records

Sample Collection Documents and Records	On-Site Analysis Documents and Records	Off-Site Analysis Documents and Records	Data Assessment Documents and Records
• Water sample collection logs • Identification of Quality Control (QC) samples • Chain-of-Custody records for samples • Airbills • Corrective action reports • Documentation of corrective action reports • Documentation of deviation from methods • Documentation of internal Quality Assurance (QA) review • Field logbooks • Daily field reports • Change requests	• Field logbooks	• Chain-of-Custody records for samples • Sample receipt forms and sample tracking forms • Preparation and analysis forms and/or logbooks • Tabulated data summary forms and raw data for field samples, standards, QC checks and QC samples • Case narrative • Sample chronology (time of receipt, extraction and analysis) • Identification of QC samples • Communication logs (including telephone logs and electronic mail) • Corrective action reports • Definition of laboratory qualifiers • Documentation of corrective action results • Electronic data deliverables • Instrument calibration reports • Laboratory name • Laboratory sample identification numbers • Reporting forms, completed with actual results • Signatures for laboratory sign-off (e.g., laboratory manager) • Standards traceability records • Initial precision and accuracy tests	• Automated Data Review (ADR) reports • Project library from ADR • Data validation reports • Communication logs (including telephone and electronic mail) • Corrective action reports • Laboratory assessments • Laboratory QA plan • Method Detection Limits (MDLs) study information • National Environmental Laboratory Accreditation Program accreditation

QAPP Worksheet #30 – Analytical Services

Sample Locations	Matrix	Analytical Group	Concentration Level	Analytical Method	Data Package Turnaround Time	Laboratory
Monitoring Wells	Groundwater	Target VOCs [1] Anions [2] Dissolved gases [3] Dissolved organic carbon Sulfide Alkalinity	Low Level Per method Per method Per method Per method Per Method	8260C 9056A RSK 175 9060 9034 310.2	21 days	CT Laboratories
Soil Samples	Soil	Total organic carbon	Per Method	9060A	21 days	CT Laboratories
Vertical Aquifer Profile Boreholes	Groundwater	VOCs	Per Method	8260B	24 hours	Environmental Chemistry Consulting Services, Inc.
Grain size distribution	Soil	Soil property	Not applicable	ASTM D4464	21 days	PTS Laboratories
Monitoring Wells	Groundwater	Molecular Biological Tool/TCE-degrading microbes	Not applicable	CENSUS	21 days	Microbial Insights
Monitoring Wells	Groundwater	Carbon isotope ratio for Trichloroethene	Not applicable	CSIA	21 days	Microseeps

[1] Target VOCs (volatile organic compounds): Trichloroethene, 1,2-cis-dichloroethene, 1,2-trans-dichloroethene
[2] Anions: Chloride, nitrite, nitrate, sulfate
[3] Dissolved gases: Methane, ethane, ethane
Note: Ferrous iron will be analyzed in the field immediately upon sample collection using Hach 8146. Analytical SOPs are listed in Worksheet #23.
ASTM – American Society for Testing Materials; CSIA – Compound specific isotope analysis

QAPP Worksheet #31 – Planned Project Assessments

Assessment Type	Frequency	Internal or External	Organization Performing Assessment	Person(s) Responsible for Performing Assessment	Person(s) Responsible for Responding to Assessment Findings	Person(s) Responsible for Identifying and Implementing Corrective Actions	Person(s) Responsible for Monitoring Effectiveness of Corrective Action
Daily Quality Control Assessment during Field Activities	Daily during field activities	Internal	GEO Consultants, LLC (GEO)	Paul Lewers, Field Operations Manager (GEO)	Paul Lewers, Field Operations Manager (GEO)	Natalie Magill, Technical Manager (GEO)	Larry Copeland, Project Manager (GEO)
Overall project assessment	Once	Internal	GEO	Jeff Douthitt, (GEO President)	Larry Copeland, Project Manager (GEO)	Larry Copeland, Project Manager (GEO)	Jeff Douthitt, (GEO President)

QAPP Worksheet #32 – Assessment Findings and Corrective Action Responses

Assessment Type	Documentation of Assessment	Individual(s) Receiving Assessment Report	Frequency for report submission	Nature of Corrective Action Response Documentation	Individual(s) Receiving Corrective Action Response	Timeframe for Response
Daily Quality Control Assessment during Field Activities	Daily Quality Control Report	Josh Van Bogaert, Technical Manager U.S. Army Corps of Engineers, Louisville District (CELRL)	To be submitted daily and compiled as an appendix to the Remedial Investigation (RI) report	To be included in Daily Quality Control Report	Josh Van Bogaert (CELRL)	To be reviewed with the RI Report.

QAPP Worksheet #33 – Quality Assurance Management Reports

Type of Report	Frequency (daily, weekly, monthly, quarterly, annually, etc.)	Projected Delivery Date(s)	Person(s) Responsible for Report Preparation	Report Recipient(s)
Daily Quality Control Report	Prepared and submitted daily in addition to being compiled and submitted with the field and laboratory documents.	Submitted daily; compiled daily reports to be submitted as a part of the Remedial Investigation (RI) Report.	Paul Lewers, Field Operations Manager GEO Consultants, LLC (GEO)	Josh Van Bogaert, Techncial Manager U.S. Army Corps of Engineers, Louisville District (CELRL)
Quality Control Summary Report	Once	To be submitted as a part of the RI Report.	Natalie Magill Technical Manager (GEO)	Josh Van Bogaert (CELRL)

QAPP Worksheet #34 – Verification (Step I) Process

Verification Input	Description	Internal/ External	Responsible for Verification (name, organization)
Chain-of-Custody	Chain-of-Custody forms and shipping documentation will be reviewed internally upon their completion and verified against the packed sample coolers they represent. The shipper's signature on the Chain-of-Custody form will be initialed by the reviewer, a copy of the form will be retained in the project file, and the original and remaining copies will be taped inside the cooler for shipment.	Internal	Paul Lewers, Field Operations Manager or designee [GEO Consultants, LLC (GEO)] Pat Letterer, Laboratory Project Manager (PM) or designee
Field Notes	Field notes will be reviewed internally and placed in the project file.	Internal	Paul Lewers, Field Operations Manager or designee (GEO)
Analytical Data Package	All analytical data packages will be verified internally by the laboratory performing the work for completeness prior to submittal. The laboratory shall complete the appropriate form documenting the organization and complete contents of each data package.	Internal	Pat Letterer, Laboratory PM (CT Laboratories)
Quality Control (QC) Summary Report	A summary of all QC sample results will be verified for completeness upon receipt of data packages from the laboratory.	Internal	Natalie Magill, Technical Manager or designee (GEO)

QAPP Worksheet #35 – Validation (Steps IIa and IIb) Process

Step IIa / IIb	Validation Input	Description	Responsible for Validation
IIa	Project and field documents	Chain-of-Custody, sample receipt forms, case narratives, communication logs, and corrective action forms will be reviewed to ensure that all samples were collected, transported, and analyzed for the requested parameters, and the laboratory used appropriate analytical methods.	Natalie Magill, Technical Manager or designee (GEO)
IIa/IIb	Quality Control (QC) summary forms, Raw data	100% validation of Level IV data packages containing groundwater analytical results from off-site fixed-base laboratory, excluding CENSUS/Molecular Biological Tool and compound specific isotope analysis results. In addition to all project and field documentation validation requirements, all QC sample results will be evaluated against the method quality criteria and the data will be flagged with data qualifiers, accordingly. Raw data will be reviewed, calculations will be checked, and summary forms will be verified for accuracy.	Laura Soeten, Laboratory Data Consultants

QAPP Worksheet #36 – Validation (Steps IIa and IIb) Summary

Step IIa / IIb	Matrix	Analytical Group	Validation Criteria	Data Validator
IIa/IIb	Groundwater	Target VOCs [1] Anions [2] Dissolved organic carbon Dissolved gases [3] Alkalinity Sulfide	Quality Assurance Project Plan Department of Defense (DoD) Quality Systems Manual (QSM), Version 5.0 (DoD 2013) U.S. Environmental Protection Agency (USEPA) Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review (EPA-540-R-08-01, June 2008)	Laura Soeten, Laboratory Data Consultants

[1] Target VOCs (Volatile Organic Compounds): Trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichlorothene, vinyl chloride
[2] Anions: Chloride, nitrite, nitrate, sulfate
[3] Dissolved gases: Methane, ethane, ethene, carbon dioxide

QAPP Worksheet #37 – Usability Assessment

Assessment of Measurement Quality Objectives for Chemical Data

Precision:

Precision for sample data will be calculated by evaluating data from field and laboratory duplicates, and laboratory control sample (LCS)/laboratory control sample duplicate (LCSD) and, if analyzed, matrix spike (MS)/matrix spike duplicate (MSD) pairs, as follows:

- Tabulate duplicate data and calculate the absolute value difference, average, and relative percent difference (RPD), as shown below for each duplicate pair:

  $$RPD = \frac{|x_1 - x_2|}{(x_1 + x_2)/2} \times 100$$

  Where:

  x_1 = concentration of Sample 1of duplicate pair

  x_2 = concentration of Sample 2 of duplicate pair

  RPDs will not be calculated in cases where one analyte of the duplicate pair was reported as non-detect.

- Qualitatively evaluate the significance of data that fall outside the project goals for precision. Usability of data outside of project goals for precision is dependent on the degree of exceeding Quality Control (QC), if there is a potential high or low sample result bias, if associated sample results are significant compared to screening levels, and if the sample is critical to the investigation findings. If data quality problems arise, the analytical laboratory will be notified for corrective action, as appropriate.

Accuracy:

Accuracy for sample data will be calculated by evaluating data from blanks and QC samples, as described below:

Blanks

- Tabulate the data from the blank samples.
- Identify any blank samples in which chemicals are detected.
- If contaminants are detected in the blanks, those compounds detected in associated environmental samples at less than five times the blank value (less than ten times the blank value for common laboratory contaminants) will be qualified as not detected.

Spikes

The procedure for assessing MS/MSD (if analyzed), and surrogate spike samples are as follows:

- Tabulate spike sample data and calculate the percent recovery, as shown below for each sample.

$$Percent\ \ Recovery\ (\%R) = \frac{T - X}{A} \times 100$$

Where:

T = total concentration found in spiked sample

X = original concentration in sample matrix prior to spiking

A = actual spike concentration added to sample

- Qualitatively evaluate the significance of data that fall outside the project goals for accuracy. Usability of data outside project goals for accuracy is dependent on the degree that QC is exceeded, if there is a potential for high or low sample result bias, and if associated sample results are significant when compared to screening levels.

Representativeness:

The representativeness of data will be qualitatively assessed by evaluating whether or not sample collection and analytical procedures described in the Field Sampling Plan were followed.

Completeness:

Completeness calculations will use only verified/validated data (levels as indicated in Worksheet #36). Data that are qualified as rejected (R) will be counted against completeness criteria unless acceptable data are present. QC parameters evaluated to assess completeness include holding times, surrogates, LCS/LCSD (and, if analyzed, MS/MSD) recoveries and RPDs, and field duplicate RPDs. Sample results that do not meet relevant criteria due to substantiated matrix effects, and/or are re-analyzed past holding time due to QC corrective actions and/or are "J" qualified because values are below the reporting limit, will be considered usable and will not count against the completeness assessment. Completeness shall be greater than 95%.

Comparability:

The comparability evaluation will include a qualitative assessment of analytical techniques, data quality, and sample design, as compared to previous investigations. Specific items to be evaluated include sampling and analytical method equivalency, preservation methods, detection limits, equivalent laboratory facilities and personnel, Quality Assurance (QA)/QC programs, Data Quality Objectives, and precision and accuracy estimates. If the above factors are equivalent, the data sets will be considered comparable.

THIS PAGE INTENTIONALLY LEFT BLANK

2. REFERENCES

DoD (Department of Defense) 2007. Department of Defense Policy and Guidelines for Acquisitions Involving Environmental Sampling or Testing. November. http://www.navylabs.navy.mil/Archive/ProcPolicyGuideDec07.doc

DoD (Department of Defense) 2010. DoD Quality Systems Manual (QSM) for Environmental Laboratories, Version 4.2. October.

DoD (Department of Defense) 2013. DoD Quality Systems Manual (QSM) for Environmental Laboratories, Version 5.0. July.

Earth Tech (Earth Tech, Inc.) 2005. *Draft Site Investigation and Associated Activities Report.* April.

Envirodyne Engineers 1987. Contamination Evaluation for the former Bomarc Missile Site, Raco Michigan, Final Report.

GEO (GEO Consultants, LLC) 2008. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Environmental Site Investigation (Phase III), Hiawatha National Forest, Raco, Michigan*.

GEO (GEO Consultants, LLC) 2010. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Remedial Investigation/Feasibility Study Activities, Hiawather National Forest, Raco, Michigan*.

GEO (GEO Consultants, LLC) 2013a. *Quality Control Plan, Remedial Investigation/Feasibility, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippeqa County, Michigan, FUDS Property No. E05MI0026.* Submitted to U.S. Army Corps of Engineers, Louisville District. November.

GEO (GEO Consultants, LLC) 2013b. *Site-Specific Safety and Health Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property Nol. E05MI0026*.

IT Corp. (Information Technology Corporation) 1991. *Remedial Investigation, Former Air Force Airfield and Bomarc Missile Site, Chippewa County, Michigan*.

MDEQ (Michigan Department of Environmental Quality). 2004. RRD Operational Memorandum No. 2. *Sampling and Analysis – Attachment 1: Target Detection Limits and Designated Analytical Methods*. October. http://michigan.gov/documents/deq/deq-rrd-OpMemo_2_Attachment1_283504_7.pdf

USACE (U.S. Army Corps of Engineers) 2002. *Standard Operating Procedure for Groundwater Low-Flow Purging.* Version 1.3. August.

USACE (U.S. Army Corps of Engineers, Louisville District) 2003. *Groundwater Monitoring Report, Former Raco AAF and Bomarc Missile Site, Hiawatha National Forest, Raco, Michigan.* January.

USACE (U.S. Army Corps of Engineers) 2005. Guidance for Evaluating Performance-Based Chemical Data. EM 200-1-10. June 30, 2005. http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_200-1-10.pdf

USACE (U.S. Army Corps of Engineers) 2013a. *Performance Work Statement for Raco TCE Groundwater Plume*. Revised August.

USACE (U.S. Army Corps of Engineers) 2014a. *Draft-Final Abbreviated Work Plan Verification Sampling Event*, *Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E)5MI0026.* January.

USACE (U.S. Army Corps of Engineers) 2014b. *Draft Work Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026.* March.

USEPA (United States Environmental Protection Agency) 2002. *Uniform Federal Policy (UFP)-QAPP, and U.S. Environmental Protection Agency (USEPA) Guidance for Quality Assurance Project Plans, EPA QA/G-5, QAMS*, December 2002.

USEPA (United States Environmental Protection Agency) 2005. *Uniform Federal Policy for Quality Assurance Project Plans, Part 1: UFA-QAPP Manual,* Final, Version 1, EPA-505-B-04-900A, March 2005.

USEPA (United States Environmental Protection Agency) 2012. *Uniform Federal Policy for Quality Assurance Project Plans, Optimized UFP-QAPP Worksheets,* March 2012.

USEPA (U.S. Environmental Protection Agency) 2013. Summary Table. Mid-Atlantic Risk Assessment. Last update May 2013. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

Weidemeier, T. H., Swanson, M. A., Moutoux, D. E., Gordon, E. K., Wilston, J. T., Wilson, B. H., Kampbell, D. H., Haas, P. E., Miller, R. N., Hansen, J. E. and Chapelle, F. H. 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, EPA/600/R-98/128. September.

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

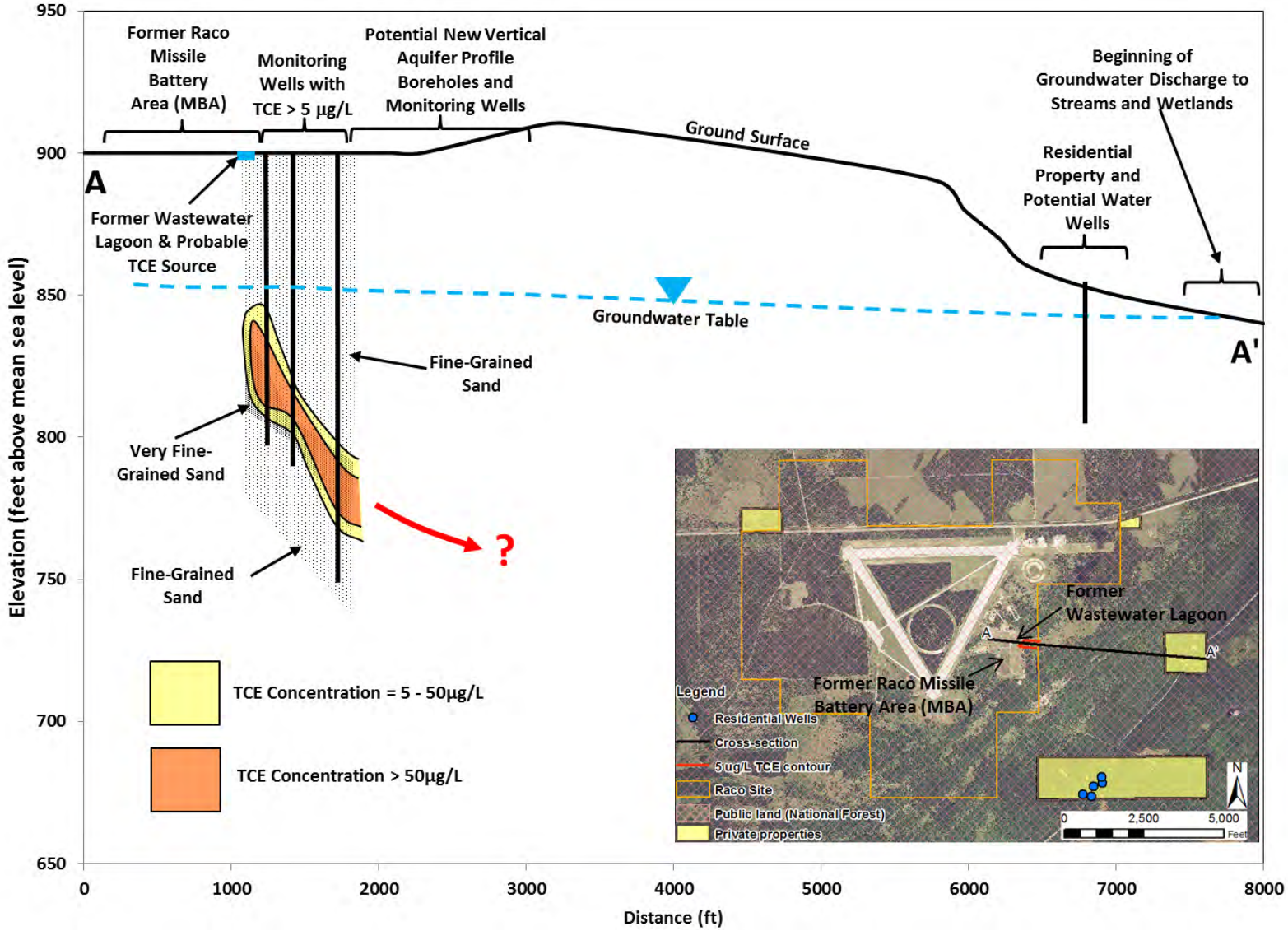
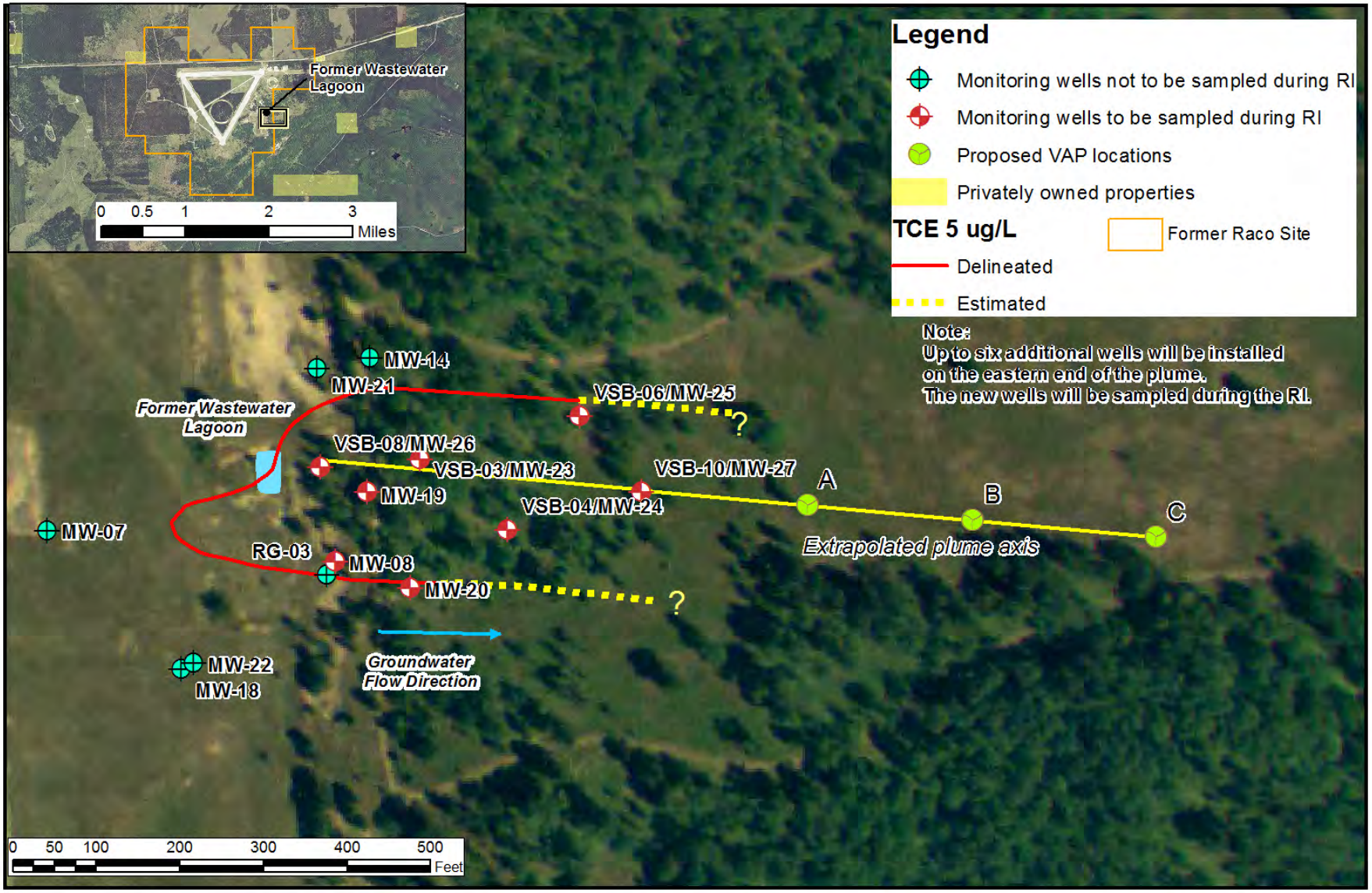


Figure B-1.
Conceptual Site Model

U.S. Army Corps of Engineers
Louisville District

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014



Base map source - Michigan Geographic Data Library, 2005

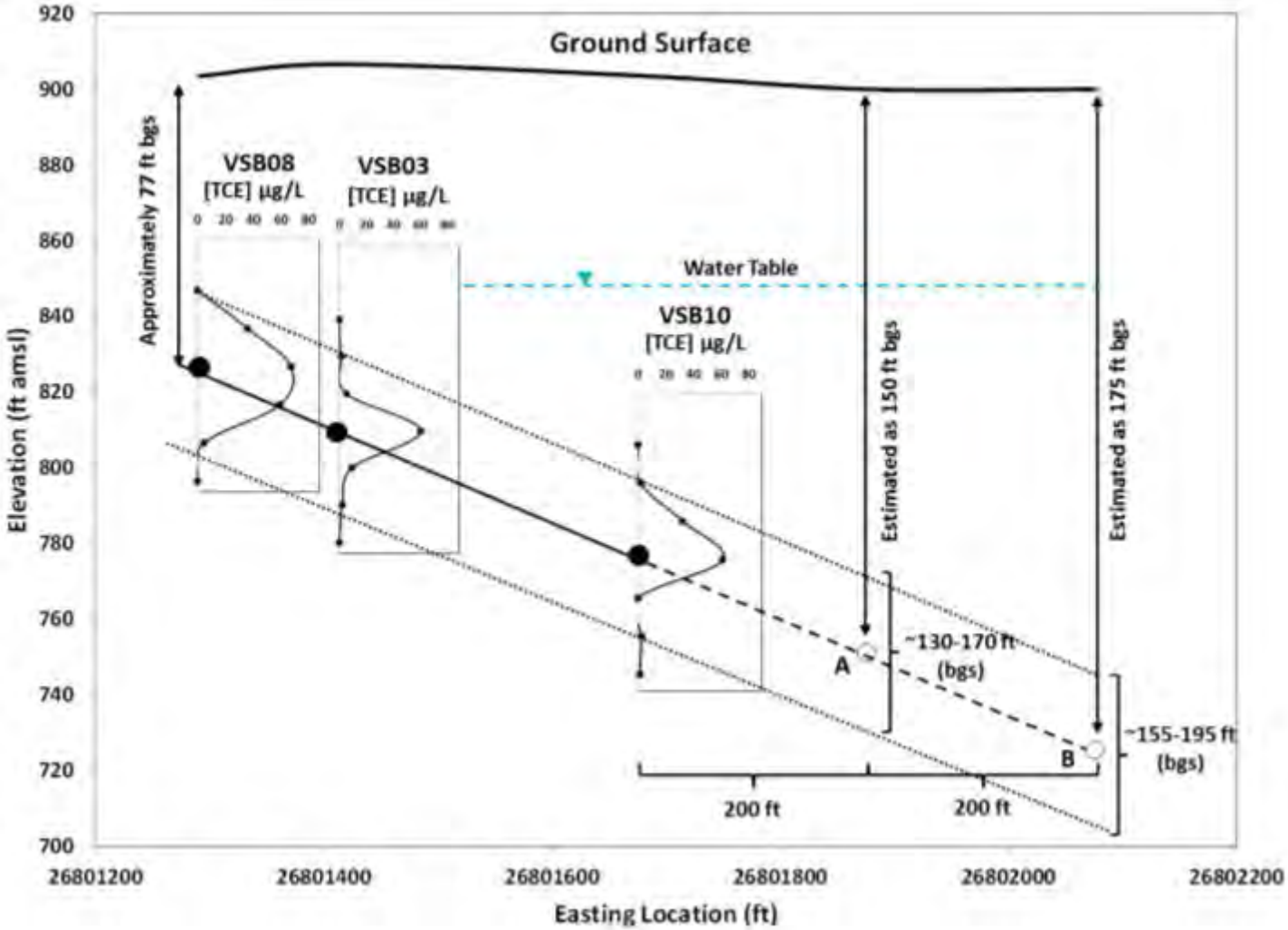
Figure B-2
Proposed locations for Vertical Aquifer Profile borings

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014



See Figure B-2 for cross section location.

Figure B-3.
Trichloroethene concentration versus depth profiles from prior Vertical Aquifer Profile (VAP) investigation (GEO 2010) and proposed VAP locations along the extrapolated plume axis

U.S. Army Corps of Engineers
Louisville District

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

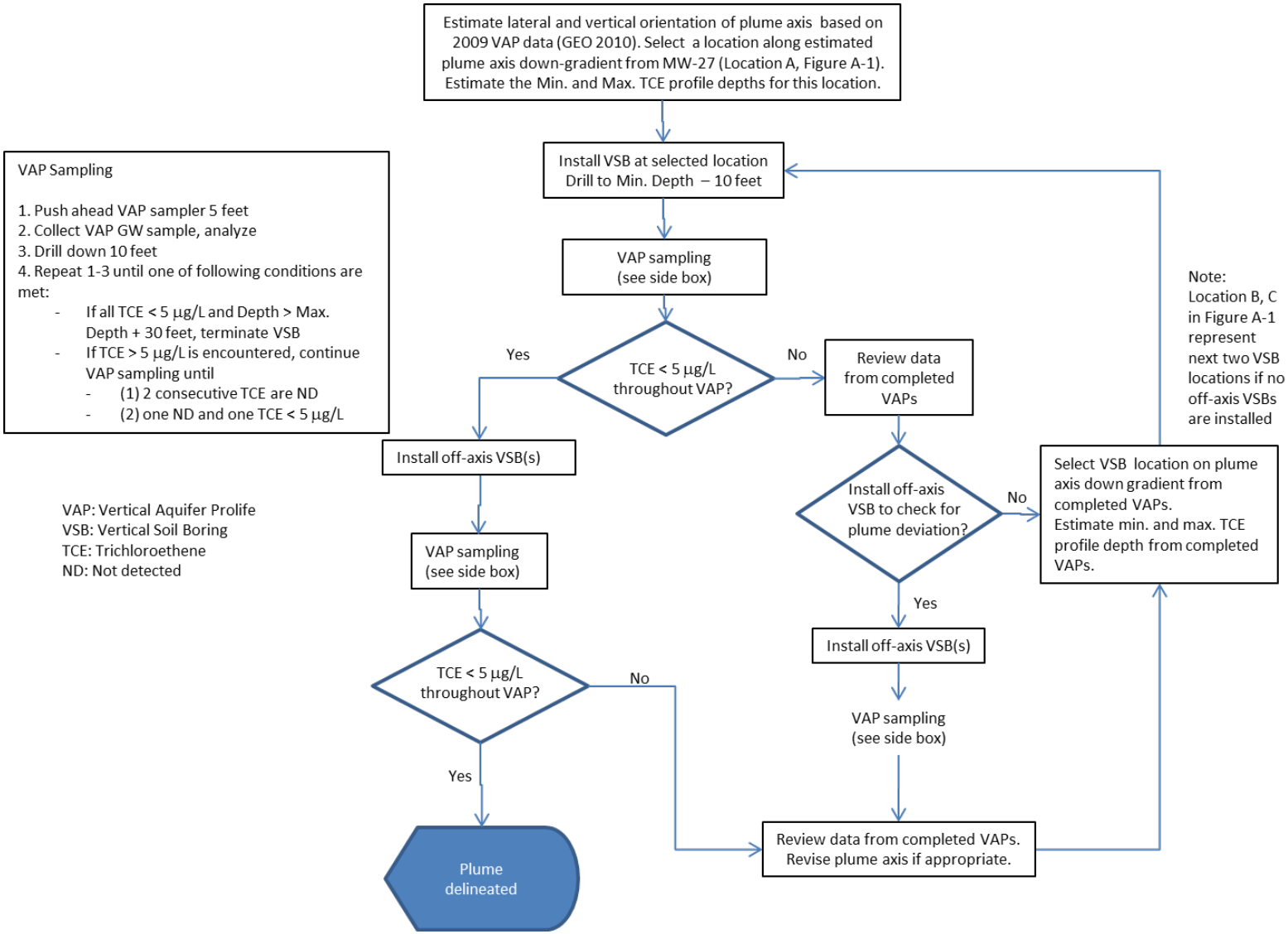


Figure B-4.
Drilling strategy flow chart for installation of VAP borings to complete delineation of the TCE plume at the Raco Site

U.S. Army Corps of Engineers
Louisville District

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site Chippewa County, Michigan

By: GEO Consultants, LLC
Date: March 2014

APPENDIX C

FIELD FORMS, CHECKLISTS AND LABORATORY ACCREDITATION CERTIFICATES

(ELECTRONIC ONLY ON CD AT FRONT OF DOCUMENT)

THIS PAGE INTENTIONALLY LEFT BLANK

Daily Quality Control Report (Page 1 of 2)

Project Name/Number:_____

Site:_____

Date:_____

Weather: ☐Clear, ☐Overcast, ☐Rain, ☐Thunderstorm, ☐Snow, ☐Other: _____

Temperature: ☐ <32°F, ☐ 32-50 °F, ☐50-70 °F, ☐70-85 °F, ☐85+ °F

Wind: ☐Still, ☐Gusty, ☐Moderate, ☐High; Direction:_____

Humidity: ☐ Dry, ☐Moderate, ☐ Humid

Activity	**Contractor/ Subcontractor**	**Equipment**	**Number of Workers**	**Total Hours Worked**

Problems Encountered	Corrective Action Taken

Total Daily Hours Worked by all Personnel:	

Day's Activities (Borings started, depth reached, borings completed, etc.)

1 day look ahead

2 day look ahead

Daily Quality Control Report (Page 2 of 2)

Tests: List type and location of the tests performed and the results of these tests.

Safety: Activity Safety Inspection

Safety Deficiencies Observed	Corrective Action Taken

Remarks:

Safety Statistics

Number of First Aid Incidents:	
Number of Recordable Incidents:	
Number of Lost Time Days:	

The FOM shall complete and sign a DQCR daily, all DQCRs to be submitted at conclusion of field work.

FOM Signature: Date:

Health and Safety Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Date:_____

Briefed on-site Personnel regarding: _____

_____

_____

Complete weekly for each site. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a "no" is checked, provide an explanation on the Noncompliance or Corrective Actions form.

Documentation	Yes	No	N/O	N/A
1. Is the Site Health and Safely Plan (SSHP) on the Site?				
2. Has the SSHP been reviewed, dated, and signed within the last year?				
3. Are the tasks being completed reflected in the hazard task analysis?				
4. Are emergency maps posted at the site and maintained in vehicles?				
5. Were daily safety checklists completed and fire extinguishers checked?				
6. Were applicable Material Safety Data Sheets at the Site?				
Observations	Yes	No	N/O	N/A
7. Is required personal protective equipment available and correctly used, maintained, and stored?				
8. Is the following emergency equipment located at each site:				
-Fire extinguisher?				
-Eyewash (15 minutes fresh water)?				
-Communications (walkie-talkie or phone)?				
-First aid kit?				
9. Is the buddy system in use?				
10. Is the site organized to allow the use of lifting equipment, avoid tripping hazards and spreading contamination?				
11. Was a random employee asked if he/she knew site hazard and emergency procedures?				
12. Is the drill rig kill switch clearly marked and easily accessible?				

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: Date:

_____ _____

Instrument Calibration Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Date:_____

Complete daily. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a "no" is checked, provide an explanation on the Noncompliance or Corrective Actions form.

Instrumental Calibration	Yes	No	N/O	N/A
1. Were all field instruments calibrated properly?				
2. Were all field instruments calibrated on the schedule in the Work Plan/SSHP?				
3. Did the Field Calibration Forms list all calibration events?				

List instruments used at the site:_____

_____

_____

_____

_____

_____

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: Date:

_____ _____

Surveying Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Date:_____

Complete one time for project. Answer each question by checking the appropriate column [yes, no, not observed (N/O) or not applicable (N/A)]. If a "No" is checked, provide an explanation on the Noncompliance and Corrective Action form.

Surveying	Yes	No	N/O	N/A
1. Was the Scope of Work reviewed with the surveyor?				
2. Was the schedule for the work provided to the surveyor?				
3. Was the survey completed by a licensed land surveyor?				
4. Were locations surveyed for horizontal and vertical control?				
5. Were conditions measured to the closest 0.1 feet and elevations measured to the closest 0.01 feet?				
6. Was the survey marker and TOC surveyed for each monitoring well?				
7. Were surveyor's closure calculations reviewed?				
8. Was surveyor interviewed by QC Inspector before leaving the Site?				

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: _____

Date: _____

Borehole and Core Logging Checklist (Page 1 of 2)

Project Name/Number:_____Site:_____

Boring/Monitoring Well Number:_____

Date:_____

Complete for each boring log. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a No is checked, provide an explanation on the noncompliance and Corrective Actions form.

Borehole Logging	Yes	No	N/O	N/A
1. Was boring logged by a geologist, geological engineer, or other qualified personnel?				
2. Was log completed and entries printed legibly on the HTRW Drilling Log?				
3. Was the log scale 1 inch = 1 foot?				
4. Were logs completed in the field (originals)?				
5. Does the log contain the following entries?				
-Unique borehole number				
-Depositional type (alluvium, till, loess, etc.)				
-Depths/Heights recorded in tenths of feet.				
-Soils classified as per USCS and fully described with numerical percents of constituents.				
-Soil moisture content and texture or cohesiveness.				
6. Was general information (top of form HTRW drilling log) completed?				
7. Were special conditions (i.e. intervals of hole instability) and their resolution recorded?				
8. Were start and completion dates and time included for boring installation activities?				
9. Were boundaries between soils noted (solid line at appropriate depth or dashed line if transitional or if observed in cuttings?				
10. Were depths at which free water was encountered and stabilized water levels recorded?				
11. Were soil sample depths recorded?				
12. If changes in drilling or sampling methods or equipment and changes in sample or borehole diameter recorded?				
13. Were soil sampling methods and recovery recorded?				
14. Was observed evidence of contamination in samples, cuttings, or drilling fluids recorded?				
15. Were abbreviations used on the log defined?				
16. Were drilling fluid losses including depth, rate, and volume in the subsurface recorded?				
Borehole Logging	Yes	No	N/O	N/A
17. Was drilling fluid described (water source, additive brand, product name, and mixture)?				
18. Were drilling pressures and driller's comments recorded?				
19. Was total depth recorded and marked with a double line?				
20. Was monitoring well diagram completed and attached to log?				
21. Was drilling fluid described (water source, additive brand, product name, and mixture)?				

Borehole and Core Logging Checklist (Page 2 of 2)

Core Logging	Yes	No	N/O	N/A
22. Was rock described using standard geologic nomenclature; e.g. rock type, relative hardness, density, texture, color, weathering, bedding, fossils, crystals, and open or closed fractures, joints, bedding planes, or cavities and filling materials?				
23. Was start and stop time of each core run recorded?				
24. Were depths to top and bottom of each core run recorded?				
25. Was length of core recovered in each core run recorded?				
26. Were the size and type of coring bit and barrel recorded?				
27. Was the depth to the bottom of the hole measured after the core was removed for each core run?				

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: _____

Date: _____

Field Documentation Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Complete daily. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a "no" is checked, provide an explanation on the Noncompliance or Corrective Actions form.

Field Documentation	Yes	No	N/O	N/A
1. Was all original field data, except boring logs, recorded in black indelible ink?				
2. Were logbooks filled out properly, accurately recounting the day's events?				
3. Were all field forms completed and information accurately recorded:				
-Daily Quality Control Report?				
-Daily Tailgate Meeting Form?				
-HTRW Drilling Log Form?				
-Field Log Books?				
-Project Photograph Log (in Log Book)?				
-Field Data Sheet?				
-Chain of Custody Forms?				

List additional field forms completed:

_____

_____

_____

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: _____

Date: _____

Sample Collection Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Sampling Date:_____

Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If "no" is checked, provide an explanation on the form.

General	Yes	No	N/O	N/A
1. Were new protective gloves worn between sampling locations and/or intervals?				
2. Were samples collected using methods described in the Work Plan?				
3. Were sample containers filled in the correct order?				
4. Was sampling equipment appropriate for the purpose and site conditions?				
5. Was sampling equipment decontaminated or disposable/dedicated equipment used between each sample?				
6. Were procedures for collecting QA/QC samples followed as per the Work Plan?				
7. Were sampling locations properly identified by land survey or GPS locator?				
8. Were bottles adequately protected from contamination prior to sample identification?				

Soil samples	Yes	No	N/O	N/A
9. Were samples collected according to the Work Plan?				
10. Was a field sampling form completed?				
11. Were the analytical parameters and QA/QC samples recorded on the Field Data Sheet?				

Water samples	Yes	No	N/O	N/A
12. Were samples collected according to the Work Plan?				
13. Was a field sampling form completed?				
14. Were the analytical parameters and QA/QC samples recorded on the Field Data Sheet?				
15. Was headspace in sample containers for volatiles eliminated?				

Corrective Actions:_____

_____

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: Date:

_____ _____

Packing, Storing, and Shipment of Samples Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Sampling Date:_____

Boring/Monitoring Well Number(s):_____

_____

_____

_____

Surface Soil Sample Number(s):_____

_____

_____

_____

Complete daily. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a "no" is checked, provide an explanation on the Noncompliance or Corrective Actions form.

Packing, Storing, and Shipment of Samples	Yes	No	N/O	N/A
1. Were the samples handled according to the Work Plan and QAPP?				
2. Did the samples remain in ice from collection until cooler was taped for shipment?				
3. Were Chain of Custody forms filled out accurately and completely, including project name and number, sampling date, sampling time, analytical parameters, preservatives, size and number of containers for each analytical parameter, and media sampled?				
4. Were Chain of Custody forms signed and dated by the preparer, placed in water resistant bagging, and included in the cooler?				
5. Were signed and dated custody seals properly placed on the cooler and the cooler sealed with strapping tape?				
6. Was a shipping label attached to the cooler?				

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: Date:

_____ _____

Investigation-Derived Waste Management Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Sampling Date:_____

Boring/Monitoring Well Number:_____

Complete weekly for each site. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a "no" is checked, provide an explanation on the Noncompliance or Corrective Actions form.

Investigation-Derived Waste Management	Yes	No	N/O	N/A
1. Was all IDW managed according to the Waste Management Plan?				
2. Were soil cuttings, drilling fluids, decontamination water, development water, and PPE containerized?				
3. Were all containers properly labeled and stored?				
4. Were all containers in satisfactory condition?				

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: _____

Date: _____

Mobilization/Demobilization Checklist (Page 1 of 3)

Project Name/Number:_____

Site:_____

Sampling Date:_____

Complete as indicated. Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If a No is checked, provide an explanation on the noncompliance and Corrective Actions form.

Complete 4 weeks prior to start of field activities.

Site Access and Security	Yes	No	N/O	N/A
1. Has a copy of the Right of Entry Permit(s) been received?				
2. Are the time frames of the Right of Entry Permit(s) adequate for the entire job including IDW disposal?				

Permits and Licenses	Yes	No	N/O	N/A
3. Are all subcontractors licensed to operate in the state?				
4. Are license numbers of subcontractors recorded in the project files?				
5. Have subcontractors provided proof of insurance?				
6. Have variances been obtained from the state?				

If yes, provide a lists of variances obtained:

_____

_____

_____

Coordination with Property Owners and Tenants	Yes	No	N/O	N/A
7. Has the property owner been contacted?				
8. Did the property owner designate a contractor staging area?				
9. Did the property owner designate a contractor IDW staging area?				
10. Did the property owner approve a source for water?				

Coordination with Environmental Authorities	Yes	No	N/O	N/A
11. Has the State approved the Work Plan?				
12. Has the State been informed of planned sampling events?				
13. Has USEPA approved the Work Plan?				
14. Has USEPA been informed of planned sampling events?				

Mobilization/Demobilization Checklist (Page 2 of 3)

Complete 1 week prior to start of field activities.

Safety Planning and Equipment	Yes	No	N/O	N/A
15. Has the SSHP been submitted to the subcontractors for review?				
16. Have all personnel read and signed the SSHP?				
17. Was the local hospital contacted to verify the phone number and address?				
18. Can the hospital treat anticipated chemical exposures?				
19. Are all MSDSs in a file to take to the field?				
20. Are all required instruments reserved and complete with calibration standards and manuals?				
21. Do the instruments meet manufacture maintenance and calibration standards?				

Complete within 1 week of Notice to Proceed.

Logistical Planning	Yes	No	N/O	N/A
22. Have the Work Plan documents been approved by USACE?				
23. Has the SSHP been approved by Health and Safety Services?				
24. Has Notice to Proceed from USACE been received?				
25. Are the project personnel available and scheduled?				
26. Are subcontractors available?				
27. Do subcontractors' SOWs correspond to the approved Work Plan?				
28. Has the laboratory agreed to the planned sample volume load?				
29. Has the bottle order been placed?				
30. Have the correct sample containers been received?				
31. Has USACE been notified of schedule?				

Complete not less than 1 week before fieldwork is scheduled to begin.

Utility Clearances	Yes	No	N/O	N/A
32. Has the State or Local utility clearance agency been contacted and a meeting scheduled?				
33. Has a representative from each notified utility agency been called to confirm the utility meeting?				
34. Was a utility work authorization number recorded?				
35. Was the property owner asked about the existence of any underground utilities or tanks?				

Mobilization/Demobilization Checklist (Page 3 of 3)

Environmental Site Protection	Yes	No	N/O	N/A
36. Are drilling and sampling locations accessible without property damage?				
37. Is work area limited to prevent property damage?				
38. Is IDW area greater than 100 feet away from a major stream, tributary, or drinking water well?				
39. If field activities damage property, will measures be taken to restore the Site (explain below)?				

Demobilization	Yes	No	N/O	N/A
40. Was the site returned, as much as possible, to its original condition?				
41. Was each work area policed for trash?				
42. Did the site point of contact inspect the site?				
51. Was the integrity of each container of IDW inspected?				

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: Date:

Environmental Chemistry Consulting Services, Inc.
2525 Advance Road
Madison, WI 53718
608-221-8700 (phone)
608-221-4889 (fax)

CHAIN OF CUSTODY

Lab Work Order #:

Mail Report To:
Company:
Address:
E-mail Address:

Project Number:
Project Name:
Project Location:

Preservation Codes
Analyses Requested

Turn Around (check one): ☐ Normal ☐ 5 BDs ☐ 3 BDs ☐ 2 BDs ☐ 24 hrs

If Rush, Report Due Date:

Sampled By (Print):

Invoice To:
Company:
Address:

Sample Description	Collection Date	Collection Time	Matrix	Total # of Containers							Comments	Lab ID	Lab Receipt Time
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			
					☐	☐	☐	☐	☐	☐			

Preservation Codes
A=None B=HCL C=H_2SO_4
D=HNO_3 E=EnCore F=Methanol
G=NaOH O=Other (Indicate)

Matrix Codes
A=Air S=Soil W=Water O=Other

Rush TAT Multipliers
5 Business Days = 1.5x
3 Business Days = 2x
2 Business Days = 2.25x
24 Hours = 2.5x
must be pre-arranged

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date:	Time:

Custody Seal: ☐ Present ☐ Absent ☐ Intact ☐ Not Intact
Seal #s:
Shipped Via:
Receipt Temp:
Temp Blank: ☐ Y ☐ N

Rev. 3/2006

Chain of Custody

Page _____ of _____

Company:
Project Contact:
Telephone:
Project Name:
Project Number:
Project Location:
Sampled By:

Regulatory Program:
UST RCRA SDWA NPDES
Solid Waste Other _____

CT LABORATORIES

1230 Lange Court, Baraboo, WI 53913
608-356-2760 Fax 608-356-2766
www.ctlaboratories.com

Turnaround Time
Normal RUSH*
Date Needed _____

*Notify Lab prior to sending in RUSH samples. Surcharges:
24 hr 200% 2-3 days 100% 4-9 days 50%, subject to change without notice.

Lab Use Only
Place Header Sticker Here:

Mail Report To:
Company:
Address:
City/State/Zip:

Invoice To:
Company:
Address:
City/State/Zip:

PO No.

Client Special Instructions:

Landfill License Number:

ANALYSES REQUESTED

Collection Date	Collection Time	Grab/ Comp	Sample ID Description	Filtered? Y/N	**Matrix:									Total # of Containers	Preservation*	Lab ID #
				Fill in Spaces with Bottles per Test												

*** Preservation Code**
A=None B=HCL
C=H2SO4 D=HNO3
E=Encore F=Methanol
G=NaOH
O=Other _____

Relinquished By:	Date/Time	Relinquished By:	Date/Time
Received by:	Date/Time	Received for Laboratory by:	Date/Time

Ice Present Yes No
Temperature _____
Cooler # _____

****Matrix**
S–Soil **A**–Air **Sl**–Sludge **M**–Misc Waste
GW–Groundwater **SW**–Surface Water
WW–Wastewater **DW**–Drinking Water

Project Name	Project Manager
Project Number	Client
Surface Elevation	Top of Casing Elevation
Total Depth	GPS Coordinates

WATER LEVEL MEASUREMENTS

Well	Location	Date	Time	Measurement	Barometer	Initial

Measure from notch/mark, and top of inner casing

Signature: _____

Date: _____Date Entered Electronically: _____Initials: _____

GEO Consultants, LLC
Well Development Log Form

WELL DEVELOPMENT LOG	WELL NO.:	PAGE 1 OF 1
INSTALLATION: Flush mount	SITE:	
CONTRACT NO./TASK ORDER NO.: W912QR-08-D-0030	CLIENT: USACE - CELRL	
CONTRACTOR: GEO Consultants, LLC	DEV. CONTRACTOR:	
DEV. START:	DEV. END	
DEVELOPED BY:		

Dev. Method _____

Equipment _____

Pre-dev. Water Level _____ Maximum drawdown during pumping _____ ft at _____ gpm
Range and average discharge rate _____
Total quantity of water discharged by pumping _____
Disposition of discharge water _____

Time	Volume Removed (gal)	Temperature (ºC)	pH (SU)	Spec. Cond. (µmhos/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Remarks

HTRW DRILLING LOG

	DISTRICT:	HOLE NUMBER
1. COMPANY NAME:	2. DRILL SUBCONTRACTOR:	SHEET ____ OF ____

3. PROJECT:	4. LOCATION:
5. NAME OF DRILLER:	6. MANUFACTURERS DESIGNATION OF DRILL:
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	8. HOLE LOCATION:
	9. SURFACE ELEVATION:
	10. DATE STARTED: / 11. DATE COMPLETED:
12. OVERBURDEN THICKNESS	15. DEPTH GROUNDWATER ENCOUNTERED:
13. DEPTH DRILLED INTO ROCK	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED:
14. TOTAL DEPTH OF HOLE	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY):

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR

LOCATION SKETCH/COMMENTS SCALE:

HTRW DRILLING LOG

HOLE NUMBER

PROJECT:

INSPECTOR

SHEET OF

ELEV. (A)	DEPTH (B)	DESCRIPTION OF MATERIALS (C)	HEADSPACE SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX	ANALYTICAL SAMPLE NO. (F)	REMARKS (G)

QUANTA DAILY CALIBRATION

Hydrolab # GEO-461-1
GEO-461-2
GEO-461-3

By TC JH BG MC JB VM RT JB

Date:_____

pH CALIBRATION

Buffer +/- .1 SU	Lot #	Exp. Date	Vendor	Time	Temp (Celsius)	pH	Adj. To
pH 4							
pH 7							
pH 10							

D.O. AIR CALIBRATION

Solution Temp (C):_____ Local B.P.:_____

% Saturation:_____ % Saturation (fixed): 100%

DO mg/l Reading (+/- 0.2 mg/l) _____@_____Deg Celsius

Does reading meet DO Saturation Values acceptance criteria?_____Yes _____No
If No, Recalibrate or check Operations Manual for maintenance.

CONDUCTIVITY CALIBRATION

Standard Value:
1412 (umhos) 1.412 (mS) Lot #_____ Exp:_____ Manufacturer:_____

Temperature(C):_____ Conductivity(+/- 20 umhos):_____ Adjusted To:_____

TURBIDITY CALIBRATION PERFORMANCE CHECK

4-Beam Turbidity Quick-Cal Cube QCC#:81181

GEO 461-1=75.0 +/- 20%
GEO 461-2=77.9 +/- 20%
GEO 461-3=77.0 +/- 20%

Reading _____NTU

_____Reading is within acceptance criteria of the Quick-Cal Cube for the instrument to be used.
_____Reading is not within acceptance criteria of the Quick-Cal Cube for the instrument to be used. If reading is not within the Quick-Cal Cube acceptance criteria, perform primary calibration according to operational manual.

ORP Calibration

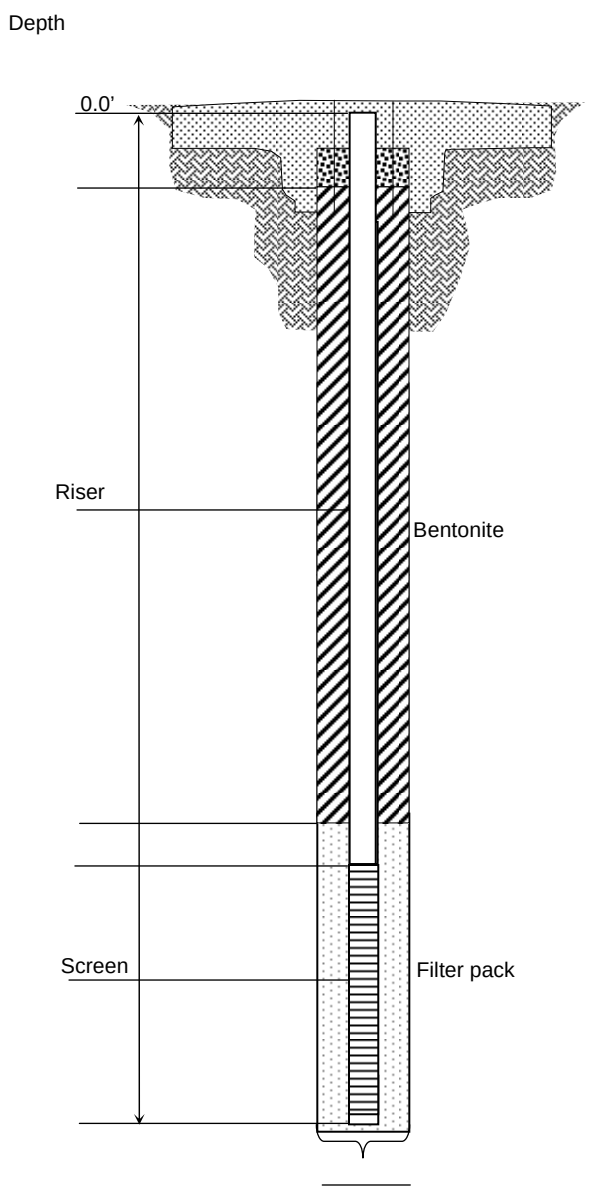
ZoBell Solution:
Lot #: _____ Expiration Date: _____

ZoBell Solution's ORP Value: _____+/- 10 mV @_____Deg C

Reading Prior to Calibration: _____mV @_____Deg C
Reading After Calibration: _____+/- 10 mV @_____Deg C

Comments:

Site:	Installation:	Well No.
Client:	Contract No./Task Order No.:	
Contractor: GEO Consultants, LLC	Drill Contractor:	
Start Date: End Date:	Datum:	
	Coordinates: Northing: Easting:	
	Elevation (ft amsl): Surface TOC	



NOT TO SCALE

Protective Casing
Material Type:
Diameter:
Depth BGS: Weep Hole? (Y / N):
Guard Posts (Y / N):

Surface Pad
Composition and Size:

Riser Pipe
Type:
Diameter:
Length (TOC to TOS):
Ventilated Cap (Y / N):

Bentonite Seal
Type:
Source:
Amt. Used:
Setup/Hydration Time: Vol. Fluid Added:
Tremied (Y / N):

Primary Filter Pack
Graduation Designation:
Grain Size:
Amt. Used:
Tremied (Y / N):

Screen
Type:
Diameter:
Length:
Slot Size:
Interval Below TOC:

U.S. Army Corps of Engineers
Kansas City District

Permanent Monitoring Well Construction Log

GEO Consultants, LLC
A Geological Engineering and Environmental Services Company
Kevil, Kentucky

Waste Item Container Log

Item/Container of	Origin Date:	Project Name:
Area of Collection:	Container condition:	Project Number:

Waste Material Placed in (or Removed) From Container (note point of origin)	Quantity	Depositor		Comments (If Waste is removed from container, then final disposition must be noted)
		Initials	Date	

Container Generator Signature	Date

The American Association for Laboratory Accreditation

World Class Accreditation

Accredited DoD ELAP Laboratory

A2LA has accredited

CT LABORATORIES

Baraboo, WI

for technical competence in the field of

Environmental Testing

In recognition of the successful completion of the A2LA evaluation process that includes an assessment of the laboratory's compliance with ISO/IEC 17025:2005, the 2003 NELAC Chapter 5 Standard, and the requirements of the Department of Defense Environmental Laboratory Accreditation Program (DoD ELAP) as detailed in the current DoD Quality System Manual for Environmental Laboratories (QSM); accreditation is granted to this laboratory to perform recognized EPA methods as defined on the associated A2LA Environmental Scope of Accreditation. This accreditation demonstrates technical competence for this defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009*).

Presented this 1st day of May 2012.

President & CEO
For the Accreditation Council
Certificate Number 3317.01
Valid to June 30, 2014

For the tests or types of tests to which this accreditation applies, please refer to the laboratory's Environmental Scope of Accreditation.

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005

CT LABORATORIES
1230 Lange Court
Baraboo, WI, 53913
Dan Elwood Phone: (608) 356 2760
DElwood@CTLaboratories.com

ENVIRONMENTAL

Valid To: June 30, 2014 Certificate Number: 3317.01

In recognition of the successful completion of the A2LA evaluation process, (including an assessment of the laboratory's compliance with ISO IEC 17025:2005, the 2003 NELAC Chapter 5 Standard, and the requirements of the DoD Environmental Laboratory Accreditation Program (DoD ELAP) as detailed in the current DoD Quality Systems Manual for Environmental Laboratories) accreditation is granted to this laboratory to perform recognized EPA methods using the following testing technologies and in the analyte categories identified below:

Testing Technologies

Atomic Absorption/ICP-AES Spectrometry, Gas Chromatography, Gas Chromatography/Mass Spectrometry, Gravimetry, High Performance Liquid Chromatography, Ion Chromatography, Misc.- Assay, Electronic Probes (pH, O_2), Oxygen Demand, Hazardous Waste Characteristics Tests, Spectrophotometry (Visible), Spectrophotometry (Automated), IR Spectrometry, Titrimetry, Total Organic Carbon, Turbidity

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Classical Chemistry			
Alkalinity	----------	EPA 310.2	----------
Ammonia (as N)	----------	EPA 350.1	EPA 350.1 / 350.2
Bromide	----------	EPA 300.0 / EPA 9056	EPA 9056
Biological Oxygen Demand	----------	SM 5210B	----------
Chemical Oxygen demand	----------	EPA 410.4	EPA 410.4 / SM 5220 D
Chloride	----------	EPA 300.0 / EPA 9056	EPA 9056
Conductivity	----------	EPA 9050A	----------
Cyanide	----------	EPA 9010 / 9012	EPA 9012
Fluoride	----------	EPA 300.0 / EPA 9056	EPA 9056
Hardness	----------	SM 2340 B / EPA 6010C	----------
Nitrate + Nitrite	----------	EPA 300.0 / 353.2 / 9056	EPA 353.2 / 9056
Nitrate (as N)	----------	EPA 300.0 / 353.2 / 9056	EPA 353.2 / 9056
Nitrite (as N)	----------	EPA 300.0 / 353.2 / 9056	EPA 353.2 / 9056
Nitrogen, Total Kjeldahl	----------	EPA 351.2	----------
Orthophosphate (as P)	----------	EPA 300.0 / 365.1 / 9056	EPA 365.1 / 9056
Phosphorus, Total	----------	EPA 365.1 / 365.4	EPA 365.1 / 365.4

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Organic Carbon, Total	----------	EPA 415.1 / 9060A	EPA 9060A / Lloyd Kahn / SM 5310B
Oil and Grease / HEM	----------	EPA 1664A	EPA 9070A / 9071B
pH	----------	EPA 150.1 / 9040C / 9041A / SM4500H	EPA 9045D
Phenols	----------	EPA 9066	EPA 9066
Residue, Total	----------	SM 2540B	SM 2540B
Residue Filterable	----------	SM 2540C	SM 2540C
Residue Nonfilterable	----------	SM 2540D Modified / 160.2	SM 2540D Modified / 160.2
Residue Total Volatile	----------	EPA 160.4	SM 2540G
Salinity	----------	SM 2520B	SM 2520B
Sulfate	----------	EPA 300.0 / 9056	EPA 9056
Sulfide	----------	EPA 9034	----------
Turbidity	----------	EPA 180.1	----------
Metals			
Aluminum	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Antimony	EPA 6010C	EPA 200.7 / 200.9 / 6010 / 7010	EPA 6010C / 7010
Arsenic	EPA 6010C	EPA 200.7 / 200.9 / 6010C / 7010 / 7060A	EPA 6010C / 7010
Barium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Beryllium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Boron	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Cadmium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Calcium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Chromium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Chromium +3	EPA 6010C	EPA 7196A	EPA 7196A
Chromium +6	EPA 6010C	EPA 7196A	EPA 7196A
Cobalt	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Copper	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Iron	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Iron Ferrous	----------	SM 3500 Fe B	----------
Lead	EPA 6010C	EPA 200.7 / 200.9 / 6010C / 7010	EPA 6010C / 7010
Lithium	EPA 6010C	EPA 200.7 / EPA 6010C	EPA 6010C
Magnesium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Manganese	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Mercury	EPA 6010C	EPA 245.1 / 7470A	EPA 7471B
Molybdenum	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Nickel	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Potassium	----------	EPA 200.7 / 6010C	EPA 6010C
Selenium	EPA 6010C	EPA 200.7 / 200.9 / 6010C / 7010 / 7740A	EPA 6010C / 7010
Silica	----------	EPA 6010C	EPA 6010C
Silver	EPA 6010C	EPA 200.7 / 6010C / 7010	EPA 6010C / 7010
Sodium	----------	EPA 200.7 / 6010C	EPA 6010C
Strontium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Sulfur	----------	EPA 6010C	EPA 6010C

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Thallium	EPA 6010C	EPA 200.7 / 6010C / 7010	EPA 6010C / 7010
Tin	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Titanium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Tungsten	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Vanadium	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Zinc	EPA 6010C	EPA 200.7 / 6010C	EPA 6010C
Purgeable Organics (volatiles) Low Level			
1,1,1,2-Tetrachloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,1-Trichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,2,2-Tetrachloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,2-Trichloro-1,2,2-trifluoroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,2-Trichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1-Dichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1-Dichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1-Dichloropropene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,3-Trichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,3-Trichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,4-Trichorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,4-Trimethylbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dibromo-3-chloropropane (DBCP)	----------	EPA 8260B / 8260C / 8011	EPA 8260C / 8011
1,2-Dibromomethane (EDB)	----------	EPA 8260B / 8260C / 8011	EPA 8260C / 8011
1,2-Dichloro-1,2,2-trifluoroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,3-Dichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,3-Dichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,4-Dichloro-2-butane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,4-Dichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,4-Dioxane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1-Chlorohexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2,2-Dichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2,3-Dichloro-1-propene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Butanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Chloroethyl vinyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Chlorotoluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Hexanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
4-Chlorotoluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
4-Methyl-2-pentanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Acrylein	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Acrylonitrile	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Acetone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Benzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Bromobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Bromodichloromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Bromoform	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Bromomethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Carbon disulfide	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Carbon tetrachloride	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chloroform	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chloromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
cis-1,2-Dichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
cis-1,3-Dichloropropene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Cyclohexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Cyclohexanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dibromochloromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dibromomethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dichlorodifluoromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dichlorofluoromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Diisopropyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Ethyl acetate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Ethyl benzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Ethyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Hexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Iodomethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl acetate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl iodide	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl methacrylate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl tert butyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methylcyclohexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methylene chloride	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
m & p -Xylene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Naphthalene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
n-Buytlbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
o-Xylene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Propylene oxide	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
p-Isopropyltoluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
sec-Butylbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Styrene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
tert-Butyl alcohol	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
tert-Butylbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Tetrachloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Tetrahydrofuran	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Toluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
trans-1,2-Dichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
trans-1,3-Dichloropropene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Trichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Trichlorofluoromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Vinyl acetate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Vinyl chloride	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Xylenes, total	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Purgeable Organics (volatiles) Medium Level			
1,1,1,2-Tetrachloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,1-Trichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,2,2-Tetrachloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,2-Trichloro-1,2,2-trifluoroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1,2-Trichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1-Dichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1-Dichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,1-Dichloropropene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,3-Trichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,3-Trichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,4-Trichorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2,4-Trimethylbenzene	----------	EPA 8020A / 8260B / 8260C	EPA 8020A / 8260B / 8260C
1,2-Dibromo-3-chloropropane (DBCP)	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dibromomethane (EDB)	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,3,5-Trimethylbenzene	----------	EPA 8020A / 8260B / 8260C	EPA 8020A / 8260B / 8260C
1,2-Dichloro-1,2,2-trifluoroethane	----------	EPA 8260C	EPA 8260C
1,2-Dichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dichloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,2-Dichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,3-Dichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,4-Dichloro-2-butane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,4-Dichlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1,4-Dioxane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
1-Chlorohexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2,2-Dichloropropane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2,3-Dichloro-1-propene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Butanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Chloroethyl vinyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Chlorotoluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
2-Hexanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
4-Chlorotoluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
4-Methyl-2-pentanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Acetone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Benzene	----------	EPA 8020A/ 8021B / 8260B / 8260C	EPA 8020A/ 8021B / 8260B / 8260C
Bromobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Bromodichloromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Bromoform	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Bromomethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Carbon disulfide	----------	EPA 8260B / 8260C	EPA 8260B / 8260C

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Carbon tetrachloride	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chlorobenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chloroethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chloroform	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Chloromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
cis-1,2-Dichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
cis-1,3-Dichloropropene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Cyclohexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Cyclohexanone	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dibromochloromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dibromomethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dichlorodifluoromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Dichlorofluoromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Diisopropyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Ethyl acetate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Ethyl benzene	----------	EPA 8020A/ 8021B / 8260B / 8260C	EPA 8020A/ 8021B / 8260B / 8260C
Ethyl ether	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Hexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Iodomethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl acetate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl iodide	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl methacrylate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methyl tert butyl ether	----------	EPA 8020A/ 8021B / 8260B / 8260C	EPA 8020A/ 8021B / 8260B / 8260C
Methylcyclohexane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Methylene chloride	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
m & p -Xylene	----------	EPA 8020A/ 8021B / 8260B / 8260C	EPA 8020A/ 8021B / 8260B / 8260C
Naphthalene	----------	EPA 8020A/8260C	EPA 8020A/8260C
n-Buytlbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
o-Xylene	----------	EPA 8020A/ 8021B / 8260B / 8260C	EPA 8020A/ 8021B / 8260B / 8260C
Propylene oxide	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
p-Isopropyltoluene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
sec-Butylbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Styrene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
tert-Butyl alcohol	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
tert-Butylbenzene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Tetrachloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Tetrahydrofuran	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Toluene	----------	EPA 8020A/ 8021B / 8260B / 8260C	EPA 8020A/ 8021B / 8260B / 8260C
trans-1,2-Dichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
trans-1,3-Dichloropropene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Trichloroethene	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Trichlorofluoromethane	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Vinyl acetate	----------	EPA 8260B / 8260C	EPA 8260B / 8260C

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Vinyl chloride	----------	EPA 8260B / 8260C	EPA 8260B / 8260C
Xylenes, total	----------	EPA 8020A/ 8021B/8260C	EPA 8020A/ 8021B/8260C
Dissolved Gasses			
Carbon Dioxide	----------	RSK 175 / SM 4500 CO2 D	----------
Ethane	----------	RSK 175	----------
Ethene	----------	RSK 175	----------
Methane	----------	RSK 175	----------
Extractable Organics (semivolatiles)			
1,2,4,5-Tetrachlorobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
1,2,4-Trichlorobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
1,2-Dichlorobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
1,3-Dichlorobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
1,4-Dichlorobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
1,4-Dioxane	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
1-Methylnaphthalene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,3,4,6-Tetrachlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,4,5-Trichlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,4,6-Trichlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,4-Dichlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,4-Dimethylphenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,4-Dinitrophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,4-Dinitrotoluene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,6-Dichlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2,6-Dinitrotoluene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Chloronaphthalene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Chlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Ethoxyethanol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Methylnaphthalene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Methylphenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Naphthylamine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Nitroaniline	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
2-Nitrophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
3 & 4-Chlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
3 & 4-Methylphenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
3,3'-Dichlorobenzidine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
3-Nitroaniline	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4,6-Dinitro-2-methylphenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4-Bromophenyl-phenyl ether	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4-Chloro-3-methylphenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4-Chloroaniline	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4-Chlorophenyl-phenyl ether	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4-Nitroaniline	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
4-Nitrophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Acenaphthene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Acenaphthylene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Acetophenone	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Alpha Terpineol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Aniline	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Anthracene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Atrazine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Azobenzene & 1,2-Diphenylhydrazene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzaldehyde	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzidine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzo(a)anthracene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzo(a)pyrene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzo(b)fluoranthene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzo(g,h,i)perylene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzo(k)fluoranthene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzoic acid	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Benzyl alcohol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Biphenyl	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Bis(2-chloroethoxy)methane	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Bis(2-chloroethyl)ether	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Bis(2-chloroisopropyl)ether	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Bis(2-ethylhexyl)phthalate	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Butylbenzylphthalate	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Caprolactam	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Carbazole	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Chrysene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Dibenzo(a,h)anthracene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Dibenzofuran	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Diethylphthalate	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Dimethylphthalate	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Di-n-butylphthalate	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Di-n-octylphthalate	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Fluoranthene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Fluorene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Hexachlorobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Hexachlorobutadiene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Hexachlorocyclopentadiene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Hexachloroethane	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Hexachlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Hexachloropropene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Indeno(1,2,3-cd)pyrene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Isophorone	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Naphthalene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Nitrobenzene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
n-Nitrosodiethylamine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
n-Nitrosodimethylamine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
n-Nitroso-di-n-propylamine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
n-Nitrosodiphenylamine & Diphenylamine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
N-Nitrosopyrrolidine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Pentachlorophenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Phenanthrene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Phenol	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Pyrene	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Pyridine	----------	EPA 8270C / 8270D	EPA 8270C / 8270D
Pesticides/PCBs			
Aldrin	EPA 8081B	EPA 8081B	EPA 8081B
alpha-BHC	EPA 8081B	EPA 8081B	EPA 8081B
beta-BHC	EPA 8081B	EPA 8081B	EPA 8081B
delta-BHC	EPA 8081B	EPA 8081B	EPA 8081B
gamma-BHC (Lindane)	EPA 8081B	EPA 8081B	EPA 8081B
alpha-Chlordane	EPA 8081B	EPA 8081B	EPA 8081B
gamma-Chlordane	EPA 8081B	EPA 8081B	EPA 8081B
DDD (4,4)	EPA 8081B	EPA 8081B	EPA 8081B
DDE (4,4)	EPA 8081B	EPA 8081B	EPA 8081B
DDT (4,4)	EPA 8081B	EPA 8081B	EPA 8081B
Dieldrin	EPA 8081B	EPA 8081B	EPA 8081B
Endosulfan I	EPA 8081B	EPA 8081B	EPA 8081B
Endosulfan II	EPA 8081B	EPA 8081B	EPA 8081B
Endosulfan sulfate	EPA 8081B	EPA 8081B	EPA 8081B
Endrin	EPA 8081B	EPA 8081B	EPA 8081B
Endrin aldehyde	EPA 8081B	EPA 8081B	EPA 8081B
Endrin ketone	EPA 8081B	EPA 8081B	EPA 8081B
Heptachlor	EPA 8081B	EPA 8081B	EPA 8081B
Heptachlor Epoxide (beta)	EPA 8081B	EPA 8081B	EPA 8081B
Methoxychlor	EPA 8081B	EPA 8081B	EPA 8081B
Chlordane (technical)	EPA 8081B	EPA 8081B	EPA 8081B
Toxaphene (total)	EPA 8081B	EPA 8081B	EPA 8081B
Aroclor 1016	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1221	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1232	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1242	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1248	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1254	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1260	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1262	EPA 8082A	EPA 8082A	EPA 8082A
Aroclor 1268	EPA 8082A	EPA 8082A	EPA 8082A
Acetochlor	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Alachlor	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Atrazine	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Chlorpyrifos	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Cyanazine	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Desethylatrazine	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Desisopropylatrazine	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Metolachlor	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Metribuzin	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
Simazine	----------	EPA 8270C SIM / 8270D SIM	EPA 8270C SIM / 8270D SIM
Low Level PAH			
Acenaphthene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Acenaphthylene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Anthracene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Benzo(a)anthracene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Benzo(b)fluoranthene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Benzo(k)fluoranthene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Benzo(g,h,i)perylene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Benzo(a)pyrene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Chrysene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Dibenz(a,h)anthracene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Fluoranthene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Fluorene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Indeno(1,2,3-cd)pyrene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
1-Methylnaphthalene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
2-Methylnaphthalene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Naphthalene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Phenanthrene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Pyrene	----------	EPA 8310 / 8270C SIM / 8270D SIM	EPA 8310 / 8270C SIM / 8270D SIM
Explosives			
2-Amino-4,6-dinitrotoluene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
4-Amino-2,6-dinitrotoluene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
1,3-Dinitrobenzene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
2,3-Dinitrotoluene	----------	EPA 8330A / 8330B / 8270C SIM / 8270D SIM	EPA 8330A / 8330B / 8270C SIM / 8270D SIM
2,4-Dinitrotoluene	----------	EPA 8330A / 8330B / 8270C SIM / 8270D SIM	EPA 8330A / 8330B / 8270C SIM / 8270D SIM
2,5-Dinitrotoluene	----------	EPA 8330A / 8330B / 8270C	EPA 8330A / 8330B / 8270C

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
		SIM / 8270D SIM	SIM / 8270D SIM
2,6-Dinitrotoluene	----------	EPA 8330A / 8330B / 8270C SIM / 8270D SIM	EPA 8330A / 8330B / 8270C SIM / 8270D SIM
3,4-Dinitrotoluene	----------	EPA 8330A / 8330B / 8270C SIM / 8270D SIM	EPA 8330A / 8330B / 8270C SIM / 8270D SIM
2,5-Dinitrotoluene	----------	EPA 8330A / 8330B / 8270C SIM / 8270D SIM	EPA 8330A / 8330B / 8270C SIM / 8270D SIM
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
Nitrobenzene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
2-Nitrotoluene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
3-Nitrotoluene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
4-Nitrotoluene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
Tetryl (Methyl-2,4,6-trinitrophenylnitramine)	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
1,3,5-Trinitrobenzene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
2,4,6-Trinitrotoluene	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
3,5-Dinitroaniline	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
PETN	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
Nitroguanidine	----------	EPA 8330A / 8330B	EPA 8330A / 8330B
Nitroglycerine	----------	EPA 8330A / 8330B / 8332	EPA 8330A / 8330B / 8332
Nitrocellulose	----------	ACOE ERDC / EPA 9056M	ACOE ERDC / EPA 9056M
Volatile Fatty Acids			
Acetic acid	----------	EPA 9056M	EPA 9056M
Butyric acid	----------	EPA 9056M	EPA 9056M
Formic acid	----------	EPA 9056M	EPA 9056M
Lactic acid	----------	EPA 9056M	EPA 9056M
Propionic acid	----------	EPA 9056M	EPA 9056M
Pyruvic acid	----------	EPA 9056M	EPA 9056M
Glycols			
Ethylene glycol	----------	EPA 8015B	EPA 8015B
Propylene glycol	----------	EPA 8015B	EPA 8015B
Petroleum Hydrocarbons			
Gas Range Organics (GRO) Diesel Range Organics (DRO) Alaska GRO Alaska DRO Alaska RRO	----------	EPA 8015B EPA 8015B AK 101 AK 102	EPA 8015B EPA 8015B AK 101 AK 102 AK 103
Wisconsin GRO Wisconsin DRO	----------	WI GRO WI DRO	WI GRO WI DRO

Parameter/Analyte	Bio Tissue	Nonpotable Water	Solid Hazardous Waste
HazardousWaste Characteristics			
Ignatibility	----------	EPA 1010	EPA 1010
Paint Filter Liquids Test	----------	----------	EPA 9095A
Reactivity	----------	EPA SW 846 Ch 7	EPA SW 846 Ch 7
Synthetic Precipitation Leaching Procedure (SPLP)	----------	EPA 1312	EPA 1312
Toxicity Characteristic Leaching Procedure (TCLP)	----------	EPA 1311	EPA 1311
Prep & Clean-up Methods			
VOC	----------	EPA 5030B	EPA 5035
Organic Semi-volatiles	----------	EPA 3510C / 3535A / 3620C / 3640A / 3660B / 3665A	EPA 3540C / 3545 / 3545A / 3546 / 3580A 3620C / 3640A / 3660B / 3665A
Metals	----------	EPA 3005A / 3010 ./ 3015 / 3020 / 3051	EPA 3050B / 3051
VOC in Air	Air		
Benzene	NIOSH 1500	----------	----------
Ethyl benzene	NIOSH 1500	----------	----------
Toluene	NIOSH 1500	----------	----------
Xylene	NIOSH 1500	----------	----------

The American Association for Laboratory Accreditation

World Class Accreditation

Accredited DoD ELAP Laboratory

A2LA has accredited

CT LABORATORIES

Baraboo, WI

for technical competence in the field of

Environmental Testing

In recognition of the successful completion of the A2LA evaluation process that includes an assessment of the laboratory's compliance with ISO/IEC 17025:2005, the 2003 NELAC Chapter 5 Standard, and the requirements of the Department of Defense Environmental Laboratory Accreditation Program (DoD ELAP) as detailed in the current DoD Quality System Manual for Environmental Laboratories (QSM); accreditation is granted to this laboratory to perform recognized EPA methods as defined on the associated A2LA Environmental Scope of Accreditation. This accreditation demonstrates technical competence for this defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009*).

Presented this 1st day of May 2012.

President & CEO
For the Accreditation Council
Certificate Number 3317.01
Valid to June 30, 2014

For the tests or types of tests to which this accreditation applies, please refer to the laboratory's Environmental Scope of Accreditation.

Field Change Request (FCR)

FCR #: _____ Date: _____

Project: _____ ❑ Change in cost to client (see cost section below)

Contract #: _____ ❑ No change in cost to client

Requestor

Name: _____ Organization: _____

Phone: _____ Title: _____

Signature: _____

Baseline Identification

Baseline(s) Affected: ❑ Cost ❑ Scope ❑ Milestone ❑ Method ❑ Other: _____

Affected Document (Title, Number, and Section): _____

_____

Description of Change: _____

_____

_____

_____

Justification

_____

_____

_____

_____

Impact of Not Implementing Request

_____

_____

_____

_____

Participants Affected by Implementing Request:

_____

_____

Cost

Cost Estimate: _____ Estimate Signature: _____

Phone: _____ Date: _____

Approval

Previous FCR Affected ❑ Yes ❑ No If Yes, FCR #:_____

Client Name: _____ Client Signature: _____

Decontamination Checklist (Page 1 of 1)

Project Name/Number:_____

Site:_____

Sampling Date:_____

Boring/Monitoring Well Number(s):_____

Answer each question by checking the appropriate column [yes, no, not observed (N/O), or not applicable (N/A)]. If "no" is checked, provide an explanation on the form.

Equipment	Yes	No	N/O	N/A
1. Was all sampling equipment decontaminated properly prior to use and between sample intervals?				
2. Was each decontamination event recorded in the logbook?				
3. Was IDW (decontamination water) handled in accordance with the approved work plan?				

Corrective Actions:_____

_____

_____

_____

_____

_____

The QC inspector shall sign this checklist upon completion of all items on the checklist.

QC Inspector Signature: Date:

_____ _____

GEO CONSULTANTS, LLC

A Geological Engineering and Environmental Services Company

Technical Operating Procedure

LOGBOOKS

GEO-TEC-005

Revision 3

Prepared by: A. Michael Bosch

Approved by: _____, 11/16/11
Jeff Doughty, P.E. – President Date

Record of Changes

Revision Number	Changes and/or Affected Page(s)	Effective Date
0	New Procedure	-
1	All	-
2	All	01/29/2004
3	Complete Revision – All pages affected.	11/16/2011

Next review required no later than: November 16, 2012

TABLE OF CONTENTS

1.0 PURPOSE 3

2.0 SCOPE 3

3.0 TRAINING 3

4.0 OTHER DOCUMENTS NEEDED 3

5.0 WHAT TO DO
- 5.1 Obtain, Identify, and Assign a Logbook 3
- 5.2 Develop and Control Data Forms for Logbooks 4
- 5.3 Prepare a New Logbook for Use 5
- 5.4 Follow General Rules for Logbook and Form Use 5
- 5.5 Record Daily Information in a Logbook 7
- 5.6 Correct a Logbook Entry 9
- 5.7 Transfer a Logbook to New Custodian 10
- 5.8 Complete One Logbook and Start a New Logbook 10
- 5.9 Perform End-of-Day Logbook Activities 10
- 5.10 Review an Active Logbook 12
- 5.11 Review a Completed Logbook 13
- 5.12 Disposition a Completed Logbook 13

6.0 RECORDS
- 6.1 General Requirements 14
- 6.2 Records Generated 14

7.0 SOURCE DOCUMENTS 14

8.0 ATTACHMENTS
- Attachment A – Definitions and Acronyms 15
- Attachment B – Example of Logbook Daily Summary 16
- Attachment C – Example of Typical Logbook Entries 17

PURPOSE

1.1 This procedure establishes criteria and guidelines for logbook content and control and provides guidelines for accurate and complete documentation of activities.

1.2 This procedure establishes requirements for data forms or sketches affixed to logbook pages to ensure they are adequately reviewed, properly sized, securely attached, and controlled.

SCOPE

2.1 The requirements of this procedure apply to logbooks used by GEO Consultants, LLC (GEO) and its subcontractors and teaming partners, if applicable.

2.2 These requirements apply to logbooks used to document a work activity (e.g., site, project, sampling, laboratory, maintenance). They also apply to data forms or labels that are permanently inserted into a logbook and used to document data or other pertinent information (e.g., sample collection information, field measurements, data assessment checklists).

2.3 **Exceptions:** The requirements of this procedure do **not** apply to communication or personal logbooks. They also do **not** apply to data forms that are not inserted into a logbook.

TRAINING

3.1 All GEO personnel who work directly on a project shall complete documented Required Reading of this procedure or any revision thereof within 30 days of issuance or within 30 days of being employed by GEO.

OTHER DOCUMENTS NEEDED

4.1 GEO Quality System procedure GEO-QSP-401, *Control of Documents and Records*

4.2 GEO Quality System procedure GEO-QSP-403, *Control of Procedures and Forms*

4.3 GEO Quality System procedure GEO-QSP-801, *Audits and Surveillances*

WHAT TO DO

5.1 Obtain, Identify, and Assign a Logbook

Project Manager

5.1.1 Purchase **or** otherwise obtain logbooks which meet the following criteria:

- Pages shall be bound
- Pages should be pre-numbered, and
- Logbooks should be waterproof or designed so that they do not fall apart when wet..

NOTE: Logbooks shall be controlled during tracking, handling, and usage to ensure they are not lost or damaged.

5.1.2 Record the following information on the **outer front cover** of each logbook using an indelible marking pen or paint pen (black or white):

- Project name and number
- Unique logbook name and number
- Sequential Document Control number (if more than one)
- Activity or site name
- "Start Date" (date to be filled in later), and
- "Completion Date" (date to be filled in later).

Project Manager

5.1.3 **IF** multiple logbooks are used for a project,
THEN maintain a project logbook inventory log to document the physical inventory of logbooks not yet issued, logbooks that have been issued, and logbooks that were returned.

5.1.4 Use the project logbook inventory log, if applicable, to identify the name of any person assigned a GEO logbook and the date it was assigned.

Logbook Custodian

5.1.5 **IF** data forms or sketches are **not** needed for insertion into the logbooks, **THEN** GO TO Subsection 5.3.

WHAT TO DO

5.2 Develop and Control Data Forms for Logbooks

Project Manager or Designee

NOTE: The use of pre-printed data forms or sketches affixed to a logbook page can save time in the field and help ensure consistency and completeness in the data that is recorded.

5.2.1 Develop most data forms under a controlled process defined in GEO Quality Systems procedure GEO-QSP-403 by meeting the following criteria:

- Most forms shall be controlled and identified through a procedure, work instruction, or operator aid
- Each form shall have an identifying number on the bottom left hand corner of the form that consists of:
  - form number
  - form revision number or date (preferred)
  - "Page x of y" if more than one page
- Each form shall include space to enter a date and signature of the person recording the information
- Most recent revision of each form should be accessible on the GEO intranet.

5.2.2 **IF** a data form or sketch is **not** controlled as shown above **AND** needs to be used in a logbook (e.g., project-specific form to collect data),
THEN identify the form with the project number and date and initials of the form title on the bottom left hand corner of the form
AND obtain the approval signature/date of the Project Manager on a copy of the data form or sketch to acknowledge that it was reviewed and is adequate for the intended purpose
AND put that signed copy in the Project file
AND control access to ensure that only the latest revision is used.

NOTE: An adhesive-backed form is preferred (easier to attach in the field), but a form may be affixed to a page with glue or double-sided tape. Avoid use of staples or overlapping tape. The entire periphery of the form should adhere to the page to avoid loose edges. Ensure that the adhesive-backed forms are of the design that are water resistant and will not become unattached when wet. It may be helpful to attach forms to the left-hand side of the page and leave the right-hand page blank for notes regarding information not covered on the form.

5.2.3 Ensure that the size of any data form or sketch will fit on the logbook page without extending beyond the page margins and will also allow enough space for information entered on the top and bottom of the page to which it is affixed (i.e., page number and required page signature space still visible).

WHAT TO DO

5.3 Prepare a New Logbook for Use

Logbook Custodian

5.3.1 **IF** pages in a new logbook have **not** already been pre-numbered,
THEN manually number all of the pages before the initial use of the logbook.

5.3.2 Record the date a logbook was first used in the field using an indelible marking pen or paint pen next to "Start Date" on the front cover of each field logbook.

5.3.3 Record the following information on the **inside of the front cover** of each logbook using black indelible ink:

- Logbook Number (from outside cover)
- GEO Project Manager's name
- Office/return address
- Original Custodian (+ name, signature, initials)
- Important telephone numbers, radio call numbers, as applicable, for ready access
- Emergency contact numbers, as applicable, for ready access.

5.3.4 Reserve **and** mark **and** use the first three or four pages of a logbook as a Table of Contents for that logbook if the logbook does not already contain a Table of Contents (as some logbook manufacturers do).

5.3.5 Mark the top of each page of the Table of Contents as shown below:

Logbook Number
TABLE OF CONTENTS

Date	Description of Activities	Page(s)

5.3.6 Ensure that the following items are available and ready for use before starting the work in the field using a logbook.

- Project-specific plans,
- Indelible (waterproof) black ink pen, or pencils
- Data forms (as required for specific activity),
- Logbook(s) and plastic bag(s) as protection from rain, and
- Ruler or similar scale (if needed).

WHAT TO DO **5.4 Follow General Rules for Logbook and Form Use**

Logbook Custodian

NOTE: The intent of keeping a logbook is for the reader to be able to recreate an event as accurately and completely as possible based on the written information in the logbook. Logbooks may become legal documents: clarity and completeness is critical.

5.4.1 Record as much pertinent information as possible to adequately and clearly describe the field work that was performed (refer to Subsection 5.5 for examples of pertinent information).

5.4.2 Ensure that each entry includes all important relevant information, but is not too wordy (quality and clarity of the information, not the quantity, is the objective) **and** use only commonly encountered acronyms.

Logbook Custodian

5.4.3 Precede each entry and the start and stop of a field activity with the time of day (24-hour clock).

5.4.4 Complete all entries using black indelible ink **and** write as legibly as practical.

5.4.5 Maintain all pages in a controlled logbook **and DO NOT** remove any pages for any reason.

5.4.6 Enter information on consecutive lines and pages **and** DO NOT skip any

lines or pages between daily entries.

5.4.7 **IF** any blanks within the data entries on a logbook or a form are NOT used,
THEN write "N/A" (Not Applicable) in the empty space or mark through with a diagonal "Z" line.

5.4.8 Record the information directly into the logbook in "real time" mode.

5.4.9 DO NOT transfer the information from other notes for recopying into the logbook, except for measurements recorded by others (e.g., Industrial Hygiene).

5.4.10 Sign/date the on the bottom-left of each page as you complete each page, or at the end of each day..

5.4.11 **IF** a diagonal "Z" line and signature are used to void a blank page,
THEN an additional signature and date at the bottom of the blank page is not required.

5.4.12 Ensure that all blank areas between daily entries has a large "Z" drawn across the blank lines or pages and a signature and date at the bottom of lines or pages between entries.

5.4.13 Verify that each blank data form or sketch to be inserted into a logbook is the correct form or sketch by comparing it with the latest form or sketch in the controlled procedure or the approved copy in the Project file.

5.4.14 Maintain an adequate supply of data forms or sketches to have readily available for use in the field.

5.4.15 Complete each entry on blank lines provided on the data form or sketch using indelible black ink.

5.4.16 **IF** any blanks within the data entries on a form or sketch are **not** used,
THEN write "N/A" in the blank line or empty space using a black indelible pen.

5.4.17 Ensure that any data form or sketch used in a logbook is firmly affixed to the page (refer to note before Step 5.2.3).

5.4.18 Place a signature across the corner of the form/sketch and onto the logbook page to signify that the form or sketch is part of the page and was not used to cover up any other entry.

Logbook Custodian

5.4.19 DO NOT cover over any written or pre-printed information when affixing a data form or sketch.

5.4.20 **IF** additional information is necessary to provide pertinent information and no additional space is available on the data form **AND** if space is available on the logbook page under the data form,
THEN record the additional information under the data form and indicate the insertion by initialing and dating at the end of the insertion.

5.4.21 **IF** the date is included any place on the data form/sketch **AND** if the signature is at the bottom of the data form/sketch **AND** the lower edge of the data form/sketch is located near the bottom of a logbook page,
THEN an additional signature and date at the bottom of the logbook page is not required.

WHAT TO DO **5.5 Record Daily Information in a Logbook**

Logbook Custodian

NOTE #1 A logbook provides detailed entries for all activities completed on each working day for a specific activity or event related to a particular project. The information recorded in logbooks shall also satisfy data recording requirements of any procedure that governs that activity.

NOTE #2 Consider as many of the following items in this subsection that may be applicable as logbook entries for a particular project or contract.

5.5.1 Begin to record the first set of daily entries on the next blank right-hand page after the Table of Contents.

5.5.2 Reserve the first right-hand logbook page (and the following left hand page, if needed) of each day's entry for a daily summary of major accomplishments or activities that day **and** place a "Z" line, initials, and date on the blank or partially used previous left-hand page (refer to Attachment B for an example).

5.5.3 Start all entries for a day's activities on a right hand page in the logbook.

5.5.4 Ensure that all entries consist of legible and objective observations and descriptive notations that omit opinions and subjective comments (refer to Attachment C for examples of typical logbook entries).

5.5.5 Enter the date (month/day/year, XX/YY/ZZZZ) and Logbook Number (needed if logbook pages are later copied) in the top line of each page.

5.5.6 Identify names of attendees and instructions from the Plan of the Day meeting. Note all personnel on-site, if a Plan of the Day meeting is not held.

5.5.7 Describe current weather conditions relevant to the activity (e.g., temperature, wind direction and velocity, sunny/cloudy/dusty, recent precipitation, precipitation and form) upon start of a work day, major changes during the day, and at the end of a work day.

Logbook Custodian

5.5.8 Describe site conditions that may affect work performance or impact sample quality (e.g., discoloration on ground, water around sampling point, fumes or engine exhaust).

5.5.9 Enter the specific location(s) where the work was performed.

5.5.10 Identify the names of personnel assigned to perform a task and company name, including support personnel and subcontractors (e.g., Health and Safety, drillers).

5.5.11 Identify the names of any personnel changes that occurred during the day and the time they occurred.

5.5.12 Identify names of visitors, their title and employer, reason they are at the job site, brief summaries of conversations, and times of arrival/departure **and** ask the visitors questions to obtain this information if not volunteered.

5.5.13 Provide a brief description of each activity performed that day.

5.5.14 List all field equipment (not hand tools or instruments) used and their

serial numbers or other unique identifying information.

5.5.15 Describe all measurements made and samples collected, unless recorded by automatic methods (e.g., data logger), the use of which should be referenced in the logbook.

5.5.16 Include the following information, as applicable, for field measurements taken using instruments: name of technician; instrument(s) used; calculations; results; calibration data; media measured; measurement types (e.g., turbidity, temperature, conductivity, pH); measurement units; and other relevant information, comments, and/or observations. Ensure that measurement units on a form are consistent with what is taken in the field (e.g. temperature measurements in Fahrenheit vs. Celsius).

5.5.17 Provide information about sampling events that includes the following: types of samples collected; sample collection methods; sample locations; sample identification numbers; sample preservation; chain-of-custody information; analyses completed/requested; and other relevant information.

5.5.18 Document any deviations approved (and by whom) or one-time difficulties (e.g., small movement in sampling point if refusal is encountered) encountered in events or activities that are described in sufficient detail.

5.5.19 Describe any variances or changes approved, including any upgrades or downgrades of personal protective equipment and references to appropriate documentation, such as a change request form.

5.5.20 Provide results of health and safety or radiological monitoring, including the instrument type, model, serial number, calibration standards used, and applicable limits.

5.5.21 Describe any relevant correspondence (written, personal, two-way radio, and/or telephone conversations).

Logbook Custodian

5.5.22 Describe any issues, concerns, or problems and their resolution, including any equipment failures or other delays with a description of downtime, standby time, repairs, replacements, and/or recalibrations, as applicable.

5.5.23 Document decontamination activities, noting special decontamination needs and/or any difficulties encountered.

5.5.24 Identify names of attendees at and information from an End of Day meeting, if applicable.

5.5.25 Sign **and** date the bottom of each page (except when blank spaces are cancelled out by a "Z" in which case a signature and date already exist).

WHAT TO DO

5.6 Correct a Logbook Entry

Logbook Custodian

5.6.1 DO NOT use erasers, correction tape, or whiteout fluid to cover or erase an entry.

5.6.2 DO NOT obliterate an incorrect entry **and** ensure that a data form or sketch is **not** placed over previously recorded information.

NOTE: Any error on a data form or logbook entry should be corrected by the same person who made the original entry, whenever feasible.

5.6.3 Indicate any deletion or change by marking through the original material with a **single line**; then initial and date the change.

5.6.4 Indicate any insertion to correct an omission or to clarify information by initialing and dating the insertion.

5.6.5 Ensure that any addition, correction, or deletion is made and initialed by the same person who made the original entry.

5.6.6 Place an explanation for a correction on the same page, if space is available, **or** reference the next available page on which the explanation and relevant new information can be written.

5.6.7 **WHEN** additional space was not available for needed information,
THEN record the needed information in another location on the same or next page
AND note where the additional information can be found.

5.6.8 Ensure that additional recorded information also refers back to the page to which it relates.

WHAT TO DO	5.7	**Transfer a Logbook to New Custodian**
Logbook Custodians		**NOTE:** Use of a logbook by a second person assisting the assigned custodian is **not** treated as a custodian transfer.
	5.7.1	**WHEN** the custody of a logbook in use is transferred to another person, **THEN** place an entry in the logbook to document the change in custody **AND** record full name and date in the logbook of the person releasing or relinquishing custody **AND** the person receiving custody of the logbook must place an entry that documents the receipt of custody **AND** record full name and date in the logbook of the person receiving custody.
	5.7.2	Communicate any transfer of logbook custody to the Project Manager as soon as practical.
Project Manager	**5.7.3**	Record any transfer of logbook custody in the logbook inventory log.

WHAT TO DO	5.8	**Complete a Logbook and Start New Logbook**
Logbook Custodian	**5.8.1**	(Recommended Practice) Ensure that a spare blank field logbook assigned to the custodian is readily available in the field whenever it appears that the current one may be filled during that workday.
	5.8.2	Record all activities performed on a day in the same field logbook (preferred).
	5.8.3	**IF** information for one workday exceeded the space in one logbook, **THEN** start a new logbook for continuance **AND** add a statement at the end of the full logbook to identify the

logbook used for continuance
AND add a statement as the first entry in the new logbook to reference the filled logbook.

5.8.4 Record the date a logbook was last used in the field using an indelible marking pen or paint pen next to "Completion Date" on the front cover of each completed field logbook.

5.8.5 Transfer a completed logbook back to the Project Manager or Designee at the end of the day.

WHAT TO DO **5.9 Perform End-of-Day Logbook Activities**

Logbook Custodian

5.9.1 **WHEN** work activities have been completed for a day **AND** all information for that day's activities has been entered in the logbook,
THEN enter the summary information for that day's activities reserved at the beginning of the day's entries
AND update the Table of Contents at the start of the logbook to record the actual page number(s) for that day's activities
AND verify that the unused area of each unused logbook page or partial page has been filled in with a "Z" line, initials, and a date.

Logbook Custodian

5.9.2 DO NOT use a "Z" to blank out open lines in the Table of Contents unless the logbook is full.

5.9.3 Maintain responsibility for a logbook until either custody is transferred to another custodian or the logbook has been returned to its designated storage location upon completion of the daily activities.

5.9.4 Keep logbooks in an approved location, unless written permission has been given in advance by a Project Manager to keep a logbook in a different location.

Project Manager or Designee

NOTE: The basic method to protect logbooks is to maintain them in protective storage when they are not in use. A project team may determine that the risk of loss of one or more logbooks is unacceptable and additional measures are needed to protect the data.

5.9.5 Store **and** safeguard each logbook, including blank ones, whenever not in active use for field work to ensure they are not lost or damaged.

5.9.6 Consider one or more of the following reasons to periodically copy logbook pages to prevent:

- Loss of Contained Information Due to Misplacement or Loss
- Damage to Contained Information by Fire or Water
- Loss of Data That Cannot be Recovered (data or observations cannot be duplicated at a later date since they would not represent conditions at the time of the original activity)
- Loss of Contained Information Through Theft or Tampering
- Loss of GEO's Record of Performance (e.g., logbooks will be transferred to the client at one or more specific intervals).

NOTE: Copies of logbook pages are actually uncontrolled copies of a controlled document (the logbook) as described in GEO Quality System procedure GEO-QSP-401, but they should **not** be stamped "Uncontrolled" since they may be needed to replace the original logbook in case of damage or loss.

5.9.7 **IF** the Project Manager or Designee determined that copies of logbook pages need to be made,

THEN communicate that need and the frequency (e.g., end of each workday) to project personnel
AND store the copies of the logbook pages in a secure location separate from where the original logbooks are stored.

5.9.8 **WHEN** the project work has been completed **AND** all logbooks have been accounted for **AND** original logbooks are a deliverable to the client,
THEN connect the copies from each logbook
AND mark "Uncontrolled Copy" on the first page of each collection of logbook pages
AND include the logbook copies with other GEO project records.

WHAT TO DO

Project Manager or Designee

5.10 Review an Active Logbook

NOTE #1 A logbook review is intended to verify that use of field logbooks is performed in accordance with project requirements (logbooks are being properly identified, information entered to record activities is adequate and complete, and logbooks are being properly safeguarded).

NOTE #2 A logbook review may be scheduled as a GEO surveillance if it is also documented in accordance with requirements of GEO Quality Systems procedure GEO-QSP-801 in addition to the review documentation required by this procedure in the logbook itself.

NOTE #3 Periodic reviews of logbooks provide an opportunity to stop incorrect practices or omissions before the entire logbook or several logbooks are noncompliant and require extensive corrections when that is possible.

5.10.1 Schedule a logbook review at periodic intervals when a logbook is **not** in active use (e.g., lunch or other time field work is **not** being performed). The frequency of logbook reviews should use a graded approach, dependent on the level of effort and experience of the field crew.

5.10.2 Initiate a field logbook review on the page following a signature that indicates the last logbook review **or** on the first page of daily entries, if no review had been previously performed for that logbook.

5.10.3 Conduct periodic reviews of data forms and logbooks (including data forms placed in logbooks) prepared by a logbook custodian to verify the following:

- accuracy of entries,
- legibility and clarity of entries,
- completeness to ensure that at least the minimum required information was recorded,
- data forms or sketches are latest approved version,
- consistency of information recorded,
- signature and date of entries by the custodian, and
- compliance with the logbook requirements in this procedure.

5.10.4 Ask the logbook custodian/author any questions related to content to obtain clarification or discuss errors.

5.10.5 **WHEN** a logbook review has been completed,
THEN write "logbook review" after the last entry
AND place the reviewer's initials and the date reviewed in the bottom

right-hand comer of the logbook or data form page.

5.10.6 Review any needed corrections or clarifications with the logbook custodian or author.

Logbook Custodian

5.10.7 Make any needed changes or clarifications identified by the logbook review.

Project Manager or Designee

5.10.8 Verify that all of the needed changes and/or clarifications were made in the logbook.

WHAT TO DO **5.11 Review a Completed Logbook**

Project Manager

5.11.1 Receive a completed logbook from a Logbook Custodian **and** update the project logbook inventory log to show that it has been received.

Project Manager or Designee

NOTE #1 Most client contracts specify that logbooks be transmitted to the client for retention at intervals specified in a contract. GEO requires that all submittals be properly reviewed prior to transmittal to a client.

NOTE #2 A review of a logbook or several logbooks may be scheduled as a GEO surveillance if it is also documented in accordance with requirements of GEO Quality Systems procedure GEO-QSP-801 in addition to the review documentation required by this procedure in the actual logbooks.

5.11.2 Perform a review of a completed logbook as soon as practical after it has been received.

5.11.3 **IF** the logbook had received one or more reviews in accordance with Subsection 5.10 of this procedure,
THEN give the logbook a quick review of the portion that had previously been reviewed
AND give the logbook a thorough review of the portion completed since the last review.

5.11.4 **IF** the logbook had **not** received any reviews in accordance with Subsection 5.10 of this procedure,
THEN give the entire logbook a thorough review.

5.11.5 Review any needed corrections or clarifications with the logbook custodian or author.

Logbook Custodian

5.11.6 Make any needed changes or clarifications identified by the logbook review.

Project Manager or Designee

5.11.7 Verify that all needed changes and/or clarifications were made in that logbook.

5.11.8 Maintain the reviewed logbook for eventual transmittal to the client.

WHAT TO DO **5.12 Disposition a Completed Logbook**

Project Manager or Designee

NOTE: Controlled access and protective storage requirements are defined in GEO Quality System procedure GEO-QSP-401, *Control of Documents and Records*. A graded approach may be necessary for remote field work.

5.12.1 Make copies of data forms and logbooks unless ALL of the following

criteria are met:

- controlled access to logbooks is in place (to ensure logbooks are not misplaced, lost, stolen, or tampered with),
- logbooks are not a project deliverable (will remain with GEO),
- original logbooks are maintained in a fire-proof cabinet, and
- loss or damage during use is unlikely.

Project Manager or Designee

5.12.2 **IF** all of the criteria discussed in Step 5.9.1 are **NOT** met,
THEN copy data forms and logbook pages on a specified frequency (refer to Subsection 5.9)
AND maintain copies in a secure location separate from the original
AND provide originals to the client on a specified frequency.

5.12.3 **IF** data forms and logbook copies are also made for communication purposes,
THEN make copies at the frequency defined in the project plan or Statement of Work.

5.12.4 Maintain any copies of the logbooks with the Project files.

RECORDS

6.1 General Requirements

Generate **and** maintain records in accordance with GEO Quality System procedure GEO-QSP-401, *Control of Documents and Records.*

6.2 Records Generated

6.2.1 Completed logbooks

6.2.2 Data forms and sketches and their approvals

6.2.3 Copies of logbook pages (if logbooks are a contract deliverable)

SOURCE DOCUMENTS

7.1 GEO Quality System procedure GEO-QSP-402, *Preparation and Reviews of Technical Documents*

Attachment A

Definitions and Acronyms

1.0 DEFINITIONS

1.1 **Data Form** – A uniquely identified, single-sided page or pages, usually with pre-printed spaces or a table for convenient, manual information entry. It is controlled to ensure only current copies are used. A data form is used for the permanent recording of information pertaining to various data collection activities (e.g., sample collection information forms, field measurement forms, data assessment checklist, etc.).

1.2 **Logbook** – A master reference summarizing all site activities on a daily basis and providing a detailed description of all environmental or laboratory activities.

1.3 **Logbook Custodian/Author** – A person who assumes primary responsibility for recording complete and timely information related to field or laboratory activities.

2.0 ACRONYMS

2.1 **GEO** – GEO Consultants, LLC

2.2 **N/A** – Not Applicable

2.3 QSP – Quality Systems Procedure

2.4 REV.- - Revision

Attachment B

Example of Logbook Daily Summary

Page 1 of 1

18	19
(diagonal line "Z" in open space with initials and date)	Date: 4/8/10 Logbook #1 TEAM MEMBERS: John Smith: Geologist, GEO Bill Jones: Sampler Dave Brown: Driller, Deep Hole, Inc. Jeff Dole: Drillers Helper, Deep Hole, Inc. SITE LOCATION: LF1, SG001 – SG003 ACTIVITY: Soil Boring EQUIPMENT: CME 75 HSA Rig, augers, spit spoon samples, liners OVM #3 Hydac pH, meter #2 PPE: Level D: SG001 – SG003 Level C: SG003 (0 – 60 ft BGS) WEATHER: Cloudy 0800 – 1230, 60 deg. F VISITORS: 9:00 to 9:15, Jim Johnson (EPA) 14:30 to 16:30, G. Washington (USACE) ISSUES: None (diagonal line "Z" in open space) (signed name/initials and date at the bottom of the page)

Attachment C

Example of Typical Logbook Entries

20

Date: 4/8/10 Logbook #1

0725 Arrived at drill site to set-up soil boring - 001.

0745 Began Geoprobe boring and advance rods to 4 feet.

0750 Collected screening sample SG-00 1-0-004- M using steel sleeve specified in technical memo. After removal from borehole, sample liner screened with OVM (O ppm). Sample headspace filled with silica sand, ends covered with Teflon tape and capped. Sample ID marked on liner with permanent marker and end caps marked with top and bottom (red/top, black/bottom). Liner placed in zip-lock bag, sealed, and placed on ice in sample cooler.

0750 Geoprobe rods advanced to 8 feet where sample #abc is collected for confirmation analysis at fixed-based laboratory. Confirmation sample collected at this depth because 8 ft BGS is near the bottom of the former UST location. Sample screened with OVM (0 ppm) labeled, secured, and placed on ice in sample cooler.

(diagonal line "Z" in open space)

(signed name/initials and date at the bottom of the page)

21

Date: 4/8/10 Logbook #1

810 Sampling completed at soil boring 001.

0830 Geoprobe rig shut down and moved, leave XXX location to return to decontamination area to steam clean rig, rods, and associated equipment

930 Collected ground water sample at MW-45 located at XYX Landfill. Sample was collected for the following parameters:

Analysis	Bottle	Lot #	Preservation
VOCS	3-40 ml glass	3464	HCl to pH 2
SVOCS	1-80 oz glass	0016	None
TPH	1-800 oz glass	2681	HCl to pH 2
Metals(F/o)	2, 1-L poly	0082	Nitric to pH 2
Pesticides/ PCBs	1-80 ox glass	0011	None
Cyanide	1-22 poly	1111	NaOH pH 12

1000 End of sampling

1300 Begin SG-01 at XYY location using a hollow stem auger drill (CME 75) and split-spoon samplers.

1315 Collect soil sample 22-SG-002-0-008 using a 2 foot long (3 inch diameter) split spoon.

(diagonal line "Z" in open space)

(signed name/initials and date at the bottom of the page)

GEO CONSULTANTS, LLC

A Geological Engineering and Environmental Services Company

Technical Operating Procedure

SAMPLE CHAIN OF CUSTODY

GEO-TEC-006

Revision 4

Prepared by: Mike Bosch

Approved by: _____ / 1/23/12
Jeff Douthitt, P.E. – President Date

Effective Date: May 1, 2010

Record of Changes

Revision No.	Affected Page(s)	Effective Date	Approval	Approval Date
0	All			
1	All			
2	All	12/1/06	J. Boulton	12/4/06
3	All	05/01/10	J. Boulton	
4	Title Page, Approval/Review Dates	01/23/12	J. Douthitt	1/23/12

Next review required no later than: January 23, 2013

TABLE OF CONTENTS

1.0 PURPOSE 3

2.0 SCOPE 3

3.0 TRAINING PREREQUISITES 3

4.0 OTHER DOCUMENTS NEEDED 3

5.0 WHAT TO DO
- 5.1 Prepare a Sample Label and a Chain-of-Custody Form for Each Sample 3
- 5.2 Collect Samples and Complete Sample Labels and Chain of Custody Forms 4
- 5.3 Transfer Samples and COC Forms to Another Organization 5

6.0 RECORDS
- 6.1 General Requirements 7
- 6.2 Quality Records 7
- 6.3 Non-Quality Records 7

7.0 SOURCE DOCUMENTS 7

8.0 ATTACHMENTS
- Attachment A - Definitions and Acronyms 8

PURPOSE

1.1 This procedure describes the requirements for completion of Chain-of-Custody (COC) records and the maintenance of those records to ensure the integrity of samples from collection to final disposition by documenting possession of transfers. If the client requests their own forms or sample collection standards to be used, GEO Consultants, LLC (GEO) and its subcontractors will oblige by said requests.

SCOPE

2.1 This procedure applies to all personnel who perform work activities for GEO and its subcontractors except if superseded by a customer's or partner's procedure that has been defined for use to support a specific contract or subcontract.

2.2 No changes or deviations to this procedure are allowed to be implemented unless approved in advance by the approver of this procedure and the customer's contract representative (if applicable).

TRAINING PREREQUISITES

3.1 Required Reading and Orientation.

OTHER DOCUMENTS NEEDED

4.1 GEO-TEC-003, *Records Management*

4.2 Definitions and acronyms related to this procedure are provided in Attachment A.

WHAT TO DO

5.1 Prepare a Sample Label and Chain-of-Custody Form for Each Sample

GEO Project Manager **or** Designee

5.1.1 Generate a unique sample identification number for each sample to be taken for a particular project (exception: a contract may require that the customer develop the unique sample numbers).

NOTE 1: A sample label is required for each sample collected to provide unique identification of each sample.

NOTE 2: All entries on a sample label shall be made using black indelible ink.

NOTE 3: Unique sample identification numbers and label information shall be generated by GEO unless otherwise specified in a customer contract.

Sample Technician **or** Field Sample Manager

5.1.2 Enter the following information on each sample label (prior to the sampling event whenever possible) unless a customer requires different label information:

- Project identification number
- Unique sample identification number
- Sampling description and location
- Storage and preservation requirements
- Sample team member name
- (Sampling date and time would be filled in later).

5.1.3 Attach each sample label to a clean sample container.

5.1.4 Use a separate COC form for each sampling event to be taken for a particular project (exception: a contract may require that the customer provide COC forms).

Sample Technician **or** Field Sample Manager

NOTE: A separate COC form may be required for each analytical sample to provide traceability of possession from initial sample collection through each sample transfer and/or final disposition. In some cases, several samples may be included on the same COC form if they will accompany each other through analysis.

5.1.5 Initiate a COC form for each sample to be taken.

5.1.5 Enter the following information (prior to the sampling event whenever possible) on each COC form (exception: a COC form generated by the customer may contain somewhat different information):

- Matrix of sample
- Project number
- Unique sample identification number
- Sampling description and location
- Number of sample containers
- Storage and preservation requirements
- Type of sample collected (i.e., grab or composite)
- Parameters to be analyzed
- Sample team member
- Any pertinent information in "Remarks" or "Comments" section.

5.2 Collect Samples and Complete Sample Labels and Chain-of-Custody Forms

NOTE: The field sampler is responsible for the proper collection, handling, and custody of each sample until it has been properly and formally transferred to another person or organization (e.g., analytical laboratory).

5.2.1 Collect each sample in a laboratory-approved sample container with a label.

NOTE: All entries on COC forms and labels shall be made using black indelible ink.

5.2.2 Complete the sample label information by recording the following information:

- Date and time sampled (military time)
- Any other information required on the label.

5.2.3 Apply a custody seal, if required by the customer, to each container in a manner such that it can be readily observed whether tampering has occurred.

Sample Technician

5.2.4 Complete the COC information at the time of the sampling event by recording the following information on each COC form:

- Date and time sampled (military time)
- Volume of sample (if required for specific analysis and calculations)
- Any pertinent information in "Remarks" or "Comments" section.

NOTE 1: "Positive control" requires one or more of the following:

- physical possession
- visual control/oversight tamper prevention
- secured storage (i.e., lock and key).

Sample Technician

NOTE 2: COC procedures are **not** required for transfer of samples between field personnel or between lab personnel in the same work group. To simplify the COC record, as few people as possible should handle samples.

5.2.5 Maintain positive control and preservation (if required) of each sample from collection until transfer to another custodian or disposition of the sample.

5.2.6 Maintain positive control of the COC form for each sample from collection until transfer to another custodian or analysis of the sample after which a copy is returned to the GEO Project Manager or Designee.

5.3 Transfers Samples and COC Forms to Another Organization

Sample Technician

NOTE: Some projects designate a Field Sample Manager who collects samples from the sample technicians and distributes or ships the samples to a customer or a laboratory. Other projects require a sample technician to distribute or ship the samples directly.

5.3.1 **IF** the project has a GEO Field Sample Manager assigned to coordinate the transfer of samples to be analyzed,
THEN proceed to Step 5.3.3.

5.3.2 **IF** the project does **NOT** have a GEO Field Sample Manager,
THEN proceed to Step 5.3.6.

5.3.3 Sign each COC form as "relinquished by" **and** enter the date and time.

5.3.4 Transfer the samples and the COC forms to the Field Sample Manager.

Field Sample Manager

5.3.5 Sign the COC form as "received by" **and** enter the date and time.

Sample Technician **or** Field Sample Manager

5.3.6 Maintain positive control and preservation (if applicable) of samples and forms from collection until transfer to another custodian.

NOTE: The steps for splitting a sample apply only to a Field Laboratory.

5.3.7 **IF** a sample does **NOT** need to be split,
THEN proceed to Step 5.3.14.

5.3.8 **IF** a sample does need to be split for analysis (e.g., comparative analyses at more than one laboratory),
THEN follow Steps 5.3.9 through 5.3.13.

5.3.9 Prepare one new clean sample container with a new sample identification label and one new COC form for the sample to be split from the original sample.

5.3.10 Split the sample into two samples, placing half of the sample in the original sample container and half in the new sample container.

Sample Technician **or** Field Sample Manager

5.3.11 Document the original COC form and sample identification number on the new COC form in the Remarks or Comments section.

5.3.12 Maintain positive control and preservation (if applicable) of samples and COC forms from collection until transfer to another custodian or analysis and disposition of the sample.

5.3.13 **IF** a sample will be analyzed only by a GEO Field Laboratory (if one exists),
THEN forward the completed COC form to the GEO Project Manager or Designee
AND proceed to Step 5.3.28.

5.3.14 **IF** a sample will be analyzed by an **off-site** laboratory,
THEN proceed to Step 5.3.23.

5.3.15 **IF** the samples will be analyzed by a **non-GEO on-site** laboratory **OR** the on-site laboratory will ship the sample to an off-site laboratory for analysis,
THEN proceed to Step 5.3.17.

5.3.16 Review the COC form to ensure accuracy and completeness.

5.3.17 Sign the COC form as "relinquished by" **and** enter the date and time.

5.3.18 Physically transfer each sample and its original COC form to the on-site laboratory sample custodian.

On-Site Laboratory Custodian

NOTE: The date/time will be the same for both signatures when custody is transferred directly to another person or organization on-site.

5.3.19 Assume possession of the samples **and** sign the COC form as "received by" **and** enter the date and time.

5.3.20 Maintain positive control and preservation (if applicable) of samples and COC forms from collection until transfer to another custodian or the sample has been analyzed.

5.3.21 Provide a copy of the signed COC form to the GEO Sample Technician or Field Sample Manager **and** proceed to Step 5.3.28.

GEO Sample Technician **or** Field Sample Manager **or** GEO Field Lab

5.3.22 **IF** a samples requires shipment by GEO to an **off-site** laboratory,
THEN sign each COC form as "relinquished by"
AND enter the date and time.

NOTE: When a sample is shipped via common carrier (e.g., Federal Express), the date/time will **not** be the same for both signatures. Common carriers are **not** required to sign the COC forms.

5.3.23 Package samples according to Department of Transportation (DOT) requirements for shipment to the appropriate laboratory for analysis, with separate COCs for each sample included in a plastic bag within the sealed shipping container.

GEO Sample Technician **or** Field Sample Manager **or** GEO Field Lab

5.3.24 Process the off-site shipment according to the applicable DOT regulations.

5.3.25 Fax/deliver a copy of each COC form to the GEO Project Manager or Designee.

NOTE: When samples are shipped to an off-site laboratory, the receiving laboratory sample custodian signs the COC record **and** returns/faxes a copy to the GEO Project Manager or Designee.

Off-Site Laboratory Sample Custodian

5.3.26 Provide a copy of the signed COC form to the Field Sample Manager or Project Manager or Designee for temporary retention as a working record

5.3.27 Maintain the COC record in accordance with satellite document management center (DMC) requirements (locked in fireproof file cabinets, etc.) in accordance with GEO-TEC-003, *Records Management.*

Sample Technician **or** Field Sample Manager

5.3.28 Periodically forward all COC forms that have been retained in the satellite DMC to the GEO Project Manager or Designee in accordance with GEO-TEC-003, *Records Management.*

RECORDS

6.1 General Requirements

Generate **and** maintain records in accordance with GEO-TEC-003, *Records Management*, and any records requirements specified by a customer in a contract.

6.2 Quality Records

6.2.1 COC records

6.2.2 DOT shipment papers (if applicable)

6.3 Non-Quality Records

None

SOURCE DOCUMENTS

7.1 U. S. Environmental Protection Agency, *Field Branches Quality System and Technical Procedures*

7.2 49 Code of Federal Regulations (CFR) Part 100 to 185, *Transportation*

7.3 GEO-TEC-005, *Logbooks*

Attachment A
Definitions and Acronyms
Page 1 of 1

1.0 Definitions

1.1 **Chain-of-Custody** – A process used to document the transfer of custody of samples from one individual to another from collection until final disposition.

1.2 **Custody Seal** – A tape-like seal that is often part of the Chain-of-Custody process and is used to prevent tampering with samples after they have been taken and before they are analyzed by a laboratory.

1.3 **Sample Custody** – A sample is under custody if:

- it is in the field personnel's possession; or
- it is in the field personnel's view, after being in their physical possession; or
- it was in the field personnel's physical possession and then it was secured to prevent tampering; or
- it is placed in a designated secure area.

2.0 Acronyms

2.1 **COC** – Chain-of-Custody

2.2 **DMC** – Document Management Center

2.3 **DOT** – Department of Transportation

GEO CONSULTANTS, LLC

A Geological Engineering and Environmental Services Company

Technical Operating Procedure

EQUIPMENT CLEANING AND DECONTAMINATION

GEO-TEC-010

Revision 6

FINAL - 02/22/2012

Prepared by: A. Michael Bosch

Approved by: _____ / 2/22/12
Jeff Douthitt, P.E. – President Date

Record of Changes

Revision Number	Changes and/or Affected Page(s)	Effective Date
0	New Procedure	-
1	All	-
2	All	-
3	All	02/01/2006
4	All	05/01/2010
5	Non-Intent changes (references updated) and editorial corrections	06/01/2011
6	None (Reauthorization)	2/22/2012

Next review required no later than: February 22, 2013

TABLE OF CONTENTS

1.0 PURPOSE 4

2.0 SCOPE 4

3.0 PRECAUTIONS AND LIMITATIONS 4

4.0 TRAINING 5

5.0 OTHER DOCUMENTS NEEDED 5

6.0 APPROVALS, NOTIFICATIONS, AND LIMITING CONDITIONS 6

7.0 PRE-PERFORMANCE ACTIVITIES 6

8.0 SPECIAL TOOLS, EQUIPMENT, PARTS, AND SUPPLIES 6

9.0 WHAT TO DO
- 9.1 Decontaminate Drill Rigs, Heavy Equipment, and Downhole Equipment After Each Borehole 7

10.0 WHAT TO DO
- 10.1 Field Cleaning Procedure 8
- 10.2 Minimum Specifications for Field Decontamination Pad 8
- 10.3 Drill Rig 9
- 10.4 Drilling Equipment 9
- 10.5 Equipment Used for Collection of Trace Organic and Inorganic Compounds 10
- 10.6 "Classic Parameter" Sampling Equipment 10
- 10.7 Goulds® Pump Cleaning 10
- 10.8 Redi-Flo2 Pump Cleaning 11
- 10.9 Well Sounders, Tapes, and Depth Indicators 11
- 10.10 Automatic Sampler Tubing 11

11.0 WHAT TO DO
- 11.1 Automatic Wastewater Sampling Equipment 11
- 11.2 ISCO® and Other Automatic Sampling Equipment 11
- 11.3 ISCO® 1680, 2700, and 3700 Rotary Funnel, Distributor, and Metal Tube 11
- 11.4 All Automatic Sampler Heads 12
- 11.5 Reusable Glass Composite Sample Containers 12
- 11.6 Plastic Reusable Composite Sample Containers 12
- 11.7 ISCO® 1680 Reusable Glass Sequential Sample Bottles 13
- 11.8 ISCO® 1680, 2700, and 3700 Reusable Glass Sequential Bottles for GC/MS Analyses 13
- 11.9 Bottle Siphons for Composite Containers 13
- 11.10 Reusable Teflon Composite Mixer Rods 14

12.0 WHAT TO DO
- 12.1 Submersible Pump and Hoses Used To Purge Groundwater Wells 14
- 12.2 Goulds® Pump Cleaning Procedures 14
- 12.3 Redi-Flo2 Pump 14
- 12.4 Redi-Flo2 Ball Check Valve Cleaning 14

13.0 WHAT TO DO
13.1 Cleaning Procedures for Tubing 15
13.2 Silastic® Pump Tubing 16
13.3 Teflon® Sample Tubing 16
13.4 Stainless Steel Tubing 16
13.5 New Glass Tubing 17

14.0 WHAT TO DO
14.1 Cleaning Procedures For Miscellaneous Equipment 17
14.2 Well Sounders, Tapes, and Depth Indicators 17
14.3 Weirs, Staff Gages, Velocity Meters, Stream Gaging Equipment, and Miscellaneous Sampling Equipment Not Specified in Other Cleaning Procedures 17
14.4 Field Analytical Equipment 18
14.5 Ice Chest and Shipping Containers 18
14.6 Pressure Field Filtration Apparatus 18
14.7 Organic/Analyte-Free Water Storage Containers 19
14.8 Portable Solvent Rinse System 19
14.9 Garden Hose 19
14.10 Portable Tanks for Tap Water 20
14.11 Trace Organic and Inorganic Constituent Sampling Equipment 20

15.0 POST-PERFORMANCE WORK ACTIVITIES 21

16.0 RECORDS
16.1 General Requirements 21
16.2 Records Generated 22

17.0 SOURCE DOCUMENTS 22

18.0 ATTACHMENTS
Attachment A – Definitions and Acronyms 23
Attachment B – PCB-Contaminated Sampling Equipment 25

PURPOSE

1.1 This procedure provides methodology for cleaning sampling and other equipment in the field and at a designated decontamination pad in compliance with the requirements of the United States Environmental Protection Agency (USEPA) and any applicable State and local regulators.

SCOPE

2.1 This procedure applies to all personnel who perform work activities for GEO Consultants, LLC (GEO), and its subcontractors unless it is superseded in part or in whole by a customer's or partner's procedure that was defined for use to support a specific contract or subcontract.

PRECAUTIONS AND LIMITATIONS

3.1 Environmental, Safety, and Health Precautions

3.1.1 Field personnel will be required to wear personal protective clothing and safety equipment as specified in the site-specific health and safety plan. At a minimum, the following general precautions shall be taken during cleaning operations:

- Safety glasses or goggles and clean chemical-resistant gloves (or other protective gloves as specified in the project-specific health and safety plan) will be worn during all cleaning operations.
- When cleaning heavy items, such as hollow-stem augers or other drill rig equipment, safety shoes or boots will be worn.
- All solvent rinsing operations will be conducted while wearing appropriate protective clothing under a fume hood or in the open (never in a closed room).
- No eating, smoking, drinking, chewing, or any hand-to-mouth contact shall be permitted during cleaning operations.

3.1.2 Nitric acid and hexane rinses should only be completed when sampling for metals or polar organics, such as pesticides, polychlorinated biphenyl (PCBs), or petroleum hydrocarbons, because of acid burn and ignitability hazards.

3.1.3 When solvents are substituted for a particular purpose, remove them completely from sampling equipment and containers to avoid analytical interferences or the creation of hazardous waste. Allow field sampling equipment to air-dry a minimum of 24 hours before use so any solvents used during decontamination would not be detected in the samples collected with the equipment.

NOTE: The occurrence of solvent residual is often dependent on the time of year sampling is conducted. In the summer, volatilization is rapid, thereby reducing the potential for solvent residuals.

3.1.4 The following general precautions should be followed when using a high-pressure hot water sprayer:

- Never refuel the high-pressure hot water sprayer while it is running.
- Check wind direction when setting up and preparing for steam cleaning to prevent accidental burns from steam or hot water.
- All extension cords must have a ground fault circuit interrupter (GFCI).
- **IF** the high-pressure hot water sprayer requires electrical power, **THEN** ensure that all extension cords are **not** resting in water to reduce potential for shock hazard.

3.1.5 Collect hazardous solvents and rinses with water to remove these solvents for appropriate disposal. Label as "solvent for recovery" or "solvent for disposal."

NOTE #1 PCB-contaminated sampling waste (CSW) shall **not** be left unattended, but it may be placed in a designated location for temporary storage.

NOTE #2 Containers, equipment, or items in which material exists that contains 50 ppm or greater PCBs shall have a M_L label (6 inch by 6 inch standard, may be proportionately reduced to 2 inch by 2 inch) or, if a smaller label is needed, a M_S label (1 inch by 2 inch standard, may be proportionately reduced to 0.4 inch by 0.8 inch) affixed as required by 40 CFR 761.40 & 40 CFR 761.45. Other marking requirements may also apply.

3.1.6 Dispose of PCB-CSW containing 50 ppm or greater PCBs in the proper waste container with the appropriate M_L or M_S label and date-to-storage immediately following the sampling event. An entry must be documented on the container log sheet as to the type of waste deposited.

3.1.7 Reusable PCB-contaminated sampling equipment (CSE) must be decontaminated and verified clean according to Toxic Substance Control Act (TSCA) specifications. (Refer to Attachment B, "PCB-Contaminated Sampling Equipment.")

3.1.8 Only personnel wearing clean chemical-resistant gloves to prevent recontamination should handle cleaned equipment.

3.1.9 If cleaned sampling equipment is not to be reused immediately; it shall be wrapped in aluminum foil (shiny side out), sealed in plastic, and labeled with date cleaned. Note any exceptions to these cleaning procedures on the plastic or in logbook.

3.1.10 Transport only the amount of equipment expected to be used in a sampling event to the field.

3.2 Work Environment Limitations

3.2.1 The immediate supervisor may make determinations as to whether work may or may not be performed due to safety hazards caused by adverse weather conditions or other work environment limitations.

TRAINING

4.1 All field personnel should have access to and be knowledgeable of this procedure and the following associated procedures and documents before initiating any decontamination activities:

- GEO-TEC-005, *Logbook*
- GEO-TEC-011, *Temporary Storage of Waste Materials*
- Project-specific documents, including field sampling plan, waste management plan, health and safety plan, and quality assurance project plan

4.2 All personnel who perform or supervise equipment decontamination activities shall, prior to performing or supervising equipment decontamination activities, complete required reading of this procedure and any subsequent revision within 30 days of issuance **or** within 30 days of beginning employment with GEO.

OTHER DOCUMENTS NEEDED

5.1 GEO Quality Systems procedure GEO-QSP-403, *Control of Records*

5.2 GEO Technical Operating procedure GEO-TEC-005, *Logbook*

5.3 GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples*

5.4 GEO Technical Operating procedure GEO-TEC-011, *Temporary Storage of Waste Materials*

NOTE: Definitions and acronyms related to this procedure are provided in Attachment A.

APPROVALS, NOTIFICATIONS, AND LIMITING CONDITIONS

6.1 Obtain approval and requirements from the appropriate customer personnel in charge of the site where the work is being performed prior to using any decontamination pad or equivalent facilities (if they are available for use).

PRE-PERFORMANCE ACTIVITIES

7.1 Inspection of Equipment Arriving at a Customer's Site

Personnel Responsible for Equipment Inspections

7.1.1 Inspect incoming equipment for any contaminants to minimize the potential for cross contamination from another hazardous waste site and to assure it is in safe working conditions.

7.1.2 Inspect drill rigs and similar equipment for any leaks of oil, grease, fuel, and hydraulic oils.

7.1.3 Inspect seals and gaskets to ensure they are free of fluid leaks.

7.1.4 Inspect cables (e.g., winch cables) for frays.

7.1.5 Inspect augers, drill rods, drill bits, and casing to ensure they are free of any paint, ink, or any other coatings that may wear off during drilling.

7.1.6 Steam clean or pressure wash drilling rigs, sample equipment (e.g., split spoons), backhoes, forklifts, and other associated equipment before using for any on-site activities, regardless of the condition upon arrival at the customer's site.

7.1.7 Decontaminate all on-board pumps and hoses by pumping clean, hot water through them to remove any residual contamination.

SPECIAL TOOLS, EQUIPMENT, PARTS, AND SUPPLIES

8.1 Ensure that all applicable items needed for a particular task are available for use and are in good condition:

- field logbook
- black indelible pens and markers
- lab coats and neoprene aprons
- clean chemical-resistant gloves
- safety glasses/goggles/face shields
- other protective clothing and equipment (see the project-specific health and safety plan)
- portable gravity-fed eye wash station
- fire extinguisher (Type ABC dry chemical)
- storage cabinet for flammable materials
- (continued)

8.1 (Continued)

- plastic buckets and troughs
- folding table(s) and/or sawhorses
- 2- to 5-gallon manual pump sprayers
- Nalgene® or Teflon® sprayers or wash bottles
- high-pressure hot water sprayer equipped with an automatic soap dispenser (if needed)
- bottle brushes
- stiff-bristle brushes
- aluminum foil
- absorbent pads/spill kit
- duct tape
- plastic sheeting
- disposable wipes or rags
- nitric acid solutions
- isopropyl alcohol
- tap water
- deionized, analyte-free, or organic-free water
- appropriate decontamination solvents (pesticide-grade or better)
- phosphate-free detergent (Liquinox® or equivalent)
- disinfectant soap
- Material Data Safety Sheets (MSDS) for materials in work site.

WHAT TO DO

9.1 Decontaminate Drill Rigs, Heavy Equipment, and Downhole Equipment after Each Borehole

Decontamination Personnel

NOTE #1 Drilling rigs, direct push technology rigs, heavy equipment (forklifts and backhoes), and all downhole equipment, which includes hand-operated augers (e.g., Little Beaver), hollow-stem auger flights, drill rods, drill casing, temporary surface casings, and drill bits, will be cleaned and decontaminated between each location (as determined by the work plan) using this section of this procedure.

NOTE #2 All downhole equipment will be scanned for radiological contaminants (if applicable) and wrapped in plastic for transport between the drill-site and decontamination pad. All downhole equipment considered contaminated based on radiological scanning will require an initial "field" decontamination consisting of a phosphate-free detergent wash followed by potable water rinse before it can be transported to the permanent decontamination pad for more intensive cleaning.

9.1.1 Drive the drill rig, forklift, or backhoe onto the decontamination pad (if available) so that all equipment is fully contained within the decontamination area.

9.1.2 Pump any standing water from the sump into the designated storage container.

9.1.3 Segregate decontamination fluids from rainwater **and** transfer it to separate containers.

9.1.4 Provide racks or sawhorses at least two feet above the ground for cleaning associated equipment to prevent splash back on the item being cleaned.

Decontamination Personnel

9.1.5 Set up a "clean" area upwind of the decontamination area to receive cleaned equipment for drying **and**, at a minimum, cover the ground, tables, or other surface on which "clean" equipment is placed with clean plastic sheeting.

9.1.6 Clean with tap water and soap, using a brush if necessary.

9.1.7 Place drilling equipment that has been steam-cleaned on racks or sawhorses at least two feet above the floor of the decontamination pad.

9.1.8 Clean the inside of augers, drill rods, etc., which are hollow or have holes that transmit water or drilling fluids **and** clean areas that have been or will be exposed to potentially contaminated soils with a high-pressure hot water sprayer.

9.1.9 Inspect equipment thoroughly (tools, rods, augers, etc.).

9.1.10 **IF** severe rust, corrosion, paint, or hardened grout is present,
THEN sandblast **and** re-clean the equipment.

9.1.11 Clean the entire exterior of the rig, backhoe, or forklift with a special emphasis on those areas that are over the borehole, including the Kelly bar, mast, backhoe bucket, drilling platform, hoist and chain pull-downs, spindles, cathead, and the undercarriage according.

9.1.12 Clean the motor, hydraulic lift, oil fill, and fuel tank.

9.1.13 Flush the grout pump with tap water until clean, and drain.

9.1.14 Wash the grout mixer with the high-pressure hot water sprayer to remove any contamination.

WHAT TO DO **10.1 Field Cleaning Procedures**

Decontamination Personnel

NOTE: In some cases, client requirements may take precedence over requirements in these procedures.

10.1.1 Follow the procedures in this section for cleaning items in the field.

WHAT TO DO **10.2 Minimum Specifications for Field Decontamination Pad**

Decontamination Personnel

10.2.1 Construct the pad in an area known or believed to be free of surface contamination.

10.2.2 Construct so that the pad does **not** leak.

10.2.3 Construct the pad, whenever possible, on a level, paved surface with one corner lower than the others to facilitate removal of wastewater.

10.2.4 **IF** Step 10.2.3 is **not** possible,
THEN create a lined sump or pit in one corner or along the side of the pad.

10.2.5 Construct sawhorses or racks to hold equipment while being cleaned. These shall be a minimum of two feet above the surface of the pad to prevent splash back.

Decontamination Personnel

10.2.6 Remove water from the pad frequently to prevent run over.

10.2.7 Line the pad with a seamless, water-impermeable material (this material should be easily replaceable or repairable).

10.2.8 Deactivate the pad upon completion of the activity.

10.2.9 Remove all waste/rinse water for disposal according to GEO Technical Operating procedure GEO-TEC-011, *Temporary Storage of Waste Materials.*

> **CAUTION**
>
> **DO NOT** PUT ANY SOLVENT RINSATES IN THE PIT.

10.2.10 Collect all solvent rinseates in containers for disposal according to GEO-TEC-011, *Temporary Storage of Waste Materials,* or a project-specific waste management plan.

10.2.11 **IF** leaks develop in the pad during the decontamination process,
THEN contact the appropriate customer representative who will determine if sampling and analyses of the soil shall be required.

10.2.12 Remove equipment from the decontamination pad **and** cover with clean, unused plastic.

10.2.13 **IF** stored overnight,
THEN secure the plastic to ensure it stays in place.

WHAT TO DO **10.3 Drill Rig**

Decontamination Personnel

10.3.1 Steam-clean between boreholes (soap and high-pressure hot water) any portion of the drill rig, backhoe, etc., that is over the borehole (Kelly bar of mast, backhoe buckets, drilling platform, hoist or chain pull-downs, spindles, cathead, etc.).

10.3.2 Rinse thoroughly with tap water.

WHAT TO DO **10.4 Drilling Equipment**

Decontamination Personnel

NOTE: Drilling equipment includes augers, drill stems, rods, tools, and associated equipment.

10.4.1 Place equipment that is to be steam-cleaned and rinsed on racks, sawhorses, or pallets located a minimum of two feet above the decontamination pad to prevent splash back.

> **CAUTION**
>
> To prevent damage, **DO NOT** solvent rinse polyvinyl chloride (PVC) or plastic items.

10.4.2 Clean drilling equipment with tap water and soap, using a brush if necessary, to remove particulate matter and surface films **and** vigorously brush the interior surfaces of the hollows or holes of hollow-stem augers, etc.

Decontamination Personnel

10.4.3 **IF** matter is difficult to remove with the brush,
THEN steam-clean on racks, sawhorses, or pallets as an alternative to brushing.

10.4.4 Rinse thoroughly with tap water.

WHAT TO DO

10.5 Equipment Used for the Collection of Trace Organic and Inorganic Compounds

Decontamination Personnel

10.5.1 Clean the equipment with tap water and soap, using a brush if necessary, to remove particulate matter and surface films **or** steam-clean equipment on racks or sawhorses as an alternative to brushing.

10.5.2 Rinse thoroughly with tap water.

10.5.3 Rinse thoroughly with analyte-free water.

10.5.4 Rinse thoroughly with isopropyl alcohol.

10.5.5 Rinse thoroughly with organic/analyte-free water.

10.5.6 **IF** organic/analyze-free water is **not** available,
THEN allow equipment to completely air-dry.

10.5.7 Remove the equipment from the decontamination area **and** cover it with plastic.

10.5.8 **IF** equipment will be stored overnight,
THEN wrap it in aluminum foil (shiny side out)
AND cover it with clean, unused plastic.

10.5.9 **IF** equipment cannot be cleaned utilizing the above procedures,
THEN discard it in an appropriate manner.

WHAT TO DO

10.6 "Classic Parameter" Sampling Equipment

Decontamination Personnel

10.6.1 Rinse flow-measuring equipment with tap water between measuring locations.

10.6.2 Rinse other sampling equipment with analyte-free water between locations, using a brush, if necessary, to remove deposits of material or sediment.

10.6.3 **IF** rinsed with analyte-free water,
THEN flush at the next sampling location with the water to be sampled before collecting the sample.

WHAT TO DO

10.7 Goulds® Pump Cleaning

Decontamination Personnel

10.7.1 GO TO Subsection 12.2 of this procedure.

WHAT TO DO **10.8 Redi-Flo2 Pump Cleaning**

Decontamination Personnel

10.8.1 GO TO Subsections 12.3 and 12.4 of this procedure.

WHAT TO DO **10.9 Well Sounders, Tapes, and Depth Indicators**

Decontamination Personnel

10.9.1 GO TO Subsection 14.2 of this procedure.

WHAT TO DO **10.10 Automatic Sampler Tubing**

Decontamination Personnel

10.10.1 Flush tubing with tap water and soap.

10.10.2 Rinse tubing thoroughly with tap water.

10.10.3 Rinse tubing with analyte-free water.

WHAT TO DO **11.1 Automatic Wastewater Sampling Equipment**

Decontamination Personnel

11.1.1 Follow the procedures in this section for cleaning automatic wastewater sampling equipment in the field. In some cases, customer requirements may take precedence over these procedures.

WHAT TO DO **11.2 ISCO® and Other Automatic Sampling Equipment**

Decontamination Personnel

11.2.1 Wash the exterior and accessible interior (excluding the waterproof timing mechanism) portions of the automatic samplers with soap and tap water **and** then rinse with tap water.

11.2.2 Check **and** replace, if necessary, the desiccant in the flow meters each time the equipment is cleaned.

11.2.3 Clean the face of the timing case mechanism with a clean damp cloth.

11.2.4 **IF** dedicated tubing is used at the same sampling location for the same environmental media **AND** tubing appears to be in good condition (i.e., no algae or sludge build-up),
THEN decontaminate according to Subsection 10.10
OR discard tubing (sample intake and pump tubing) **and** replace with new tubing.

11.2.5 Install new pre-cleaned Silastic pump tubing (see Subsection 13.2 for cleaning instructions for this tubing).

WHAT TO DO **11.3 ISCO® 1680, 2700, and 3700 Rotary Funnel, Distributor, and Metal Tube**

Decontamination Personnel

11.3.1 Clean with hot tap water, soap, and a brush.

Decontamination Personnel

11.3.2 Rinse thoroughly with analyte-free water.

11.3.3 Replace in sampler.

WHAT TO DO **11.4 All Automatic Sampler Headers**

Decontamination Personnel

11.4.1 Disassemble header **and**, using a bottle brush, wash with hot tap water and soap.

11.4.2 Rinse thoroughly with analyte-free water.

11.4.3 Dry parts thoroughly **and** reassemble header, **and** wrap with aluminum foil.

11.4.4 Seal in plastic.

WHAT TO DO **11.5 Reusable Glass Composite Sample Containers**

Decontamination Personnel

NOTE: When these containers are used to collect samples that contain oil, reuse, or other hard to remove materials, it may be necessary to rinse the containers several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials. Any bottles that have a visible film, scale, or discoloration remaining after this cleaning procedure should be discarded.

11.5.1 Wash containers thoroughly with hot tap water and a phosphate-free laboratory detergent (e.g., Liquinox®), using a bottlebrush to remove particulate matter and surface film.

11.5.2 Rinse containers thoroughly with hot tap water.

11.5.3 Rinse container with at least 10% nitric acid.

11.5.4 Rinse containers thoroughly with tap water.

11.5.5 Rinse containers thoroughly with analyte-free water.

11.5.6 Rinse twice with at least 10% nitric acid.

11.5.7 Allow to air-dry for at least 24 hours.

11.5.8 Cap with aluminum foil or Teflon® film.

WHAT TO DO **11.6 Plastic Reusable Composite Sample Containers**

Decontamination Personnel

NOTE: Any containers that have a visible film, scale, or other discoloration remaining after this cleaning procedure should be discarded.

11.6.1 Wash containers thoroughly with hot tap water and laboratory detergent, using a bottlebrush to remove particulate matter and surface film.

11.6.2 Rinse containers thoroughly with tap water.

11.6.3 Rinse containers with at least 10% nitric acid.

Decontamination Personnel

11.6.4 Rinse containers thoroughly with tap water.

11.6.5 Rinse containers thoroughly with analyte-free water.

11.6.6 Cap with aluminum foil or Teflon® film.

WHAT TO DO **11.7 ISCO® 1680 Reusable Glass Sequential Sample Bottles**

Decontamination Personnel

NOTE: For collecting samples for Gas Chromatograph/Mass Spectrometer (GC/MS) (or equivalent) analyses, use cleaning procedure in Subsection 11.8.

11.7.1 Rinse with 10% nitric acid.

11.7.2 Rinse thoroughly with tap water.

11.7.3 Wash in dishwasher at wash cycle, using laboratory detergent cycle, followed by tap analyte-free water rinse cycles.

11.7.4 Replace bottles in covered automatic sampler base.

11.7.5 Cover with aluminum foil for storage.

WHAT TO DO **11.8 ISCO® 1680, 2700, and 3700 Reusable Glass Sequential Bottles for GC/MS Analyses**

Decontamination Personnel

11.8.1 Rinse with 10% nitric acid.

11.8.2 Rinse thoroughly with tap water.

11.8.3 Wash in dishwasher at wash cycle, using laboratory detergent cycle, followed by tap and analyte-free water rinse cycles.

11.8.4 Rinse twice with 10% nitric acid.

11.8.5 Allow to air-dry for at least 24 hours.

11.8.6 Replace in covered, automatic sampler case.

11.8.7 Cover with aluminum foil for storage.

11.8.8 Mark the base as follows: "Cleaned for organic analyses."

WHAT TO DO **11.9 Bottle Siphons for Composite Containers**

Decontamination Personnel

11.9.1 Before use, rinse tubing with solvent **and** place in drying oven overnight.

11.9.2 Cap the ends of the siphon with aluminum foil and/or Teflon® film for storage.

11.9.3 Seal the tubing in plastic **and** label.

11.9.4 Thoroughly flush the siphon with sample before use.

WHAT TO DO **11.10 Reusable Teflon Composite Mixer Rods**

Decontamination Personnel

11.10.1 Wash equipment thoroughly with soap and hot tap water, using a brush or scrub pad to remove any particulate matter or surface film.

11.10.2 Rinse equipment thoroughly with hot tap water.

11.10.3 Rinse equipment with at least a 10% nitric acid solution.

11.10.4 Rinse equipment thoroughly with tap water.

11.10.5 Rinse equipment thoroughly with analyte-free water.

11.10.6 Rinse equipment thoroughly with solvent.

11.10.7 Allow to air-dry for at least 24 hours.

11.10.8 Wrap equipment in one layer of aluminum foil, rolling edges of foil into a "tab" to allow for easy removal.

11.10.9 Seal the foil wrapped equipment in plastic **and** label.

11.10.10 **IF** the equipment cannot be cleaned utilizing the above procedures, **THEN** discard the equipment in an appropriate manner.

WHAT TO DO **12.1 Submersible Pump and Hoses Used to Purge Groundwater Wells**

Decontamination Personnel

12.1.1 Follow the procedures in this section for cleaning pumps and hoses in the field. In some cases, customer requirements may take precedence over these procedures.

WARNING

During cleaning, always disconnect the pump from the generator or other power source.

CAUTION

To avoid damage to equipment and seals, **DO NOT** use degreasers.

WHAT TO DO **12.2 Goulds® Pump Cleaning Procedure**

Decontamination Personnel

12.2.1 Using a brush, scrub the exterior of the contaminated pump and hose with soapy tap water.

12.2.2 Rinse the soap from the outside of pump and hose with tap water.

12.2.3 Rinse the tap water residue from the outside of pump and hose with deionized water.

12.2.4 Place equipment in a polyethylene bag or wrap with polyethylene film to prevent contamination during storage or transit.

WHAT TO DO **12.3 Redi-Flo2 Pump**

Decontamination Personnel

12.3.1 Wipe the controller box with a damp cloth to immediately remove any excess water.

12.3.2 Let the controller box dry completely.

12.3.3 Follow Section 12.0 for pump cleaning.

12.3.4 Remove garden hose or pump tubing, if attached, and ball check valve **and** clean these items separately.

12.3.5 Using a brush or scrub pad, scrub the exterior of the pump with tap water.

12.3.6 Rinse with tap water.

12.3.7 Rinse with analyte-free water.

12.3.8 Completely air-dry.

12.3.9 Place equipment in clean plastic bag.

WHAT TO DO **12.4 Redi-Flo2 Ball Check Valve Cleaning**

Decontamination Personnel

NOTE: The analyte-free water within the pump head should be changed according to manufacturer's instructions after it is returned from the field to the permanent cleaning pad.

12.4.1 Completely dismantle the ball check valve.

12.4.2 Check for wear and/or corrosion **and** replace as needed.

12.4.3 Using a brush, scrub all components with soap and hot tap water.

12.4.4 Rinse with analyte-free water.

12.4.5 Completely air-dry.

12.4.6 Reassemble the ball check valve.

12.4.7 Reattach ball check valve to the pump head.

WHAT TO DO **13.1 Cleaning Procedures for Tubing**

Decontamination Personnel

13.1.1 Follow the procedures in this section for cleaning tubing in the field. In some cases, customer requirements may take precedence over these procedures.

WHAT TO DO **13.2 Silastic® Pump Tubing**

Decontamination Personnel

13.2.1 **IF** dedicated tubing is used at the same sampling location for the same environmental media **AND** tubing appears to be in good condition (i.e., no algae or sludge build-up),
THEN decontaminate according to Section 10.10 (Automatic Sampler Tubing)
OR replace with new tubing in the automatic samplers and peristaltic pumps after each sampling event.

13.2.2 After installation, cap the exposed ends with clean, unused aluminum foil.

WHAT TO DO **13.3 Teflon® Sample Tubing**

Decontamination Personnel

NOTE: For the collection of groundwater samples for trace organic compounds or Inductively Coupled Argon Plasma (ICP) Spectrophotometer analysis, use only new or dedicated Teflon® tubing which has been pre-cleaned as follows.

13.3.1 Rinse outside of tubing with analyte-free water.

13.3.2 Flush interior of tubing with analyte-free water.

13.3.3 **IF** excess water is present in the tubing,
THEN expel the water with air pressure using a pump equipped with a drying filter.

13.3.4 Coil tubing **and** cap ends with aluminum foil.

13.3.5 Seal the foil-wrapped tubing in plastic **and** label.

WHAT TO DO **13.4 Stainless Steel Tubing**

Decontamination Personnel

NOTE: For the collection of groundwater samples, equipment will be cleaned as follows between monitoring wells or parts within a monitoring well.

13.4.1 Purge two to three times the well's volume prior to collecting the next sample.

13.4.2 Once sampling is complete, repeat Step 13.4.1 **and** dry **and** cap ends with aluminum foil.

13.4.3 Wrap tubing in one layer of aluminum foil, rolling edges into a "tab" for easy removal.

13.4.4 Seal the foil-wrapped tubing in plastic **and** label.

13.4.5 **IF** the equipment cannot be cleaned utilizing these procedures,
THEN dispose of the equipment in an appropriate manner
OR handle it according to the sampling and analyses plan or waste management plan.

WHAT TO DO **13.5 New Glass Tubing**

Decontamination Personnel

13.5.1 Rinse thoroughly with nitric acid.

13.5.2 Air-dry for at least 24 hours.

13.5.3 Wrap tubing completely with aluminum foil.

13.5.4 Seal tubing in plastic (one tube/pack) to prevent contamination during storage.

WHAT TO DO **14.1 Cleaning Procedures for Miscellaneous Equipment**

Decontamination Personnel

14.1.1 Follow procedures in this section for cleaning miscellaneous equipment in the field. In some cases, customer requirements may take precedence over these procedures.

14.1.2 **IF** field cleaning for immediate reuse,
THEN the equipment does **not** have to be air-dried as described in the following procedures.

WHAT TO DO **14.2 Well Sounders, Tapes, and Depth Indicators**

Decontamination Personnel

14.2.1 Wash with soap and tap water.

14.2.2 If possible, rinse with tap water.

14.2.3 Rinse with analyte-free water.

14.2.4 Allow to air-dry overnight.

14.2.5 Wrap equipment in aluminum foil (with tab for easy removal) **and** seal in plastic **and** date.

WHAT TO DO **14.3 Weirs, Staff Gages, Velocity Meters, Stream Gaging Equipment, and Miscellaneous Sampling Equipment Not Specified in Other Cleaning Procedures**

Decontamination Personnel

NOTE: **DO NOT** use this procedure (Subsection 14.3) for equipment to be used in the collection of samples for trace organic or inorganic analyses.

14.3.1 Wash with soap and hot tap water.

14.3.2 **IF** soap is **not** appropriate,
THEN steam clean with analyte-free water.

14.3.3 Rinse with hot tap water.

14.3.4 Rinse thoroughly with analyte-free water.

14.3.5 Completely air-dry before storing.

WHAT TO DO **14.4 Field Analytical Equipment**

Decontamination Personnel

14.4.1 Wipe instruments with a clean, damp cloth.

14.4.2 Rinse probes (pH, conductivity, dissolved oxygen, etc.) with analyte-free water.

14.4.3 Air-dry before storage.

WHAT TO DO **14.5 Ice Chest and Shipping Containers**

Decontamination Personnel

14.5.1 Wash interior and exterior with soap and water.

14.5.2 Rinse with clean tap water.

14.5.3 Air-dry before storage.

14.5.4 **IF** the container is severely contaminated,
THEN clean it as thoroughly as possible
AND render it unusable
AND properly dispose of it.

WHAT TO DO **14.6 Pressure Field Filtration Apparatus**

Decontamination Personnel

NOTE: When this equipment is used to collect samples that contain oil, grease, or other hard-to-remove materials, it may be necessary to rinse the containers several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials. In extreme cases, it may be necessary to steam-clean the equipment. If the equipment cannot be cleaned utilizing these procedures, it should be discarded.

14.6.1 Wash equipment thoroughly with soap and hot tap water, using a brush to remove any particulate matter or surface film.

14.6.2 Rinse equipment thoroughly with hot tap water.

14.6.3 Rinse equipment with 10% nitric acid solution.

14.6.4 Rinse equipment thoroughly with analyte-free water.

14.6.5 Rinse equipment thoroughly with solvent **and** allow to air-dry for at least 24 hours.

NOTE: Pressure should be applied to the apparatus after each rinse step (water and acid) to drive the rinse material through the porous glass filter holder in the bottom of the apparatus.

14.6.6 Assemble the apparatus and cap both the pressure inlet and sample discharge lines with aluminum foil to prevent contamination during storage.

14.6.7 Wrap equipment in one layer of aluminum foil, rolling edges into a "tab" for easy removal.

Decontamination Personnel

14.6.8 Seal the foil-wrapped equipment in plastic with current date written on the plastic.

WHAT TO DO

14.7 Organic/Analyte-Free Water Storage Containers

Decontamination Personnel

14.7.1 Wash containers thoroughly (interior and exterior) with hot tap water and laboratory detergent, using a bottlebrush to remove particulate matter and surface film.

> **CAUTION**
>
> Use only soft brushes. **DO NOT** use scouring pads of any type.

14.7.2 Rinse containers thoroughly with hot tap water.

14.7.3 Rinse containers thoroughly with tap water.

14.7.4 Rinse containers thoroughly with analyte-free water.

14.7.5 Rinse containers thoroughly with solvent **and** allow to air-dry for at least 24 hours.

14.7.6 Cap with aluminum foil or Teflon® film.

14.7.7 Use only containers cleaned as specified above whenever transporting organic/analyte-free water to the field.

14.7.8 Thoroughly rinse the interior of the container with organic/analyte-free water prior to filling.

14.7.9 Cap with one layer of aluminum foil, **and** label the container as "organic/analyte-free water" and include the date it was prepared.

14.7.10 **DO NOT** store the organic/analyte-free water more than three days before transporting it to the field for use.

WHAT TO DO

14.8 Portable Solvent Rinse System

Decontamination Personnel

14.8.1 Replace Teflon® tubing, if necessary (see Section 13.3 for cleaning procedure).

14.8.2 Wash nozzle and tubing fittings with hot, soapy water.

14.8.3 Rinse with analyte-free water.

14.8.4 Wrap nozzle and tubing ends with aluminum foil.

WHAT TO DO

14.9 Garden Hose

Decontamination Personnel

14.9.1 Brush exterior with soap and tap water.

14.9.2 Rinse with tap water.

Decontamination Personnel

14.9.3 Flush interior with tap water until clear (minimum of one gallon).

14.9.4 Let air-dry completely.

14.9.5 Coil **and** place in clean plastic bag.

WHAT TO DO **14.10 Portable Tanks for Tap Water**

Decontamination Personnel

14.10.1 Scrub interior (if feasible) and exterior with soap and tap water.

14.10.2 Rinse with tap water.

14.10.3 Let air-dry completely.

14.10.4 Close tank.

WHAT TO DO **14.11 Trace Organic and Inorganic Constituent Sampling Equipment**

Decontamination Personnel

NOTE: When this sampling equipment is used to collect samples that contain oil, grease, or other hard-to-remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials before proceeding with the first steps. In extreme cases, it may be necessary to steam-clean the field equipment before proceeding with Step 14.11.1.

14.11.1 **IF** sampling equipment **cannot** be cleaned utilizing the following steps, **THEN** discard that sampling equipment in an appropriate manner.

14.11.2 **IF** sampling equipment is made of Teflon® or glass, **THEN** proceed to Step 14.11.4.

14.11.3 **IF** sampling equipment is made of steel or stainless steel, **THEN** proceed to Step 14.11.11.

14.11.4 Wash equipment thoroughly with soap and hot tap water, using a brush or scrub pad to remove any particulate matter or surface film.

14.11.5 Rinse equipment thoroughly with hot tap water.

NOTE #1 Small equipment may be soaked in the solution instead of being rinsed with it.

NOTE #2 Prepare fresh nitric acid solution for each cleaning session.

14.11.6 Rinse equipment with 10% nitric acid solution.

14.11.7 Rinse equipment thoroughly with analyte-free water.

14.11.8 Rinse equipment thoroughly with solvent **and** allow to air-dry at least 24 hours.

14.11.9 Wrap equipment in one layer of aluminum foil, rolling edges of foil into a "tab" for easy removal.

Decontamination Personnel

14.11.10 Proceed to Step 14.11.16.

14.11.11 Wash equipment thoroughly with soap and hot tap water, using a brush or scrub pad to remove any particulate matter or surface film.

14.11.12 Rinse equipment thoroughly with hot tap water.

14.11.13 Rinse equipment thoroughly with analyte-free water.

14.11.14 Rinse equipment thoroughly with solvent **and** allow to air-dry at least 24 hours.

14.11.15 Wrap equipment in one layer of aluminum foil, rolling edges of foil into a "tab" for easy removal.

14.11.16 Seal the foil-wrapped equipment in plastic **and** label.

POST-PERFORMANCE WORK ACTIVITIES

15.1 If applicable, the client's Radiological Control personnel must monitor all equipment for radioactivity before it is released from the customer's site. This requirement includes any equipment leaving for maintenance or repairs. Radiation screening will be maintained by continuous field screening and thorough periodic wipe sampling by the Radiological Control personnel. See the project-specific health and safety plan for additional details of this requirement (if it applies).

Decontamination Personnel

15.2 Place all equipment and sample containers cleaned utilizing these procedures in a clean storage area.

15.3 **IF** sufficient storage space is unavailable,
THEN take precautions to keep from contaminating cleaned material by covering with aluminum foil and plastic **and** place it in cabinets or in a shielded area.

15.4 Prepare a Request for Disposal form in accordance with GEO-TEC-011, *Temporary Storage of Waste Materials,* (or client's equivalent form) for disposal of wastes generated.

15.5 Complete field or decontamination logbook entries to include:

- Time and date
- Location
- Name of individual performing the decontamination
- Type of Quality Control (QC) sample submitted
- Equipment cleaned
- Deviations (if any)
- List of equipment needing repair
- Lot number of solvent used

RECORDS

6.1 General Requirements

Generate **and** maintain records in accordance with requirements of GEO Quality Systems procedure GEO-QSP-403, *Control of Records.*

6.2 Records Generated

6.2.1 Field or decontamination logbook entries

SOURCE DOCUMENTS

7.1 Title 40 Code of Federal Regulations (CFR) Section 761, Subpart C (761.40 & 761.45), *Marking of PCBs and PCB Items*

7.2 U.S. Environmental Protection Agency, *Superfund Field Operations Methods,* EPA/540/P-87-001.1, 1987

7.2 U. S. Environmental Protection Agency, *Field Branches Quality System and Technical Procedures*

Attachment A
Definitions and Acronyms
Page 1 of 2

1.0 DEFINITIONS

1.1 Cross Contamination – The transfer of contaminants through equipment or personnel from contamination source too less or non-contaminated samples or areas.

1.2 Decontamination - The process of rinsing or otherwise cleaning the surfaces of drilling or sampling equipment to remove potentially contaminated materials.

1.3 Deionized/Analyte Free Water - Tap water treated by passing through a standard deionizing resin column. Deionized water should contain **no** heavy metals or other inorganic compounds (at or above analytical detection limits) as defined by a standard Inductively Coupled Plasma Spectrophotometer (ICP) scan.

1.4 Disinfectant Soap - Standard brand of disinfectant cleaner.

1.5 Laboratory Detergent/Soap - Standard brand of phosphate-free laboratory detergent such as Liquinox® **or** equivalent.

1.6 Nitric Acid Solution - 10% reagent-grade nitric acid in deionized water.

1.7 Organic/Analyte Free Water - Tap water treated with activated carbon and deionizing units or water from a Milli-Q system (or equivalent).

1.8 Other Solvents - Solvents substituted, as needed, for a particular investigation.

1.9 Polychlorinated biphenyl (PCB)-Contaminated Sampling Equipment (CSE) - Any equipment to be reused that is suspected to have come in contact with an M_L-labeled PCB material and/or a PCB source >/= to 50 ppm is considered to be a PCB-CSE.

1.10 PCB-Contaminated Sampling Waste - Any sampling waste that is suspected to have come in contact with an M_L-labeled PCB material and/or a PCB source >/= 50 ppm is considered to be a PCB-CSW. PCB-CSW can include such items as used personal protection equipment, sampling equipment, cleanup debris, cleaners, and solvents.

1.11 Pesticide Grade Solvent -Grade of solvent that, when analyzed by electron capture gas chromatography, produces no interference peaks greater than that given by 10 ppt (ng/L) of chlorinated hydrocarbons (as heptachlorepoxide).

1.12 Sample Containers - Include, but are not limited to, jars, vials, jugs, air sampling tubes, air sampling filters, soil gas tubes, soil sampling tubes, and air sampling bags.

1.13 Sampling Equipment - Equipment used to obtain actual samples or that might be logically assumed to have an effect on sample quality.

1.14 Standard ICP Scan - ICP scan for the following: Al, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, Sb, TI, V, and Zn.

1.15 Tap Water - Treated potable water from the customer's water treatment plant or other drinking water source.

Attachment A
Definitions and Acronyms
Page 2 of 2

1.16 Volatile Scan I - A scan for the following compounds: trichloroethene, vinyl chloride, tetrachloroethene, carbon tetrachloride, chloroform, bromodichloromethane, dichloroethene, dichloroethane, and 1,1,1-trichloroethane.

2.0 ACRONYMS

2.1 CFR – Code of Federal Regulations

2.2 CSE – Contaminated Sampling Equipment

2.3 CSW – Contaminated Sampling Waste

2.4 GC/MS – Gas Chromatograph/Mass Spectrometer

2.5 GEO – GEO Consultants, LLC

2.6 GFCI – Ground Fault Circuit Interrupter

2.7 ICP – Inductively Coupled Argon Plasma Spectrophotometer

2.8 MSDS – Material Safety Data Sheet

2.9 ng/L – nanograms per liter

2.10 pH – logarithm of hydrogen ion potential

2.11 PVC – Polyvinyl Chloride

2.12 PCB – Polychlorinated Biphenyl

2.13 ppt – parts per trillion

2.14 QC – Quality Control

2.15 TSCA – Toxic Substance Control Act

2.16 USEPA – United States Environmental Protection Agency

Attachment B
PCB-Contaminated Sampling Equipment
Page 2 of 2

PCB-dedicated equipment and tools whose external surfaces come in contact with PCBs are to be decontaminated by swabbing or wiping down with a solvent which was 5% soluble for PCBs or another acceptable PCB cleaning solution, such as "Penetone Power Cleaner." The equipment will remain dedicated to PCB-related activity (such as PCB spill cleanup activity for mechanical wet vacuum floor scrubbers) until it is declared a PCB Waste or verified to contain less than 10 micrograms per 100 square centimeters PCBs.

Equipment and tools that may contact PCBs during PCB management activities can be reused under the following conditions:

a. The equipment must be dedicated to PCB management activities, such as spill cleanup, troughing, PCB equipment servicing, waste management, etc.

b. External surfaces which become contaminated by PCBs will be decontaminated per the requirements of movable equipment under 40 CFR 761.79(b), "Decontamination."

c. The equipment will remain dedicated to PCB-related activity (such as PCB spill cleanup activity for mechanical wet vacuum floor scrubbers) until it is declared a PCB waste or verified to contain less than 10 micrograms per 100 square centimeters.

GEO CONSULTANTS, LLC

A Geological Engineering and Environmental Services Company

Technical Operating Procedure

GROUNDWATER MONITORING SAMPLING

GEO-TEC-012

Revision 3

Prepared by: A. Michael Bosch

Approved by: _____, 12/9/11
Jeff Doughitt, P.E. – President — Date

Record of Changes

Revision Number	Changes and/or Affected Page(s)	Effective Date
0	All	
1	All	07/25/2003
2	All	05/04/2006
3	All	12/09/2011

Next review required no later than: December 9, 2012

TABLE OF CONTENTS

1.0 PURPOSE 3

2.0 SCOPE 3

3.0 PRECAUTIONS AND LIMITATIONS
- 3.1 Environmental, Safety, and Health Precautions 3
- 3.2 Work Environment Limitations 4

4.0 TRAINING PREREQUISITES 4

5.0 OTHER DOCUMENTS NEEDED 4

6.0 WHAT TO DO
- 6.1 Approvals and Notifications 5
- 6.2 Special Tools, Equipment, Parts, and Supplies 5
- 6.3 Pre-Performance Activities 6
- 6.4 Choose Sample Method and Pump Type 7
- 6.5 Arrive at Non-Residential Groundwater Monitoring Well 8
- 6.6 Groundwater Sampling Using Bladder Pumps 10
- 6.7 Groundwater Sampling Using a Bailer 16
- 6.8 Groundwater Sampling Using Peristaltic Pumps 18
- 6.9 Groundwater Sampling of Residential Wells 23
- 6.10 Post Performance Activities 26

7.0 RECORDS
- 7.1 General Requirements 28
- 7.2 Records Generated 28

8.0 SOURCE DOCUMENTS 29

9.0 ATTACHMENTS
- Attachment A – Definitions and Acronyms 30
- Attachment B – Monitoring Well Data Sheet (for Logbooks) 33
- Attachment C – Order of Collection for Groundwater Samples 35

PURPOSE

1.1 This procedure describes the requirements for sampling of groundwater (GW) performed to periodically monitor GW quality.

1.2 The primary objective of this groundwater sampling procedure is the collection of samples that represent the in-situ groundwater quality by collecting samples in a manner that results in the least disturbance or change to the chemical and physical properties of the water.

SCOPE

2.1 This procedure applies to any person performing GW monitoring activities coordinated by GEO Consultants, LLC (GEO) and its subcontractors and teaming partners, if applicable.

2.2 This procedure applies to GW monitoring activities performed for wells on a client's site or for residential wells on private property that a client is obligated to monitor.

2.3 No changes or deviations to this procedure are allowed unless approved in advance by the GEO President, the Project Manager, and (in some cases) the client.

PRECAUTIONS AND LIMITATIONS

3.1 Environmental, Safety and Health Precautions

3.1.1 The minimum personal protection equipment (PPE) for GEO field personnel during a GW sampling event includes safety glasses with side shields, steel toe boots, and latex or nitrile gloves. Technicians allergic to latex should use nitrile gloves instead of latex gloves.

3.1.2 Additional PPE for GEO field personnel may be specified in the project-specific Health and Safety Plan (HASP) and/or in a task-specific Activity Hazard Analysis (AHA) and/or in Material Safety Data Sheets (MSDSs). Requirements may vary for different sampling locations.

3.1.3 The minimum PPE for GEO field personnel working in a radiologically contaminated zone will be specified in a radiological work permit prepared for work in that zone.

3.1.4 Use caution to prevent physical injury from the following potential hazards:

- Lifting injuries
- Use of pocket knives for cutting plastic sheeting or a discharge hose
- Heat or cold stress
- Slips, trips, and fall conditions
- Electrical shock associated with using submersible pumps
- Bites from insects, snakes, or small mammals living near the well
- Armed persons in areas during hunting seasons
- Biological, chemical, or radiological contamination of skin, eyes, etc.

3.1.5 Refer to GEO Corporate document GEO-03-010, *Corporate Health and Safety Program,* for other applicable health and safety requirements and safety practices that may not have been included in other project- or task-specific documents.

3.2 Work Environment Limitations

3.2.1 Extreme weather conditions may limit/exclude conduct of certain fieldwork.

3.2.2 Flooding (recent or current) that crested at or above the well cap may limit or exclude the conduct of certain types of fieldwork.

TRAINING PREREQUISITES

4.1 New personnel assigned to a GEO GW monitoring crew or other appropriate field crew shall complete hands-on training with and observation by an experienced field technician for at least 15 work days prior to working as a regular member of the field crew **and** should be familiar with all methods described in this procedure.

4.2 All GEO field personnel shall complete all GEO health and safety training and special client-required training prior to working in the field with a GEO crew.

4.3 All GEO personnel who perform or supervise collection of GW samples shall complete documented required reading of this procedure and future revisions thereof within 30 days of issuance. New personnel assigned to a GEO crew shall complete documented required reading prior to performing any of this work in the field.

4.4 Field personnel must complete documented required reading of the latest version of the GEO procedures (including GEO Corporate document GEO-03-010, *Corporate Health and Safety Program)* listed in the OTHER DOCUMENTS NEEDED section of this procedure before beginning any work activities.

4.5 All field personnel must have completed documented required reading of applicable project-specific documents that may include work plans, HASP, quality assurance project plan, site-specific sampling and analysis plan, and waste management plan. A copy of each shall be available in the field, or otherwise readily available, before the onset of any field activities. Consult these documents as necessary to obtain specific information regarding equipment and supplies, health and safety, sample collection and identification, sample packaging, and decontamination.

OTHER DOCUMENTS NEEDED

5.1 GEO Corporate document GEO-03-010, *Corporate Health and Safety Program*

5.2 GEO Quality Systems procedure GEO-QSP-401, *Control of Documents*

5.3 GEO Quality Systems procedure GEO-QSP-403, *Control of Records*

5.4 GEO Technical Operating procedure GEO-TEC-005, *Logbooks*

5.5 GEO Technical Operating procedure GEO-TEC-006, *Sample Chain of Custody*

5.6 GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples*

5.7 GEO Technical Operating procedure GEO-TEC-014, *Water Level Measurements (Well)*

5.7 GEO Technical Operating procedure GEO-TEC-030, *Field Measurements of Water Samples*

5.8 Operator manual for bladder pump cycle control box

5.9 Manufacturer's calibration instructions for water meters

WHAT TO DO **6.1 Approvals and Notifications**

Project Manager

6.1.1 Make appropriate notifications to appropriate client personnel specified in a contract or in other project documentation prior to conducting any sampling activity at a client's site or at a property owner's residential well, if applicable.

6.1.2 Make appropriate notifications to local regulatory personnel, if required (not a common requirement).

6.1.3 Verify that any permits required for sampling at a specific well location have been obtained.

GEO Field Personnel

6.1.4 Notify other parties working in the same area(s) of the GW sampling work to be performed by GEO personnel.

6.1.5 Contact each property owner in person or by telephone prior to conducting any sampling activity at a residential well, if applicable.

WHAT TO DO **6.2 Special Tools, Equipment, Parts, and Supplies**

GEO Field Personnel

6.2.1 Ensure the GEO GW sampling trailer or sampling kit has all necessary tools equipment, parts, and supplies needed for collection of GW samples that may include, but are not limited to, the following:

- key(s) for lock(s) on wells;
- photoionization detector (PID) or organic vapor analyzer (OVA);
- electronic water level indicator and tape measure;
- water quality meter (pH, specific conductivity, temperature, etc.);
- thermometer and weather barometer;
- calculator;
- new certified-cleaned sample containers of approved type(s);
- sample preservative chemicals;
- sample labels, custody seals, chain-of-custody forms, and zip-lock bags;
- filtration equipment, if required;
- insulated cooler with ice or "blue ice";
- bladder pump, tubing, sampling board, pump cycle control box;
- bailer and cord;
- peristaltic pump and tubing and garden hose;
- nitrogen tank (or air compressor), regulator, and airline;
- approved calibrated purge water collection container (tank, drum, bucket);
- plastic sheeting, trash bags, tape, and pocket knife; <u>and</u>
- decontamination equipment and supplies, including Kim-wipes, detergent, rinse bottles, methanol, isopropyl alcohol, and deionized (DI) water.

GEO Field Personnel

6.2.2 Ensure that the GEO Groundwater Sampling personnel also have support items available for well maintenance and GW sampling that may include, but are not limited to, the following:

- site-specific work plans and documents (survey information, permits, etc.),
- applicable MSDSs for certain materials taken into the field,
- copy of this and other related procedures,
- manufacturer's calibration instructions and test solutions for water meters,
- maps of site and well locations,
- operator manual for bladder pump cycle control box,
- field logbook, data sheets, and clipboard
- indelible black-ink pens and markers
- well maintenance tools, extra batteries, flashlight, and other supplies
- personnel protective clothing and equipment,
- emergency equipment and two-way radios and/or cellular phone(s), and
- contact information (site/client personnel, laboratory, and emergencies).

WHAT TO DO

6.3 Pre-Performance Activities

GEO Field Personnel

6.3.1 Calibrate the water quality meters and other instruments to be used as specified in the manufacturer's instructions **and** document the calibration in the field logbook **and** prepare for additional periodic calibrations in the field.

6.3.2 Verify that any meters or instruments to be used in the field are operable and have fully-charged batteries.

6.3.3 Inspect the GEO sampling trailer for safety, operability, and contents **or** inspect the portable sampling kit to ensure that it contains all items needed for the sampling activity.

6.3.4 Perform any fueling of equipment in advance so that it does not have to be done in the field and become a possible source of sample contamination.

6.3.5 Avoid the use of perfumes, hand lotion, and other materials that could contaminate a sample or the sampling equipment.

6.3.6 **IF** the use of insect repellent is necessary in the field,
THEN take care not to allow the repellant to come into contact with sampling equipment
AND record the use of insect repellent in the field logbook or data sheet.

6.3.7 Inspect the ancillary tank on the sampling trailer (if so equipped) or other purge water collection containers to ensure they are **not** full.

6.3.8 Verify that all equipment has been properly decontaminated before use in each well to ensure sample integrity and to prevent cross-contamination.

6.3.9 Review applicable information (and bring it to the field for reference) related to the construction (e.g., casing diameter/material, approximate depth, screen location, pump type), sample history, and recharge rate of each well.

GEO Field Personnel

6.3.10 Determine whether work documents require that analysis for volatile organic compounds (VOCs) will be performed in the field or later in a laboratory.

6.3.11 Determine whether any wells contain light non-aqueous phase liquids (LNAPLs), such as oils, that exist as a separate phase on top of the water and whether samples of those liquids should also be taken (method not discussed in this procedure – should be provided by the client or the Project Engineer). Any LNAPLs can interfere with water level measurements and require a special probe to locate the water level and determine the LNAPL layer thickness.

6.3.12 Determine whether any wells contain dense non-aqueous phase liquids (DNAPLs) that would collect as a separate phase at the bottom of the well below the water and whether samples of those liquids should also be taken (method not discussed in this procedure – should be provided by the client or the Project Engineer). DNAPLs should not normally be disturbed (e.g., by well depth soundings); agitation may cause them to be pumped with a sample.

6.3.13 Determine whether work documents or the receiving laboratory require that sample containers be cleaned and pre-preserved by the laboratory to avoid having samples rejected upon delivery to the laboratory.

6.3.14 **IF** no requirements exist requiring GEO to use sample containers from the laboratory that will analyze the samples,
THEN buy new certified-clean sample containers
AND partially complete information on sample labels and chain-of-custody forms
AND attach sample labels
AND add any required preservative in advance (preferred by U.S. Environmental Protection Agency [USEPA]) to save time in the field.

6.3.15 Review work documents to determine the type(s) and quantities of field quality control (QC) samples needed.

6.3.16 Prepare field QC samples specified in the work documents in accordance with requirements of GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples.*

6.3.17 Inspect **and** don any specified personnel protective clothing, PPE, and other safety equipment needed to prepare field QC samples.

NOTE: Ice often lasts longer than "blue ice" on extremely hot days. Some ice should remain unmelted at delivery or samples may be rejected by the laboratory.

6.3.18 Prepare one or more insulated coolers with enough ice or blue ice to last throughout the day until samples are delivered to a laboratory.

WHAT TO DO **6.4 Choose Sample Method and Pump Type**

GEO Field Personnel

6.4.1 Refer to the work documents to determine which purging and sampling methods are required by the client.

GEO Field Personnel

6.4.2 **IF** special sampling methods (different from those in this procedure) are required by and described in project work documents,
THEN follow those methods instead of the ones in this procedure
AND supplement those methods, if applicable, by using parts of information (e.g., preparation steps, post-performance steps) in this procedure that apply to the task, but are not covered in the work documents.

NOTE: Many other types of pumps that are seldom used and may not be suitable for GW sampling include: electrical submersible (except residential), centrifugal submersible, progressive cavity (helical-rotor), gas-drive piston, passive diffusion, and surface centrifugal suction lift pumps.

6.4.3 Consider the following information on types of sampling tools commonly used to obtain GW samples from monitoring and residential wells:

Sampler Type	Related Information
Bladder Pump	Great for efficient well purging and for obtaining representative organic and inorganic samples
Bailer	May not be appropriate for low levels of organics; method is discouraged by USEPA and some State EPAs
Peristaltic Pump	May result in 10-30% lower recoveries of purgeable organic compounds and gases since the strong negative pressure promotes degassing
Electric Submersible Pump	Good for purging and sampling deep high-yielding wells and to obtain organic and inorganic samples; typically used for residential wells
Other Types	Contact the Project Manager for detailed instructions.

6.4.4 **IF** a new pump needs to be placed into a well to permit sampling,
THEN ensure that the well is lowered slowly into position to minimize mixing of water layers
AND allow at least 48 hours for the well to stabilize before beginning any sampling activity.

6.4.5 **IF** groundwater will be sampled from one or more **non**-residential wells,
THEN GO TO Subsection 6.5 for actions to perform upon arrival at a non-residential well that requires GW sampling.

6.4.6 **IF** groundwater will be sampled from one or more residential wells,
THEN GO TO Subsection 6.9 that describes the method that includes special purging requirements.

WHAT TO DO **6.5 Arrive at a Non-Residential Groundwater Monitoring Well**

GEO Field Personnel

6.5.1 Arrive at the non-residential groundwater well scheduled for sampling.

NOTE: The well data sheet may be pasted to a page in the field logbook or used in a stand-alone basis on a clipboard, depending upon client requirements. See GEO-TEC-005, *Logbooks* for the proper way to incorporate separate data sheets into the logbook. Use of the field logbook (with data sheets attached) is preferred by GEO over separate data sheets.

GEO Field Personnel

6.5.2 Obtain a Monitoring Well Data Sheet (see Attachment B) or other data sheet required by the client for that monitoring well **and** begin to enter data.

6.5.3 Record appropriate details related to ambient air temperature, precipitation, wind, barometric pressure, and other weather conditions in the field logbook (or separate data sheet).

6.5.4 Perform a thorough visual inspection of each well and the surrounding area before removing the cap from the well.

6.5.5 Exercise caution when working near a well and when unlocking or opening a well cap (well may be under pressure, snakes or insects may be in nearby ground or brush, insect nests may be under the well cap).

6.5.6 Clear tall grass, weeds, and debris from the immediate well area.

6.5.7 Record any damage or unusual circumstances (evidence of tampering, vandalism, contamination/spills near the well, excavation or construction activities, soil washouts and depressions around the casing, noticeable smoke or other air contaminants, etc.) in the field logbook (or on a separate data sheet under "Comments and Observations").

6.5.8 Contact the Project Manger if any damage or unusual circumstances exist **and** record any special instructions by the Project Manager in the field logbook (or on the data sheet).

NOTE: A portable field table covered with a new plastic sheet at each well may be a convenient option for staging field equipment over plastic on the ground.

6.5.9 **IF** equipment will be staged on the ground **OR** a concern exists that sample equipment may come in contact with the ground,
THEN place a clean plastic/polyethylene sheet on the ground to prevent contamination of equipment

6.5.10 Stage all equipment, tools, instruments, supplies, and other items that will be needed for the sampling event to ensure they are available when needed.

6.5.11 Set up an area for decontamination of equipment, if required, that is located downwind of the well to be sampled.

6.5.12 Unlock the well cap or lid **and** remove it.

NOTE: Organic gases of concern include methane, carbon dioxide, and hydrogen sulfide. The first two may commonly occur near solid waste landfills. The latter may be associated with sewage or decaying vegetation.

6.5.13 **IF** required by a project document or a site-specific condition,
THEN monitor the headspace of the well with a PID or an OVA to determine presence of VOCs
AND record results of the check on the data sheet and/or in the field logbook
AND upgrade PPE, if necessary.

6.5.14 Inspect the condition of the cap (e.g., cracks), well casing (cracks in casing or in surface cement seal), airline, and fittings for the discharge tube.

GEO Field Personnel

6.5.15 Record any damage or unusual conditions in the field logbook (or on a separate data sheet under "Comments and Observations").

6.5.16 Contact the Project Manger if any damage or unusual conditions are found **and** record any special instructions by the Project Manager in the field logbook.

6.5.17 **IF** one or more nearby monitoring wells had been purged and sampled within the past 24 hours,
THEN record that information in the field logbook (or on the data sheet) due to possible effect on water level measurements or water quality for this well.

NOTE: All possible methods are not covered in this procedure. Contact the Project Manager for detailed instructions if a client requires a different method.

6.5.18 GO TO the appropriate subsection in this procedure depending upon which sampling method was specified to be used by the work documents:

Groundwater Sampling Method	Subsection
Using a Bladder Pump	6.6
Using a Bailer	6.7
Using a Peristaltic Pump	6.8
Groundwater Sampling of Residential Wells	6.9

WHAT TO DO

6.6 Groundwater Sampling Using a Bladder Pump

NOTE: Field personnel who are allergic to latex should use nitrile gloves.

GEO Field Personnel

6.6.1 Inspect **and** don a clean pair of latex or nitrile gloves.

NOTE: Bladder pumps are highly recommended for efficient well purging and for obtaining representative samples for both organic or inorganic contaminants.

6.6.2 Retrieve the discharge tubing from the well **and** connect the discharge tubing to the well head.

6.6.3 **IF** the discharge tubing comes in contact with the ground,
THEN decontaminate the tubing with DI water and a clean moist wipe before putting it back into the well.

6.6.4 Connect the discharge tubing from well head to the sampling box.

6.6.5 Place insulation on the discharge tube, if needed.

6.6.6 Measure the barometric pressure **and** record it in the field logbook (or on the separate data sheet).

6.6.7 Determine the static water level manually in accordance with requirements in GEO Technical Operating procedure GEO-TEC-014, *Water Level Measurements (Well)*.

6.6.8 Record the water level information on the data sheet or in the field logbook.

GEO Field Personnel

6.6.9 Refer to the operator manual as necessary for operation of the pump cycle control box.

6.6.10 Set up the pump cycle control box as specified in the operator manual.

6.6.11 Connect the pump cycle control box air hose to the well head air fittings.

6.6.12 Uncap the nitrogen cylinder tank or use a portable compressor instead of the nitrogen tank **and** securely attach a pressure regulator **and** adjust the regulator if required.

6.6.13 Inspect the air hose and fittings for damage **and** securely connect one end of the air hose to the regulator and the other end to the pump cycle control box.

6.6.14 Direct the discharge of the water quality meter so it will drain into a graduated cylinder or other appropriate container for collection and volume measurement.

NOTE: Purging is performed prior to sample collection for almost all groundwater monitoring wells to remove stagnant water from within the well casing above the screen and ensure that a representative sample is obtained.

6.6.15 Determine whether work documents require three-volume purging without a packer (Step 6.6.17), three-volume purging with a packer (Step 6.6.19), or micropurging® (Step 6.6.30) **and** go to the appropriate step.

NOTE: Three-volume purging is required for most groundwater sampling and consists of purging three times the volume of the water in the casing that is located in the zone where the pump is located. More than three volumes (up to five) may be pumped if certain field parameters have not yet stabilized.

6.6.16 **IF** the work documents require three-volume purging without a packer, **THEN** calculate the required purge volume (PV) using the following formula:

Standing water column (feet) = total well depth minus static water level depth
Single PV = standing water column (feet) times casing factor
where: Casing factor for a 2-inch well = 0.163 gallons/foot
Casing factor for a 4-inch well = 0.653 gallons/foot
Total PV (three well volumes) = single PV times 3

6.6.17 Record the calculated PV without a packer in the field logbook (or on a separate data sheet) **and** GO TO Step 6.6.21.

NOTE: A packer is an inflatable elastomeric cylinder that fits into inner casing of well and is usually positioned immediately above the screen and inflated to provide an effective barrier to isolate the stagnant water above from the sampling zone beneath it. It may be designed to allow a drop tube to run through it to allow water level tapes, transducers, pump control and discharge lines, and other monitoring and sampling equipment may extend to the isolated. Its use should be justified and potential problems evaluated.

GEO Field Personnel

6.6.18 **IF** the work documents require three-volume purging with a packer,
THEN calculate the required PV using the following formula:

Isolated zone (feet) = total well depth (feet) minus packer depth (feet)
Single purge zone volume = isolated zone (feet) times casing factor
where: Casing factor for a 2-inch well = 0.163 gallons/foot
Casing factor for a 4-inch well = 0.653 gallons/foot
Total PV (three well volumes) = single purge zone volume times 3.

6.6.19 Record the calculated PV with a packer in the field logbook (or on a separate data sheet).

6.6.20 Ensure that the pump intake for water during purging is located near the middle of the well screen so that water from the surrounding formation will flow in to replace it to provide water for sampling that is typical of that aquifer.

6.6.21 Ensure also that the pump intake for water during purging is located at least two feet above the bottom of the well to prevent excess turbidity from sediment on the bottom.

6.6.22 **IF** a packer is used,
THEN inflate the packer before starting the flow of purge water.

NOTE: Excessively high purge rates may result in introduction of groundwater from zones above or below the well screen and possibly stir up sediment, any of which could dilute or increase contaminant concentration in the samples compared to what is representative of the aquifer.

6.6.23 Start pumping the purge water from the well and ensure that the pumping rate during purging is at or below rates used for development or recovery (i.e., start at a low flow rate and increase the rate slowly if stable well level measurements indicate that the purge water is from the aquifer and not from the stagnant column of water above the screen).

NOTE: Water stabilization parameters measured during well purging shall always include pH, temperature, and specific conductance **and** may also include dissolved oxygen (D.O.) and turbidity if required by the work documents. Values for oxidation-reduction potential (ORP) should also be recorded, but may not be used to verify stabilization for some groundwater conditions.

6.6.24 Refer to the work documents to determine which stabilization parameters need to be monitored during purging.

6.6.25 Collect water stabilization samples **and** measure the stabilization parameters according to work intructions.

Parameter	Stabilization Criteria
pH	± 0.1 standard unit (SU)
Specific conductance	± 3%
Temperature	± 0.5 °C (1° Fahrenheit [F])
D.O.	± 0.3 milligrams per liter (mg/L)
Oxygen-reduction potential	± 10 millivolts (mV)
Turbidity	Considered stabilized if below 10 NTUs ± 10% if greater than 10 NTUs

GEO Field Personnel

6.6.26 Record the results of each set of stabilization measurements in the field logbook (or on a separate data sheet).

6.6.27 **WHEN** the measurements for each parameter for the last three consecutive well purgings are all within the criteria listed above **AND** three well volumes have been purged,
THEN consider the parameters to be stabilized
AND document the stabilization decision in the field logbook (or on a separate data sheet)
AND GO TO Step 6.6.46 to initiate collection of GW samples as soon as practical.

6.6.28 **WHEN** the measurements for any parameter for the last three consecutive well purgings is outside the criteria listed above,
THEN continue to take additional measurements at 3 minute intervals until stabilization occurs **or** five well volumes have been purged
AND document the stabilization decision in the field logbook (or on a separate data sheet)
AND GO TO Step 6.6.46 to initiate collection of GW samples as soon as practical.

NOTE: Micropurging® is a term used to describe low flow rate purging (100-500 milliliters [mL]/minute) in which only a single volume of the well is purged.

6.6.29 **IF** the work documents require micropurging® (purging only the volume of water in the pump and the discharge line) with a bladder pump,
THEN calculate the required PV using the following formula based upon the inside diameter of the discharge line:

1/2" diameter discharge line
PV (mL) = 40 (mL/foot) times discharge line length (feet) + 450 mL (pump)

3/8" diameter discharge line
PV (mL) = 22 (mL/foot) times discharge line length (feet) + 450 mL (pump)

6.6.30 Record the calculated PV in the field logbook (or on a separate data sheet).

6.6.31 Ensure that the intake for water during micropurging® is located near the middle of the well screen so that water from the surrounding formation flows in to replace it to provide water for sampling that is typical for that aquifer.

6.6.32 Measure the water level in the well just prior to purging using a water level meter (refer to GEO Technical Operating procedure GEO-TEC-014, *Well Water Level Measurements*) **and** repeat water level measurements at a frequency of every 5-10 minutes while purging **and** record each water level in the field logbook or on the data sheet.

NOTE: Maintaining a drawdown rate of 0.3 feet or less is commonly not possible in Upper Continental Recharge System wells.

6.6.33 Adjust the discharge rate during micropurging® as necessary to maintain a water level drawdown of less than 0.3 feet or follow work instructions if this cannot be met.

GEO Field Personnel

6.6.34 Open the valve on the sampling box so the flow is directed to the sample port.

6.6.35 Start the air compressor **or** adjust the regulator on the nitrogen cylinder **and** turn on the pump cycle control box.

NOTE: Starting the pumping rate at a low flow rate and increasing the rate slowly if well depth measurements are stable indicates that the purge water removed is from the aquifer and not from the stagnant column of water above the screen.

6.6.36 Adjust the flow rate to desired pressure output of 1/2 pounds per square inch (psi) per foot of lift.

6.6.37 Adjust the flow meter to a flow rate of 300 mL/minute or less **and** allow 300 mL or more to flow through the sampling port.

6.6.38 Close the sampling port to allow the purge water to run through the water quality meter flow-through cell **and** check for any trapped air pockets.

6.6.39 Check for any trapped air pockets and reposition the flow-through cell as necessary to remove trapped air pockets.

6.6.40 Collect all excess purge water **and** put it in the ancillary tank on the GEO sampling trailer or in other containers specified in the work documents.

6.6.41 Allow the water quality meter readings to stabilize in accordance with the following criteria:

- Water quality parameters (with the exception of Turbidity and ORP) have stabilized within approximately 10% over the last two consecutive measurements that are three minutes apart, or duration required in work instructions.
- Turbidity is considered stabilized when subsequent measurements are within approximately 10% or a turbidity measurement is 10 Nephelometric Turbidity Units (NTUs) or less
- ORP may or may not be used to determine stabilization for some groundwater conditions, but values shall be recorded.

6.6.42 **WHEN** the PV of 300 mL or more has been reached,
THEN record the initial water quality parameter readings on the data sheet in the logbook.

6.6.43 Record a minimum of three measurements, including the initial reading, in three-minute intervals for all required stabilization parameters until stability has been achieved.

6.6.44 **IF** the ancillary tank on the GEO sampling trailer becomes full of purge water,
THEN dispose of the purge water into a container at a location specified by the client in a project-specific Waste Management Plan.

6.6.45 Continue to record all necessary data (purge process, etc.) in the field logbook (or on a separate data sheet).

6.6.46 Complete information (date, time, and sampler's initials) on the labels of the sample containers waiting to be filled.

GEO Field Personnel

6.6.47 Add any required preservative to each sample container (if the containers had not been pre-preserved).

6.6.48 Open any field blanks, if required by project work documents, **and** begin the collection of samples only after stabilization of water quality parameters has been achieved.

NOTE: All samples should be collected while the water is flowing. Valving the flow on and off can affect/change the parameters that will be analyzed.

6.6.49 Collect regular samples and any field QC samples that will be analyzed for required analytes in the appropriate order as described in Attachment C to implement requirements of USEPA document SW-846, *Test Methods for Evaluating Solid Waste*.

NOTE: Samples to be monitored for VOCs shall be collected in 40 mL glass vials (called volatile organic analysis [VOA] vials) that are completely filled (no bubbles or headspace), sealed with a fluorocarbon-lined cap, and not opened until laboratory analysis.

6.6.50 Maintain the flow rate at 100 mL/minute or less during the collection of VOC samples.

6.6.51 Maintain the flow rate at 300 mL/minute or less during the collection of all other samples (other than VOC samples).

6.6.52 Verify that all field QC samples required by the work documents were collected in accordance with requirements in GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples.*

6.6.53 Turn off the pump to discontinue the flow of groundwater.

6.6.54 **IF** a well was pumped to dryness **AND** all samples were not collected,
THEN notify the Project Manager of the situation
AND record the "dry" condition in the field logbook (or on a separate data sheet)
AND return within 24 hours of initial sampling time
AND do **not** repeat the purge
AND collect one round of water quality measurements
AND record those values in the field logbook (or on a separate data sheet)
AND collect the remaining required samples.

6.6.55 **IF** a well was pumped dry during that second attempt to collect samples,
THEN notify the Project Manager of the situation
AND abandon the remaining sample collection activities
AND consider the well to be "dry"
AND record the second "dry" condition in the field logbook (or on a separate data sheet)
AND GO TO Section 6.10 to complete post-performance activities.

GEO Field Personnel

6.6.56 Secure the lid on each sample container **and** attach a custody seal, if required.

6.6.57 **WHEN** all regular and field QC samples have been collected and lids secured, **THEN** close the lids on any field blanks, if applicable.

6.6.58 Check the label on each sample container to ensure that all information blanks have been filled **and** complete the chain-of-custody forms.

6.6.59 Place each sample container in a separate zip-lock bag (if required).

6.6.60 Place each sample requiring storage at a temperature of 4 degrees (°) Centigrade/Celsius (C) in a cooler with blue ice or ice as soon as practical after it has been generated, but do not totally immerse any sample containers in water from melted ice.

6.6.61 Verify that all information related to purging and sample collection was recorded in the field logbook (or on a separate data sheet).

6.6.62 GO TO Section 6.10 to complete post-performance activities.

WHAT TO DO

6.7 Groundwater Sampling Using a Bailer

NOTE: Field personnel who are allergic to latex should use nitrile gloves.

GEO Field Personnel

6.7.1 Inspect **and** don a clean pair of latex or nitrile gloves.

NOTE: Use of a bailer may **not** be an appropriate sampling method if sampling is intended to detect low levels of organics. The bailer method is also discouraged by the USEPA and several State EPAs. Non-disposable bailers also require extensive cleaning before and after each sample. Use this method only if required by a client. Effective use of a bailer is highly dependent upon the skill, care, and consistency of the operator.

6.7.2 Record all information related to sampling with a bailer in the field logbook (or on a separate data sheet).

NOTE: Non-disposable bailers are typically made of inert materials such as stainless steel, polyvinyl chloride (PVC), or Teflon® or are Teflon®-coated. Disposable bailers are typically made of polyethylene or polypropylene. Diameter of a bailer shall be 75% or less than the inside diameter of the well casing.

6.7.3 Purge a well using a clean bailer by removing three bailers full of purge water **and** then obtain the required samples using the same steps (Steps 6.7.4 through 6.7.11), unless otherwise instructed in the work documents.

6.7.4 Attach a cleaned bailer securely to one end of the braided polypropylene or braided stainless steel cord **and** also secure the other end of the cord so it does **not** also go down the well casing.

6.7.5 Lower the bailer slowly into the well casing, being careful not to allow the cord to contact the ground (plastic sheeting should help prevent this).

GEO Field Personnel

6.7.6 Minimize contact between the bailer and the well casing as this may disturb accumulated sediments.

NOTE: Aeration is **not** desirable during sample collection, especially when samples are being collected for analysis of VOCs and/or semi-volatile organic compounds (SVOCs).

6.7.7 Allow the bailer to enter the water very slowly to minimize aeration **and** slowly lower it to the desired depth to the screen area.

6.7.8 Prevent contact between the bailer and the well bottom as this may also disturb accumulated sediments.

NOTE: Slow retrieval is important to minimize degassing, aeration, and turbidity of the sample.

6.7.9 Slowly retrieve the filled bailer to the surface (check valves are open during descent and closed when it is retrieved to collect the sample at the lowest depth) **and** be careful **not** to stop or reverse the retrieval **and** do **not** to allow the wet cord to contact the ground.

6.7.10 Discard a wet or contaminated polypropylene bailer cord after each sample has been taken (stainless steel cord would require decontamination) **and**, if applicable, discard a disposable bailer after each sample has been taken.

NOTE: Decontamination of the bailer between purge extractions may be limited to the exterior surfaces only to prevent transfer of debris or contaminants throughout the length of the well.

6.7.11 **IF** a reusable bailer will be used to collect another sample **OR** if the last sample for that well has been taken with that bailer,
THEN decontaminate a reusable bailer after each use according to the following process:

a. Add clean detergent solution to bailer, cover the ends, and slosh solution end to end while rotating the barrel to ensure washing of all interior surfaces.

b. Dump the spent detergent solution in an approved waste container.

c. Thoroughly rinse the exterior surfaces of the bailer three times with DI water **and** then rinse the interior surfaces of the bailer three times with DI water.

d. Squirt solvent (typically isopropyl alcohol or methanol) using a Teflon wash bottle dedicated for use with that solvent on the inside of the bailer's barrel **and** rotate the bailer to flush the entire inner surface.

e. Cover the ends of the bailer **and** slosh solvent end to end while rotating the barrel of the bailer.

f. Dump spent solvent in a designated waste container.

g. Repeat the solvent rinse process (substeps **d.-f.**) three times.

h. Rinse the exterior surface of the bailer with solvent **and** wipe dry with a chemical resistant wipe.

i. Repeat substep **h.** twice to clean the exterior surface three times.

j. Dispose of all wipes and spent solutions in approved waste containers.

GEO Field Personnel

6.7.12 Add any required preservative to each sample container if the containers had not been pre-preserved.

6.7.13 Open any field blanks, if required by project work documents, **and** complete information (date, time, and sampler's initials) on the labels on the sample containers waiting to be filled.

NOTE: Collect samples to be monitored for VOCs in 40 mL glass vials (VOA vials) that are completely filled (no bubbles or headspace), sealed with a fluorocarbon-lined cap, and not opened until laboratory analysis.

6.7.14 Collect regular and field QC samples that will be analyzed for the required analytes in the order as described in Attachment C to implement requirements of USEPA document SW-846, *Test Methods for Evaluating Solid Waste*.

6.7.15 Verify that all field QC samples required by the work documents were collected in accordance with requirements in GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples*.

6.7.16 Check the label on each sample bottle **and** check the chain-of-custody forms to ensure that all information blanks have been filled.

6.7.17 Secure the lid on each sample container **and** attach a custody seal (if required) **and** place each sample container in a separate zip-lock bag (if required).

6.7.18 **WHEN** all regular and field QC samples have been collected and lids secured, **THEN** close the lids on any field blanks, if applicable.

6.7.19 Place each sample requiring a storage temperature of 4°C in a cooler with blue ice or ice as soon as possible after it has been generated, but do not totally immerse any sample containers in water from melted ice.

6.7.20 GO TO Section 6.10 to complete post-performance activities.

WHAT TO DO

6.8 Groundwater Sampling Using a Peristaltic Pump

NOTE: Field personnel who are allergic to latex should use nitrile gloves.

GEO Field Personnel

6.8.1 Inspect **and** don a clean pair of latex or nitrile gloves.

> **CAUTION**
> Peristaltic pumps are **not** recommended for collection of samples that will be used for analysis of VOCs, mercury, or dissolved gases.

GEO Field Personnel

6.8.2 Insert one end of the downhole tubing into the well **and** lower it to near the center of the well screen. If well contains dedicated tubing, retrieve the tubing from the well.

6.8.3 Connect the other end of the downhole tubing to the pump head.

6.8.4 **IF** the feed or discharge tubing comes in contact with the ground **OR** becomes contaminated in any other way,
THEN decontaminate the tubing with DI water and a clean moist wipe before putting it back into the well.

6.8.5 Connect the control box to the power source in accordance with instructions in the operator's manual.

NOTE: Purging is performed prior to sample collection for almost all groundwater monitoring wells to remove stagnant water from within the well casing above the screen and ensure that a representative sample is obtained.

6.8.6 Determine whether work documents require three-volume purging without a packer (Step 6.8.7) or micropurging® (Step 6.8.16) **and** GO TO the appropriate step.

NOTE: Three-volume purging is required for most groundwater sampling and consists of purging three times the volume of the water in the well casing pumped from near the middle of the well screen. Pump more than three volumes (up to five) if certain field parameters have not yet stabilized.

6.8.7 **IF** the work documents require three-volume purging without a packer,
THEN calculate the required PV using the following formula:

Standing water column (feet) = total well depth minus static water level depth
Single PV = standing water column (feet) times casing factor
where: Casing factor for a 2-inch well = 0.163 gallons/foot
Casing factor for a 4-inch well = 0.653 gallons/foot
Total PV (three well volumes) = single PV times 3.

6.8.8 Record the calculated PV without a packer in the field logbook (or on a separate data sheet).

6.8.9 Ensure that the intake for water during purging is located near the middle of the well screen so that water from the surrounding formation will flow in to replace it to provide water for sampling that is typical for that aquifer.

NOTE: Excessively high purge rates may result in introduction of groundwater from zones above or below the well screen and possibly stir up sediment, any of which could dilute or increase contaminant concentration in the samples compared to what is representative of the aquifer.

6.8.10 Start the three-volume purge **and** ensure that the pumping rate during purging is at or below rates used for development or recovery.

NOTE: Water stabilization parameters measured during well purging shall always include pH, temperature, and specific conductance **and** may also include D.O. and turbidity, if required by the work documents. Values for ORP should also be recorded, but may not be used to verify stabilization for some groundwater conditions.

GEO Field Personnel

6.8.11 Refer to the work documents to determine which stabilization parameters need to be monitored during purging.

6.8.12 Collect water stabilization samples **and** measure the required stabilization parameters according to work instructions.

Parameter	Stabilization Criteria
pH	± 0.1 SU
Specific conductance	± 3%
Temperature	± 0.5 °C (1°F)
D.O.	± 0.3 mg/L
Oxygen-reduction potential	± 10 mV
Turbidity	Considered stabilized if below 10 NTUs ± 10% if greater than 10 NTUs

6.8.13 Record the results of each set of stabilization measurements in the field logbook (or on a separate data sheet).

6.8.14 **WHEN** the measurements for each parameter for the last three consecutive well purgings are all within the criteria listed above **AND** three well volumes have been purged,
THEN consider the parameters to be stabilized
AND document the stabilization decision in the field logbook (or on a separate data sheet)
AND GO TO Step 6.8.26 to initiate collection of GW samples as soon as practical.

6.8.15 **WHEN** the measurements for any parameter for the last three consecutive well purgings is outside the criteria listed above,
THEN continue to take additional measurements at intervals described in work instructions until stabilization occurs **or** five well volumes have been purged
AND document the stabilization decision in the field logbook (or on a separate data sheet)
AND GO TO Step 6.8.26 to initiate collection of GW samples as soon as practical.

NOTE #1 Micropurging® is a term used to describe low flow rate purging (100-500 mL/minute) in which only a single volume of the well is purged.

NOTE #2 Do **not** add extra volume to the PV since the only volume within the pump is within the tubing itself.

GEO Field Personnel

6.8.16 **IF** the work documents require micropurging® (purging only the volume of water in the pump and the discharge line),
THEN calculate the required PV using the following formula based upon the inside diameter of the discharge line:

1/2" diameter discharge line
PV (mL) = 40 (mL/foot) times discharge line length (feet)

3/8" diameter discharge line
PV (mL) = 22 (mL/foot) times discharge line length (feet)

6.8.17 Record the calculated micropurge® volume in the field logbook (or on a separate data sheet).

6.8.18 Measure the static water level in the well just prior to purging [refer to GEO Technical Operating procedure GEO-TEC-014, *Water Level Measurements (Well)*] **and** repeat the water level measurement every 5 minutes (or other frequency noted in work instructions) during purging **and** record the water level measurements in the field logbook (or on a separate data sheet).

6.8.19 Ensure that the intake for water during micropurging® is located near the middle of the well screen so that water from the surrounding formation flows in to replace it to provide water for sampling that is typical for that aquifer.

NOTE: Maintaining a drawdown rate of 0.3 feet or less is commonly not possible in Upper Continental Recharge System wells.

6.8.20 Adjust the discharge rate during micropurging® as necessary to maintain a water level drawdown of less than 0.3 feet or follow work instructions if this cannot be met.

6.8.21 Turn on the control box **and** adjust the flow rate for micropurging® at 300 mL/minute or less, or as otherwise specified in the work documents.

6.8.22 **DO NOT** collect the purge water in the ancillary tank on the GEO sampling trailer unless specifically instructed to do so.

6.8.23 **IF** purge water is required to be collected **AND** the purge water collection container becomes full,
THEN dispose of the purge water into a container at a location specified by the client in a project-specific Waste Management Plan.

6.8.24 **WHEN** the required PV has been reached,
THEN record the water quality parameter readings (only one time).

6.8.25 Repeat the water level measurement in the well immediately after micropurging® **and** record the water level measurement in the field logbook (or on a separate data sheet).

6.8.26 Complete information (date, time, and sampler's initials) on the labels on the sample containers waiting to be filled.

GEO Field Personnel

6.8.27 Open any field blanks, if required by project work documents, **and** add any required preservative to each sample container if the containers had not been pre-preserved.

6.8.28 Secure the discharge hose **and** prepare for sample collection.

6.8.29 Collect samples to be analyzed for the required analytes in the appropriate order as described in Attachment C to implement requirements of USEPA document SW-846, *Test Methods for Evaluating Solid Waste*.

6.8.30 Verify that all field QC samples required by the work documents were collected in accordance with requirements in GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples*.

6.8.31 Turn off the pump to discontinue the flow of groundwater.

6.8.32 **IF** a well was pumped to dryness **AND** all samples were not collected,
THEN notify the Project Manager of the situation
AND record the "dry" condition in the field logbook (or on a separate data sheet)
AND return within 24 hours of initial sampling time
AND do **not** repeat the purge
AND collect one round of water quality measurements
AND record those values in the field logbook (or on a separate data sheet)
AND collect the remaining required samples.

6.8.33 **IF** a well was pumped dry during that second attempt to collect samples,
THEN notify the Project Manager of the situation
AND abandon the remaining sample collection activities
AND consider the well to be "dry"
AND record the second "dry" condition in the field logbook (or on a separate data sheet)
AND GO TO Section 6.10 to complete post-performance activities.

6.8.34 Secure the lid on each sample container **and** attach a custody seal, if required.

6.8.35 **WHEN** all regular and field QC samples have been collected and lids secured,
THEN close the lids on any field blanks, if applicable.

6.8.36 Check the label on each sample container to ensure that all information blanks have been filled **and** complete the chain-of-custody forms.

6.8.37 Place each sample container in a separate zip-lock bag (if required).

6.8.38 Place each sample requiring storage at a temperature of 4°C in a cooler with blue ice or ice as soon as practical after it has been generated, but do not totally immerse any sample containers in water from melted ice.

6.8.39 Verify that all information related to purging and sample collection was recorded in the field logbook (or on a separate data sheet).

6.8.40 GO TO Section 6.10 to complete post-performance activities.

WHAT TO DO **6.9 Groundwater Sampling of Residential Wells**

NOTE: A minimum of two technicians shall be present for this type of GW sampling unless other directions are provided by the Project Manager.

GEO Field Personnel

6.9.1 Perform a courtesy notification to the property owner, preferably prior to arrival at the residential site, that the well monitoring crew plan to sample the well on a specific day.

6.9.2 Arrive at the residential well scheduled for sampling **and** notify the property owner upon arrival that the well monitoring crew is ready to begin sampling.

NOTE: The well data sheet may be attached to a page in the field logbook or used in a stand-alone basis on a clipboard, depending upon client requirements. Any information not on a data sheet should be recorded in a field logbook.

6.9.3 Obtain a Monitoring Well Data Sheet (see Attachment B) or other data sheet required by the client for that monitoring well **and** begin to enter data.

6.9.4 Record appropriate details related to ambient air temperature, precipitation, wind, barometric pressure, and other weather conditions in the field logbook (or on a separate data sheet).

6.9.5 Perform a thorough visual inspection of each well and the surrounding area before removing the cap from the well.

6.9.6 Exercise caution when working near a well and when unlocking or opening a well cap (well may be under pressure, snakes or insects may be in nearby ground or brush, insect nests may be under the well cap).

6.9.7 Clear tall grass, weeds, and debris from the immediate well area.

6.9.8 Record any damage or unusual circumstances (evidence of tampering, vandalism, contamination/spills near the well, excavation or construction activities, soil washouts and depressions around the casing, noticeable smoke or other air contaminants, etc.) in the field logbook (or on a separate data sheet under "Comments and Observations").

6.9.9 Contact the Project Manger if any damage or unusual circumstances exist **and** record any special instructions by the Project Manager in the field logbook (or on the data sheet).

NOTE: A residential well may be equipped with either a bladder pump or an electric pump.

6.9.10 **IF** the residential well is equipped with an electric pump,
THEN GO TO Step 6.9.28 to purge the well.

6.9.11 **IF** the residential ell is equipped with a bladder-type pump (not typical),
THEN unlock the well cap or lid, if locked
AND remove the well cap or lid.

GEO Field Personnel

6.9.12 Inspect the condition of the cap (e.g., cracks), well casing (cracks in casing or in surface cement seal), airline, and fittings for the discharge tube.

6.9.13 Record any damage or unusual conditions under, if applicable, "Comments and Observations" on the data sheet (stand-alone or affixed in the logbook) or in the logbook itself.

6.9.14 Contact the Project Manager if any damage or unusual conditions are observed **and** record any special instructions by the Project Manager in the field logbook (or on a separate data sheet).

NOTE: Field personnel who are allergic to latex should use nitrile gloves.

6.9.15 Don a new pair of latex or nitrile gloves.

NOTE: Micropurging® is a term used to describe low flow rate purging (100-500 mL/minute) in which only a single volume of the well is purged.

6.9.16 Prepare to micropurge® the residential well as described in the following steps (unless the client requires a three-volume purge as described in Subsection 6.6 on bladder pumps).

6.9.17 **IF** the residential well is equipped with an electrical submersible pump with a carbon filtration system,
THEN GO TO Step 6.9.30 to purge the system and collect stabilization samples.

6.9.18 **IF** the residential well is equipped with an electrical submersible pump without a carbon filtration system,
THEN purge the system **and** verify stabilization using the following steps.

a. Connect a hose to an outside faucet **and** open the faucet valve fully to receive the highest purge rate **and** continue this purge rate for 5 minutes.

b. Discharge purge water through a water hose onto the ground surface away from the faucet **and** DO NOT collect the purge water unless instructed otherwise.

c. **WHEN** the initial 5 minute purge has been completed,
THEN close the faucet valve
AND remove the garden hose from the faucet to prepare for collection of the samples from the faucet.

d. Connect the water quality meter to the water faucet **and** turn on the flow at a reduced rate of approximately 300 mL/minute or less.

e. Record a minimum of three measurements of the water quality at three-minute intervals until stability has been achieved based upon the following stabilization criteria:

- Water quality parameters (with the exception of Turbidity and ORP) have stabilized within approximately 10% over the last two consecutive measurements that are three minutes apart.
- Turbidity is considered stabilized when subsequent measurements are within approximately 10% or a turbidity measurement is 10

NTUs or less

- ORP may or may not be used to determine stabilization, but values shall be recorded.

f. GO TO Step 6.9.34 to begin to collect samples and field QC samples.

GEO Field Personnel

6.9.19 **IF** a residential well **is** equipped with a carbon filtration system, **THEN** perform the following steps to purge the system and collect samples:

a. Purge the pump and piping leading to the carbon filtration system using the spigot immediately preceding the carbon filtration system.

b. Conduct the purge **and** verify stabilization for the water coming from the spigot using Steps 6.9.29.**a** through 6.9.29.**e**.

c. Identify the three sampling ports on the filtration system (each is marked).

d. Do **not** check for stabilization at these three ports (not necessary since it was done at the spigot prior to the filter)

e. GO TO Steps 6.9.34 through 43 to collect all samples and field QC samples starting at Port One **and** repeat the sample collections for both Port Two and Port Three.

f. GO TO Step 6.9.44 after collecting samples and field QC samples from all three ports.

6.9.20 **IF** a residential well has only part of the flow to the residence going through a carbon filtration system (part filtered and part unfiltered to the residence), **THEN** check the **unfiltered** part of the flow to the residence as follows:

a. purge the unfiltered portion **and** collect samples to verify stabilization according to substeps 6.9.29.**a** through 6.9.29.**e**

b. collect samples and field QC samples for analysis from the unfiltered portion according to Steps 6.9.34 through 6.9.43

AND check the **filtered** part of the flow to the residence as follows:

a. purge the spigot before the filter (unfiltered at this point) and verify stabilization of the unfiltered flow according to substeps 6.9.30.**a**, 6.9.30.**b**, and 6.9.29.**a** through 6.9.29.**e**

b. collect unfiltered samples and field QC samples for analysis from the spigot according to Steps 6.9.34 through 6.9.43

c. collect filtered samples and field QC samples from the each of the three ports (or one port, if only one port exists) according to substeps 6.9.30.**c** through 6.9.30.**e** and Steps 6.9.34 through 6.9.43

AND identify each of the samples accordingly.

6.9.21 Complete information (date, time, and sampler's initials) on the labels on the sample containers waiting to be filled.

6.9.22 Open any field blanks, if required by project work documents, **and** add any required preservative to each sample container (if the containers had not been pre-preserved).

6.9.23 Begin collection of samples only after stabilization of water quality parameters has been achieved.

GEO Field Personnel

6.9.24 Collect regular samples and any required QC samples to be analyzed for the required analytes in the appropriate order as described in Attachment C to implement requirements of USEPA document SW-846, *Test Methods for Evaluating Solid Waste.*

6.9.25 Maintain the flow rate coming out of the water quality meter at 300 mL/minute or less during collection of all samples other than VOC samples.

NOTE: Collect samples to be monitored for VOCs in 40 mL glass vials (VOA vials) that are completely filled (no bubbles or headspace), sealed with a fluorocarbon-lined cap, and not opened until laboratory analysis.

6.9.26 Lower the flow rate coming out of the water quality meter to 100 mL/minute or less during collection of VOC samples, if applicable.

6.9.27 Close the valve above the water quality meter **and** disconnect the water quality meter from the source of sample water.

6.9.28 Verify that all field QC samples required by the work documents were collected in accordance with requirements in GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples.*

6.9.29 Secure the lid on each sample container **and** attach a custody seal, if required.

6.9.30 **WHEN** all regular and field QC samples have been collected and lids secured, **THEN** close the lids on any field blanks, if applicable.

6.9.31 Check the label on each sample container to ensure that all information blanks have been filled **and** complete the chain-of-custody forms.

6.9.32 Place each sample container in a separate zip-lock bag (if required).

6.9.33 Place each sample requiring storage at a temperature of 4°C) in a cooler with blue ice or ice as soon as practical after it has been generated, but do not totally immerse any sample containers in water from melted ice.

6.9.34 Verify that all information related to purging and sample collection was recorded in the field logbook (or on a separate data sheet).

6.9.35 GO TO Section 6.10 to complete post-performance activities.

WHAT TO DO

6.10 Post-Performance Activities

NOTE: Perform only those applicable steps in this section after completing GW sampling using the specified method.

GEO Field Personnel

6.10.1 Turn the power off on all sampling equipment and water quality meters.

6.10.2 Disconnect cycle controller from well head **and** replace discharge tubing into well if dedicated tubing is used.

6.10.3 Close the well cap or lid **and** lock the well cap or lid, if required.

GEO Field Personnel

6.10.4 Drain all purge water from the water quality meter, sampling board, and discharge tubing into the ancillary tank or drum (or on the ground for a residential well).

6.10.5 Measure **and** record the barometric pressure in the field logbook (or on a separate data sheet) after sample were collected from wells where the water levels were measured.

6.10.6 Thoroughly decontaminate the sampling board with 300 mL or more of analyte-free water (DI water) run through the sampling port **and** decontaminate the water level indicator **and** record decontamination events and times in the logbook.

6.10.7 Decontaminate a pump by pumping one gallon of DI water through it immediately after use **and** wash/wipe the exterior surfaces with a detergent solution followed by three rinses with DI water **and** thoroughly wash/wipe the exterior three times with solvent (isopropyl alcohol) **and** allow to air dry before reuse.

6.10.8 Thoroughly decontaminate all other reusable sampling equipment and tools to ensure they are clean prior to use at the next well to ensure sample integrity and prevent cross-contamination **and** record decontamination events and times in the logbook.

6.10.9 IF equipment rinsate samples are required by the work documents, THEN generate the equipment rinsate samples after decontamination has been completed in accordance with requirements in GEO Technical Operating procedure GEO-TEC-009, *Field Quality Control Samples*.

6.10.10 Ensure that all relevant information related to the sampling event, including any drastic weather changes or events, were recorded in the designated field logbook (or on a separate data sheet).

6.10.11 Collect all waste, including plastic sheeting around well and/or for the decontamination area, into a container separate from regular trash.

6.10.12 Discard all PPE used in areas that were radiologically-contaminated and areas that were not radiologically-contaminated in separate marked containers as specified by the client in a project-specific Waste Management Plan.

6.10.13 **IF** a container was used to collect waste,
THEN attach the lid securely onto the container
AND label the container with waste container labels
AND verify that the Container Log Sheet (or equivalent list identifying the contents) was completed
AND complete the Request for Disposal (RFD) form (or equivalent), if applicable.

GEO Field Personnel

6.10.14 **IF** the ancillary tank on the GEO sampling trailer was used to collect purge and stabilization water,
THEN secure the lid on the tank
AND document the addition from that well on Container Log Sheets (or equivalent).

6.10.15 Verify that all chain-of-custody forms were fully completed in accordance with requirements in GEO Technical Operating procedure GEO-TEC-006, *Sample Chain-of-Custody.*

6.10.16 Verify that all samples requiring a storage temperature of 4°C were placed in a cooler with blue ice/ice as soon as possible after they were generated.

6.10.17 **WHEN** sampling of a residential well had been completed AND the surrounding area had been cleaned up,
THEN load all equipment, documentation, and samples in the GEO sample trailer (or other vehicle if the trailer was not used)
AND notify the property owner that the well monitoring crew has completed sampling and are leaving their property.

6.10.18 Submit regular and QC samples and completed chain-of-custody forms to an on-site laboratory **or** to a local client laboratory **or** prepare the samples for shipment to an off-site laboratory, as required by the work documents.

6.10.19 Discard all containerized waste as specified by the client in a project-specific Waste Management Plan or other work document.

6.10.20 Dispose of all purge and stabilization water in the ancillary tank, if applicable, in accordance with client instructions in a project-specific Waste Management Plan or other work document.

6.10.21 Record relevant information on disposition of samples and chain-of-custody forms in the field logbook (or on a separate data sheet).

6.10.22 **IF** the project requires that copies of field logbook pages (and/or data sheets) be made overnight as insurance against possible damage or loss,
THEN turn in field logbooks and any data sheets to the Project Manager or Designee at the end of the day.

6.10.23 Notify the client before leaving the client's site as specified in the project work documents.

RECORDS

7.1 General Requirements

Generate **and** maintain records in accordance with requirements of GEO Quality System procedure GEO-QSP-401, *Control of Documents* and GEO-QSP-403, *Control of Records.*

7.2 Records Generated

7.2.1 Field logbooks

7.2.2 Data sheets, if applicable

7.2.3 Chain-of-custody forms

7.2.4 RFD forms (or equivalent), if applicable

7.2.5 Container log sheets (or equivalent), if applicable

SOURCE DOCUMENTS

8.1 U.S. Environmental Protection Agency, Region IV, *Environmental Compliance Branch, Standard Operating Procedures and Quality Assurance Manual,* 1996.

8.2 U.S. Environmental Protection Agency, Region I, *Standard Operating Procedure for Ground Water Sampling,* 2003

8.3 U.S. Environmental Protection Agency, SW-846, *Test Methods for Evaluating Solid Waste,* 1996.

8.4 American Society for Testing Materials (ASTM), Method D4448-01, *Standard Guide for Sampling Groundwater Monitoring Wells,* 2001.

Attachment A
Definitions and Acronyms
Page 1 of 3

1.0 DEFINITIONS

1.1 **Ancillary Tank** – a tank in which groundwater monitoring purge water is temporarily stored until treated and disposed.

1.2 **Bailer** – a cylindrical groundwater sampling device constructed of stainless steel or Teflon™.

1.3 **Bladder Pump** – a pump that consists of a flexible bladder inside a rigid housing. Water enters the bladder from the bottom and is squeezed to the surface through a discharge line by gas pressure applied to the outside of the bladder. An air compressor and regulator turn the pressure on and off, allowing new water to enter the bladder and the cycle is repeated, but the separate bladder chamber does not allow the sample to come in contact with the compressed air. Check valves at the top and bottom prevent backwash from the sample tube and bladder.

1.4 **Controller Box** – a cycle controller that controls the operation of the pump by regulating the air flow from a compressed-gas source to the pump.

1.5 **Micropurging®** – a purging method in which only one volume of the well is purged, usually necessitated by low flow and/or a slow recovery rate. It may also be called low stress, low flow, low impact, or minimal drawdown purging.

1.6 **Packer** – an inflatable elastomeric cylinder that fits into inner casing of well and positioned immediately above the screen that is inflated to provide an effective barrier to isolate the stagnant water above from the sampling zone beneath it. It may be designed to allow a tube to run through it to allow removal of GW samples.

1.7 **Peristaltic Pump** – a type of portable self-priming suction lift pump located on the surface that delivers samples by creating a vacuum by a series of rotating wheels that compress the sample tubing (usually disposable) lowered into the well. The sample contacts only the tubing, so no moving parts in the pump need to be decontaminated. Suction limits usually restrict their use to wells with water levels less than 25 feet below ground level.

1.8 **Purging** – the process of removing stagnant water from the monitoring well prior to sampling and replacing it with groundwater from the adjacent formation to allow collection of a more representative sample of the actual aquifer condition. (Also refer to definitions for "Micropurging®" and "Three-Volume Purging.")

1.9 **Sampling** – the process of collecting, containerizing, and preserving the groundwater sample after the purging process is complete.

1.10 **Sampling Manifold** – a device that directs the water flow from the well head to the Hydrolab or sampling port.

1.11 **Specific Conductivity** – the ability of a medium (i.e., water) to conduct an electric current, typically measured in µmhos/cm.

Attachment A
Definitions and Acronyms
Page 2 of 3

1.12 **Three-Volume Purging** – the purging method preferred by the USEPA in which three volumes of the content of the well, plus any volume in the pump) are purged. Based on water quality stabilization results, up to five volumes may be pumped if necessary.

1.13 **Turbidimeter/Nephelometer** – an instrument used to measures how much light is scattered by suspended particles in the water. The greater the scattering, the higher the turbidity. Therefore, low NTU values indicate high water clarity, while high NTU values indicate low water clarity.

1.14 **Turbidity** – a unit of measurement quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. The scattering of light increases with a greater suspended load. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU), but may also be measured in Jackson Turbidity Units (JTU).

2.0 ACRONYMS

2.1 **AHA** – Activity Hazard Analysis

2.2 **C** – Centigrade **/Celsius**

2.3 **DI** – deionized

2.4 **DNAPL** – dense non-aqueous phase liquid

2.5 **D.O.** – dissolved oxygen

2.6 **F** – Fahrenheit

2.7 **GEO** – GEO Consultants, LLC

2.8 **GW** – groundwater

2.9 **HASP** – Health and Safety Plan

2.10 **JTU** – Jackson Turbidity Units

2.11 **LNAPL** – light non-aqueous phase liquid

2.12 **mg/L** – milligrams per liter

2.13 **mL** – milliliters

2.14 **MSDS** – Material Safety Data Sheet

2.15 **mV** – millivolts

2.16 **PVC** – polyvinyl chloride

Attachment A
Definitions and Acronyms
Page 3 of 3

2.0 ACRONYMS (Cont'd)

2.17 **NTU** - Nephelometric Turbidity Units

2.18 **ORP** – Oxidation-Reduction Potential

2.19 **OVA** – organic vapor analyzer

2.20 **pH** – hydrogen ion potential

2.21 **PID** – photoionization detector

2.22 **PPE** - Personal Protective Equipment

2.23 **psi** – pounds per qquare inch

2.24 **PV** – purge volume

2.25 **QC** – Quality Control

2.26 **RCRA** – Resource Conservation and Recovery Act

2.27 **RFD** – Request for Disposal

2.28 **SU** – Standard Units

2.29 **SVOC** – semi-volatile organic compounds

2.30 **TEGD** – Technical Enforcement Guidance Document

2.31 **TOC** – total organic carbon

2.32 **TOX** – total organic halogens

2.33 **USEPA** – U.S. Environmental Protection Agency

2.34 **VOA** - volatile organic analysis

2.35 **VOC** – volatile organic compounds

2.36 **µmhos/cm** – micromhos per centimeter

Attachment B

Monitoring Well Data Sheet (for Logbooks)

Page 1 of 2

THIS ATTACHMENT CONTAINS A FORM "CONTROLLED" BY THIS PROCEDURE.

The next page contains a full size copy of the form and may be use directly. It has no headers.

It may be customized by the Project Manager based on client needs.

MONITORING WELL DATA SHEET
FIELD DATA SHEET

Site Name:	Sample Date:	Sample Time:	Sample Number (Primary Sample):
Sampled By:	Signature(s):	Sampling Method:	Sampling Location:
Client:	Contract Number:	Delivery Order:	Chain of Custody Number:
QC Sample Type: ☐ N/A ☐ Field Duplicate ☐ QA Duplicate ☐ Matrix Spike/Duplicate		QC Sample Numbers:	

Solid Sample		Aqueous Sample	
Solid Sample Type:	Sample Collection:	Aqueous Sample Type:	Well Information
☐ Surface Soil	☐ Grab	☐ Surface Water	Well Casing Size:
☐ Subsurface Soil	☐ Composite	☐ Groundwater	Total Well Depth:
☐ Sediment	☐ Multi-increment	☐ Monitoring Well	Static Water Level:
☐ Waste	☐ Other _____	☐ Domestic Well	One Purge Volume:
☐ Other _____		☐ Other _____	Start Purge:
		☐ Seep	End Purge:
Sample Description (classification, color, plasticity, moisture content, consistency)		☐ Sump	Total Purge Time:
		☐ Waste	Total Purge Volume:
		☐ Other _____	Purge Method:

Analysis

☐ Volatiles ☐ Semivolatiles ☐ Ions ☐ RCRA Metals ☐ TAL Metals ☐ Select Metals (list) _____

☐ Pesticides ☐ Herbicides ☐ PCB ☐ Cyanide ☐ Explosives ☐ Other (list): _____

Purge Data

Time (hrs)	Temperature (°C)	Conductance (µS/cm)	D.O. (mg/L)	pH (SU)	ORP (mV)	Turbidity (NTU)

Comments:

Weather Conditions: cloudy rainy sunny snowy	Temperature:	Barometer:

Attachment C
Order of Collection for Groundwater Samples
Page 1 of 1

The preferred collection and containerization order based on volatilization sensitivity for some of the more common groundwater analytes is as follows:

1. VOCs and total organic halogens (TOX);
2. Dissolved gases and total organic carbon (TOC);
3. SVOCs;
4. Metals and cyanide;
5. Major water quality cations and anions;
6. Radionuclides.

In addition to the sensitivity, the relative importance of each parameter should be evaluated on a site-by-site basis to establish sampling order protocol. Therefore, when a low-yielding well is being sampled, it may be necessary to change the order of sampling to ensure that a representative sample is collected for the most important constituents for a particular site.

The above information was obtained from an updated draft version of the *Technical Enforcement Guidance Document* (TEGD), dated November 1992. SW-846, *Test Methods for Evaluating Solid Waste,* Chapter 11, Section 11.2 refers to one preeminent Resource Conservation and Recovery Act (RCRA) document on groundwater monitoring activities, the TEGD, EPA/530-R-93-001, finalized in September 1986, available from the U.S. Environmental Protection Agency (USEPA) Office of Solid Waste.

THIS PAGE INTENTIONALLY LEFT BLANK

GEO CONSULTANTS, LLC

A Geological Engineering and Environmental Services Company

Technical Operating Procedure

WATER LEVEL MEASUREMENTS (WELL)

GEO-TEC-014

Revision 2

Prepared by: A. Michael Bosch

Approved by: _____, 12/9/11
Jeff Douthitt, P.E. - President — Date

Record of Changes

Revision Number	Changes and/or Affected Page(s)	Effective Date
0	NEW	
1	All Pages	05/04/2006
2	All Pages – added sections on automatic data logger and manual measurements	12/09/2011

Next review required no later than: December 9, 2012

TABLE OF CONTENTS

1.0 PURPOSE 3

2.0 SCOPE 3

3.0 PRECAUTIONS AND LIMITATIONS
- 3.1 Environmental, Safety, and Health Precautions 3
- 3.2 Work Environment Limitations 4

4.0 TRAINING PREREQUISITES 4

5.0 OTHER DOCUMENTS NEEDED 4

6.0 WHAT TO DO
- 6.1 Approvals and Notifications 5
- 6.2 Special Tools, Equipment, Parts, and Supplies 5
- 6.3 Pre-Performance Activities 5
- 6.4 Prepare to Take Water Level Measurements 7
- 6.5 Take Measurements with Electronic Water Level Indicator 9
- 6.6 Measure Total Depth of a Well 11
- 6.7 Take Continuous Measurements with Electronic Data Logger 12
- 6.8 Post-Performance Activities 15

7.0 RECORDS
- 7.1 General Requirements 16
- 7.2 Records Generated 16

7.0 SOURCE DOCUMENTS 16

8.0 ATTACHMENTS
- Attachment A – Definitions and Acronyms 17
- Attachment B – Groundwater Level Measurements in Immiscible Fluids 19

PURPOSE

1.1 This procedure describes the methods and procedures for the measurement of water levels in open boreholes, cased wells, and piezometers.

1.2 The primary purposes for static water level measurements may include: 1) determine the direction of groundwater flow, 2) identify areas of recharge and discharge, 3) evaluate the effects of natural and manmade stresses on the groundwater system, 4) define the hydraulic characteristics of aquifers, and/or 5) evaluate stream-aquifer relations.

SCOPE

2.1 This procedure applies to water level measurement activities coordinated by GEO Consultants, LLC (GEO), and its subcontractors and teaming partners, if applicable.

2.2 This procedure applies to water level measurement activities performed for wells on a client's site or for residential wells on private property that a client is obligated to monitor.

2.3 This procedure describes how to measure the total depth of a well and how to take water level measurements in two ways – manually (with an electronic water level indicator) and continuously (recorded with a data logger).

2.4 **Exceptions:** This procedure does **not** cover static well measurements made with older electric sounders (marked at 5-foot intervals), chalked weighted steel surveyor's tape (0.01), airline (0.20/0.25), transducer (0.01-0.10), float (0.20-0.50), popper (0.10), acoustic probe (0.02), ultrasonic (0.02-0.10), radar (0.02), and laser (0.01). Estimated accuracy in feet shown in parentheses. It also does **not** cover measurements in flowing wells.

2.5 No changes or deviations to this procedure are allowed unless approved in advance by the GEO President, the Project Manager, and (in some cases) the client.

PRECAUTIONS AND LIMITATIONS

3.1 Environmental, Safety, and Health Precautions

3.1.1 GEO's policy is to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress that is consistent with established standards.

3.1.2 The minimum personal protection equipment (PPE) for this activity includes safety glasses with side shields and steel-toe boots. Additional PPE may be required by a task-specific Activity Hazard Analysis (AHA) and/or a Health and Safety Plan for the project. PPE requirements may vary for different sampling locations and different measurement techniques.

3.1.3 Additional PPE for work in a radiologically-contaminated zone, if applicable, will be specified in a radiological work permit prepared for work in that zone.

3.1.4 Exercise caution when unlocking or opening a well cap (well may be under pressure, snakes or insects in nearby ground or brush, insect nests under well cap).

3.2 Work Environment Limitations

3.2.1 Extreme weather conditions may limit or exclude the conduct of certain types of fieldwork.

3.2.2 Special conditions may also exist in a particular well that may restrict or change how water level measurements may be taken.

3.2.3 Refer to the project documents for any other work limitations.

TRAINING PREREQUISITES

4.1 Personnel assigned to perform water level measurements shall complete hands-on training with and observation by an experienced field technician for one month prior to being considered to be qualified. If not so qualified, the procedure shall be used "in-hand."

4.2 All GEO personnel who perform or supervise this activity shall complete documented required reading of this procedure and future revisions thereof within 30 days of issuance. New personnel assigned to a groundwater monitoring crew (or other applicable field crew) shall complete documented required reading prior to performing any work in the field.

4.3 All field personnel must have completed documented required reading of project-specific documents that may include work plans, health and safety plan, quality assurance project plan, site-specific sampling and analysis plan, and waste management plan. A copy of each shall be available in the field, or otherwise readily available, before the onset of any field activities. Consult these documents as necessary to obtain specific information regarding equipment and supplies, health and safety, sample collection and identification, sample packaging, and decontamination.

4.4 Field personnel must also have completed documented required reading of the latest version of GEO Corporate document GEO-03-006, *Corporate Health and Safety Program,* to supplement applicable safety practices and requirements not specified in the project-specific work documents.

4.5 Field personnel must have completed documented required reading of the latest version of the procedures included in the OTHER DOCUMENTS NEEDED section of this procedure before beginning any sampling activities.

OTHER DOCUMENTS NEEDED

5.1 GEO Quality Systems procedure GEO-QSP-401, *Control of Documents and Records*

5.2 GEO Technical Operating procedure GEO-TEC-005, *Logbooks*

5.3 GEO Technical Operating procedure GEO-TEC-010, *Equipment Cleaning and Decontamination*

5.4 GEO Technical Operating procedure GEO-TEC-012, *Groundwater Monitoring Sampling*

5.5 KY/EM 268, *Well and Piezometer Reference Marks*

5.6 Electronic Water Level Indicator Equipment – Manufacturer's Operating Instructions

WHAT TO DO **6.1 Approvals and Notifications**

Project Manager

6.1.1 Make appropriate notifications to appropriate client personnel specified in a contract or in other project documentation prior to conducting any water level measurements of wells at a client's site.

6.1.2 Make appropriate notifications to local regulatory personnel, if required (not a common requirement).

GEO Field Personnel

6.1.3 Contact the property owner prior to conducting any activity at a residential well for which the client is responsible to monitor.

WHAT TO DO **6.2 Special Tools, Equipment, Parts, and Supplies**

GEO Field Personnel

6.2.1 Ensure that the following items (if applicable) are available, decontaminated (if applicable), and ready to use prior to initiating field activities:

- site-specific plans and documents (survey information, etc.)
- listing of well information, if available and provided
- personnel protective clothing and PPE identified in project-specific documents
- data sheets and/or field logbook
- indelible black-ink pens and markers
- key(s) for lock(s) on wells
- electronic water level indicator
- oil/water interface probes
- pressure transducer and data logger
- self-contained data logger and pressure/level sensor (e.g., miniTROLL® or equivalent)
- photoionization detector or a flame ionization detector, if required
- surveyor's tape and inert weight
- clamps or cable ties, as appropriate, to secure cable to well casing
- duct tape
- utility knife
- ruler and tape measure
- compass
- decontamination equipment and supplies (including rinse bottles, deionized water, plastic sheeting, and Kimwipes).

6.2.2 Refer also to GEO Technical Operating procedure GEO-TEC-012, *Groundwater Monitoring Sampling,* for other items since water level measurement is usually performed as part of groundwater sampling.

WHAT TO DO **6.3 Pre-Performance Activities**

GEO Field Personnel

6.3.1 Review the work plan and referenced photos, maps, and figures to identify locations for measurements, method(s) to be used, equipment needed, and any special notifications and/or permits needed prior to field entry.

GEO Field Personnel

NOTE: The United States Environmental Protection Agency (USEPA) preference is for all water level measurements at a site to be collected within a 24-hour period. Due to large numbers of wells at some sites and complications that create slowdowns (such as radiological contamination), completing all measurements that quickly may not be practical.

6.3.2 Plan work involving use of an electronic water level indicator for each work day to progress from the least contaminated wells to the most contaminated wells (USEPA preference) <u>or</u> based on the most time-efficient route during that workday <u>or</u> according to a schedule provided by the client.

6.3.3 **IF** construction, sampling, development/redevelopment was experienced for a specific piezometer, well, or open borehole,
<u>THEN</u> allow a minimum of 24 hours before taking any water level measurements to allow for water level stabilization
<u>AND</u> schedule periodic repeat measurements to determine whether a static water level has been achieved.

6.3.4 Allow <u>more than</u> 24 hours for water level recovery in wells completed in tight, low-permeability units before making water level measurements.

6.3.5 Record on data sheets and/or in the field logbook all measurements, field events, and other information that may include, but are not limited to, the following.

- any and all deviations from procedures and site-specific plans and the rationale and approvals for each change
- well identification number, date, time, manual or continuous water level measurements, and other pertinent well-specific information.

6.3.6 Check batteries on the electronic water level indicator to ensure they are fully charged and that the unit is in working order before first going into the field each day **<u>and</u>** record the battery condition in the field logbook.

6.3.7 Verify that calibration records for the electronic water level indicator are current **<u>and</u>** document that fact in the field logbook.

6.3.8 Inspect the cable of the electronic water level indicator for possible damage **<u>and</u>** **do not** use it if it has been damaged (inspect and use a replacement cable).

6.3.9 Check the accuracy of marks on the cable of an electronic water level indicator against a surveyor's tape or other measurement device near the beginning of a work day **<u>and</u>** record the results on a data sheet and/or in the field logbook.

GEO Field Personnel

6.3.10 Ensure that water level measurement instruments and equipment have been decontaminated and are protected from contamination (e.g., wrapped in aluminum foil, sealed in plastic or other storage containers, placed on plastic sheeting in staging area) to ensure they are ready for use during transport to the first location and when not used during field activities.

6.3.11 Don any specified personnel protective clothing, PPE, and other safety equipment.

WHAT TO DO

6.4 Prepare to Take Water Level Measurements

GEO Field Personnel

NOTE: Water level measurements are often taken as part of groundwater sampling activities, but may be performed as a stand-alone activity as required by a client.

6.4.1 Arrive at the first/next location scheduled for water level measurements.

6.4.2 Perform a thorough visual inspection of each well before beginning any sampling activities.

6.4.3 Record the condition of the wellhead, pad, and guard posts **and** describe any abnormal conditions exist (evidence of tampering, vandalism, etc.) in the field logbook.

6.4.4 Record factors that may affect manual or continuous water level measurements (e.g., active recharge due to a precipitation event, saturated zone being stressed due to nearby pumping, drastic atmospheric pressure changes, etc.) in the field logbook.

6.4.5 Contact the Project Manger if any problems are observed **and** record any special instructions by the Project Manager in the field logbook.

6.4.6 Use plastic sheeting to stage equipment and materials around the open borehole, well, or piezometer to protect equipment from cross-contamination.

6.4.7 Protect instruments, tools, and equipment from potential sources of contamination prior to manual or continuous water level measurements.

6.4.8 Set up a temporary decontamination area if required by the work plan.

NOTE: Exercise caution when unlocking or opening a well cap (well may be under pressure, snakes or insects in nearby ground or brush, insect nests under well cap).

6.4.9 Unlock **and** open the well cap or lid while standing upwind from the well during unlocking and opening (possibility of contaminants released into air).

GEO Field Personnel

6.4.10 **IF** required by a project document or a site-specific condition,
THEN monitor the headspace of the well with a photoionization detector or a flame ionization detector to determine presence of volatile organic compounds
AND record results of the check on the data sheet and/or in the field logbook
AND upgrade PPE, if necessary.

6.4.11 Record the condition of the casing and fitting and any problems encountered during unlocking and opening of the well on the data sheet and/or in the logbook.

6.4.12 **IF** cascading water is noticed within a well (condition can cause false readings with some types of water level measurement devices),
THEN record that condition on the data sheet and/or in the field logbook.

6.4.13 Ensure that water level measurement in each well is performed prior to purging, sampling, well depth check, or any other disturbances of the water table.

NOTE #1 The reference mark may be a mark from a permanent marker **or** a "V" notch filed into the inner well casing and located on the north side of the inner casing. Note that the top end cut of a well casing may not be perfectly square.

NOTE #2 The reference marks for any wells located on/near the Paducah Gaseous Diffusion Plant may be found in document KY/EM-268, *Well and Piezometer Reference Marks*, latest version. Other sites may have a similar document that lists the location of a reference mark for each well.

6.4.14 Try to locate a reference mark at top of a well casing as specified in a client's work document for wells at the client's site, if such a document is available.

6.4.15 **IF** no reference mark is present **AND** none is listed in document KY/EM-268 or other client document,
THEN establish a reference by filing a "V" notch on the north side of the well casing with a file or suitable cutting instrument
AND take care that the filings do not fall into the well
AND record the location of the reference mark in the field logbook
AND notify the Project Manager or Designee of the actions taken
AND record the above actions taken on a data sheet and/or in the field logbook.

6.4.16 Use the established reference mark on the north side of the top of the inner well casing for all current and future readings for that well, unless otherwise instructed by the client.

WHAT TO DO **6.5 Take Measurements with Electronic Water Level Indicator**

GEO Field Personnel

NOTE #1 An electronic water level indicator consists of an electric tape that is normally coiled on a hand-cranked reel unit containing batteries and a device which signals when the circuit is closed as soon as the probe contacts water. Electrical methods are preferred over other methods, such as steel tapes.

NOTE #2 The water level measurement may be complicated by situations described in Steps 6.5.1 through 6.5.3.

6.5.1 **IF** water is rapidly dripping or flowing into a well which makes an accurate reading difficult or impossible to obtain,
THEN add a rubber or plastic boot above or around the water level indicator probe
AND ensure that the boot is positioned so that air entrapped by the boot will not prevent the probe from making contact with the water at the water table.

NOTE: An electronic water level indicator may **not** respond to an oily surface causing an error in the level measurement.

6.5.2 **IF** a well has a layer of oil or other separate phase floating on the water,
THEN use an oil-water contact sensor probe to permit detection of the surface of the uppermost fluid in accordance with the manufacturer's instructions
AND the top of the water level below the oil
AND the difference between the two measurements represents the thickness of the oil layer.

6.5.3 **IF** a well contains immiscible contaminants,
THEN use special procedures for the measurement of fluid levels as described in Attachment B, "Groundwater Level Measurements in Immiscible Fluids."

6.5.4 Check the response of the audible or visible alarm by dipping the probe in a container with potable water (or oil level over water) to ensure that the signaling device responds to probe submergence (alarm sounds and/or red light illuminates) **OR** check the alarm using a test button/switch on instruments equipped with this feature.

6.5.5 Slowly lower the electronic water level indicator probe (or oil/water interface probe, if applicable) connected to the cable into the open borehole, well, or piezometer **and** ensure that the probe does not scrape the sides of the well casing or borehole wall while it is being lowered.

6.5.6 Stop lowering the probe as soon as the alarm sounds and/or the red light illuminates.

6.5.7 Pull up slowly on the cable holding the probe until the alarm no longer sounds and/or the red light turns off.

GEO Field Personnel

6.5.8 Very slowly lower the probe again **and** stop at the instant the alarm sounds and/or the light comes on and stays on.

6.5.9 Hold the cable to the side of the casing where reference mark is etched or notched.

6.5.10 Mark the cable with a thumb where it touches the reference mark.

6.5.11 Use a measuring device (ruler or tape measure) to determine the distance from the last marked increment on the cable to the thumb marked point on the cable **or** read the depth directly from the imprinted cable.

NOTE: Independent electronic probe measurements of static water levels using the cable should agree to within ±0.01 feet for depths of less than about 200 feet. At greater depths, independent measurements may not be as accurate. For a depth of about 500 feet, the maximum difference of independent measurement using the same cable should be within ±0.10 feet.

6.5.12 Record on the data sheet and/or in the field logbook the measurement from the electronic probe to the nearest 0.01 feet as the depth to the water level in that well.

6.5.13 Repeat Steps 6.5.5 through 6.5.12 for an additional water level measurement to verify that consistent readings were obtained.

6.5.14 **IF** the two readings agree within 0.02 feet,
THEN average the two readings to obtain the water level measurement to report for that well.

6.5.15 **IF** the two readings did **not** agree within 0.02 feet,
THEN repeat Steps 6.5.5 through 6.5.12 to obtain a third measurement **AND** average the three readings to obtain the water level measurement to report for that well.

NOTE: Rapid groundwater level changes may occur due to any of the following:

- atmospheric pressure changes (e.g., as a front moves through or just before a storm);
- tidal influences;
- changes in river stage, impoundment levels, or flow in unlined ditches;
- pumping of nearby wells; and/or
- precipitation.

6.5.16 **IF** the three readings varied considerably,
THEN contact the Project Manager immediately for further instruction **AND** record those instructions on the data sheet or in the field logbook.

GEO Field Personnel

6.5.17 **IF** historic water level measurements from that same well or piezometer are available,
THEN compare the new readings with the old to preclude measurement error (usually about the same) while recognizing any changed water level conditions.

6.5.18 Remove the electronic water level indicator (or oil-water interface probe) from the well by recoiling the cable onto the reel **and** ensure that the probe does not scrape the sides of the well casing or borehole wall while it is being raised.

6.5.19 Decontaminate the probe and the cable, using deionized water unless otherwise instructed, to prevent cross contamination when it is used at the next well. Follow protocols in GEO-TEC-010, *Equipment Cleaning and Decontamination.*

6.5.20 **IF** the initial measurements were made using an oil-water interface probe,
THEN GO TO Steps 6.5.4 through 6.5.19 to repeat the water level measurements using the regular electronic water level indicator.

6.5.21 **IF** the total depth of the well is also required to be measured,
THEN complete the water level measurements first
AND GO TO Subsection 6.6 to measure the total depth of the well
AND GO TO Step 6.5.22 prior to moving on to the next well or stopping work for the day.

6.5.22 Close **and** lock the well cap (if applicable).

6.5.23 Restore the area around the open borehole, well, or piezometer by removing all materials and equipment used to measure water level.

6.5.24 Verify that batteries on the electronic water level indicator are still adequately charged before moving on to the next well location **and** record the condition in the field logbook.

6.5.25 GO TO Step 6.5.1 above to start water level measurement activities at the next well **or** GO TO Section 6.8 to perform end of day post-performance activities.

WHAT TO DO

6.6 Measure Total Depth of a Well

GEO Field Personnel

6.6.1 Complete any measurements to determine the depth to the water level before sounding a well for the total depth of a well **and** use measurements of the depth to the water level from Subsection 6.5.

6.6.2 Decontaminate the measuring tape and weight **or** the cable and probe according to GEO-TEC-010, *Equipment Cleaning and Decontamination,* prior to making these measurements.

NOTE: DO NOT exceed the manufacturer's limit on submersion depth to avoid damage to an electronic probe. Debris at the bottom of a well may also damage an electronic probe.

GEO Field Personnel

6.6.3 Lower a decontaminated measuring tape with an inert (e.g., stainless steel) weight attached **or** lower an electronic water level indicator probe to the bottom of a well.

6.6.4 Measure the distance to the bottom from the reference point on the inner casing **and** record the total depth to the bottom of the well on a data sheet and/or in the field logbook.

6.6.5 Subtract the depth of the water level measured in Subsection 6.5 from the total distance to the bottom of the well from Step 6.6.4 to determine the total depth of water in the well **and** record that reading on a data sheet and/or in the field logbook.

6.6.6 Remove the electronic water level indicator or the weighted measuring tape from the well by slowly recoiling the cable onto the reel or raising the tape from the well **and** ensure that the probe or tape does **not** scrape the sides of the well casing or borehole wall while it is being raised.

6.6.7 Decontaminate the measuring tape and weight **or** the cable and probe according to GEO-TEC-010, *Equipment Cleaning and Decontamination,* after the measurements to prevent possible cross-contamination of other wells.

6.6.8 GO TO Step 6.5.22.

WHAT TO DO

6.7 Take Continuous Measurements with Electronic Data Logger

GEO Field Personnel

6.7.1 Review the manufacturer's operating manuals and installation instructions to ensure proper operation of the electronic data logger and pressure transducer **or** the self-contained data logger and pressure/level sensor.

NOTE: Pressure transducers are manufactured to measure pressure over a specific range of submergence. Measurements will not be accurate outside the manufacturer's specified range and may damage the transducer.

6.7.2 DO NOT use a pressure transducer outside its specified range.

6.7.3 Verify that a pressure transducer or data logger has been precalibrated by the manufacturer (most should be).

6.7.4 Consult the manufacturer's specifications concerning maintenance and chemical compatibility of the pressure transducers to be used to ensure compatibility with expected contaminants and their concentrations.

GEO Field Personnel

6.7.5 Follow manufacturer's instructions to determine the appropriate depth to secure the unit based upon the transducer, pressure/level sensor rating, and expected fluctuations in water levels.

6.7.6 Arrive at the first/next location scheduled for water level measurements using a cable and transducer **or** self-contained data logger and pressure/level sensor.

6.7.7 Perform a thorough visual inspection of each well before beginning any sampling activities.

6.7.8 Record the condition of the wellhead, pad, and guardposts (if present) **and** record their condition, especially abnormal conditions (evidence of tampering, vandalism, etc.), on the data sheet or in the field logbook.

6.7.9 Record factors that may affect manual or continuous water level measurements (e.g., active recharge due to a precipitation event, saturated zone being stressed due to nearby pumping, drastic atmospheric pressure changes, etc.) in the field logbook.

6.7.10 Contact the Project Manger if any problems are observed upon arrival and inspections of the well to receive the automatic data logger **and** include any special instructions by the Project Manager in the logbook.

6.7.11 Use plastic sheeting to stage equipment and materials around the open borehole, well, or piezometer to protect equipment from cross-contamination.

6.7.12 Protect instruments, tools, and equipment from potential sources of contamination prior to manual or continuous water level measurements.

6.7.13 Set up a temporary decontamination area if required by the work plan.

NOTE: Exercise caution when unlocking or opening a well cap (well may be under pressure, snakes or insects in nearby ground or brush, insect nests under well cap).

6.7.14 Unlock **and** open the well cap or lid while standing upwind from the well during unlocking and opening (possibility of contaminants released into air).

6.7.15 **IF** required by a project document or a site-specific condition,
THEN monitor the headspace of the well with a photoionization detector or a flame ionization detector to determine presence of volatile organic compounds
AND record results of the check on the data sheet and/or in the field logbook
AND upgrade PPE, if necessary.

6.7.16 Note the condition of the casing and fitting and any problems encountered during unlocking and opening of the well in the logbook **and** record the conditions or problems on the data sheet or in the field logbook.

GEO Field Personnel

6.7.17 **IF** cascading water is noticed within a borehole (condition can cause false readings with some types of water level measurement devices), **THEN** record that condition in the field logbook.

6.7.18 Take initial water level measurements for the well to be equipped for continuous measurements using the procedure in Subsection 6.5 and record the results on the data sheet or in the field logbook.

6.7.19 Record the transducer or self-contained data logger and pressure/level sensor serial number in the field logbook.

6.7.20 Check to ensure that the batteries in a data logger are new or fully charged prior to installation at a well.

6.7.21 Check the response of the audible or visible alarm by dipping the probe in potable water to ensure that the signaling device responds to probe submergence (alarm sounds and/or red light illuminates) **or** check the alarm using a test button/switch on instruments equipped with this feature.

6.7.22 Inspect the cable for any damage **and** do not use it if it has been damaged (inspect and use a replacement cable).

6.7.23 Decontaminate the cable and transducer **or** self-contained data logger and pressure/level sensor prior to use according to requirements in GEO Technical Operating procedure GEO-TEC-010, *Equipment Cleaning and Decontamination,* to prevent possible cross-contamination.

6.7.24 Cover sharp edges of the well casing with duct tape to protect the cables.

CAUTION: Hitting the water surface too fast as the transducer is lowered into the well may damage the transducer.

6.7.25 Slowly lower the probe connected to the cable into the open borehole, well, or piezometer **and** ensure that the probe does not scrape the sides of the well casing or borehole wall.

6.7.26 Stop lowering the probe as soon as the alarm sounds and/or the red light illuminates and resume lowering until the depth required by the work plan is reached.

6.7.27 Secure the unit at the determined depth in accordance with the manufacturer's instructions **and** use duct tape to affix the cable to the side of the well casing.

6.7.28 **IF** a separate transducer and data logger are used, **THEN** secure the cable in place by attaching a service grip (or Kellum's grip) to the well casing using a clamp, locking clip, and installation ring or cable tie to prevent slippage of the cable into the well and attach the cable to the logger before commencing with the test.

GEO Field Personnel

6.7.29 Use the procedure(s) in the manufacturer's operating manual to set the transducer depth, reference elevation, scale factor, and test number.

6.7.30 Record the cable position relative to the top of the well casing in the field logbook.

6.7.31 Contact the Project Manger if any problems are observed with the installation and setup **and** include any special instructions by the Project Manager in the logbook.

6.7.32 Turn on the data logger to begin recording data.

6.7.33 Correlate the data logger initial results with the manual water level measurement.

6.7.34 Begin the continuous water level measuring task by referring to the task-specific work plan for direction on data needs and follow the manufacturer's instructions to set up instruments for collecting that data.

6.7.35 Close **and** lock the well cap **and** move on to the next well.

6.7.36 Periodically download **and** save data from the data logger in accordance with manufacturer's instructions **and** change out the batteries to ensure continued operation.

6.7.37 **IF** removing a data logger from a well,
THEN unsecure the unit from its fixed position
AND slowly remove the probe from the well
AND close **and** lock the well cap.

6.7.38 Decontaminate the probe and cable to prevent cross contamination when it is used at the next well.

WHAT TO DO

6.8 Post-Performance Activities

GEO Field Personnel

6.8.1 Decontaminate the electronic water level indicator (probe and cable) thoroughly between each water level event (i.e., between each well) according to GEO Technical Operating procedure GEO-TEC-010, *Equipment Cleaning and Decontamination,* to prevent possible cross-contamination.

GEO Field Personnel

NOTE: Monitoring for radioactivity includes radiation screening performed by continuous field screening and by periodic wipe sampling. It includes equipment leaving the client's site for maintenance or repairs.

6.8.2 Request radiological support personnel to monitor for radioactivity all equipment used in a contamination control zone before allowing it to be released from that zone.

6.8.3 Dispose of any investigation-derived waste in accordance with instructions in the work plan.

RECORDS

7.1 General Requirements

Generate **and** maintain records in accordance with requirements of GEO Quality Systems procedure GEO-QSP-401, *Control of Documents and Records*.

7.2 Records Generated

7.2.1 Data sheets

7.2.2 Field logbooks

7.2.3 Electronic data from data loggers

SOURCE DOCUMENTS

8.1 U.S. Environmental Protection Agency, *A Compendium of Superfund Field Operations Methods,* EPA/540/P-87/001, 1987

8.2 U.S. Environmental Protection Agency, Region IV, *Environmental Compliance Branch, Standard Operating Procedures and Quality Assurance Manual,* 1996

8.3 U.S. Environmental Protection Agency, Environmental Response Team, Standard Operating Procedure #2043, Revision 0.0, *Manual Water Level Measurements,* 2000

Attachment A
Definitions and Acronyms
Page 1 of 2

1.0 DEFINITIONS

1.1 Aquifer – A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

1.2. Discharge – Depletion of water from the zone of saturation.

1.3 Electronic Data Logger – An electronic device that can be programmed to receive electrical impulses which are stored as data. Pressure transducers are designed to be used with automatic data logging instruments and send a current to the data logger. The current is proportional to the pressure and can be converted to meaningful units by the data logger.

1.4 Electronic Water Level Indicator – A graduated plastic tape, onto which a water-sensitive electrode is connected to electronically signal the presence of water (circuit closure).

1.5 Immiscible Fluids – Two or more fluid substances that will not mix, and, therefore, will exist together in a layered form. The fluid with the highest density will exist as the bottom layer. The fluid with the lowest density will exist as the top layer. Any other fluid layers will be distributed relative to their respective densities.

1.6 Piezometer – A small-diameter observation well used to measure the hydraulic head of groundwater in an aquifer

1.7 Pressure Transducer – An electric probe connected to a wire cable that is lowered into the water column of a well to measure pressure. The pressure measured is the total pressure (both the hydrostatic pressure of the fluid column above the transducer and the atmospheric pressure at the fluid surface. Changes in head are proportional to changes in the height of the water column or water level.

1.8 Protective Casing – A steel cylinder or square protective sleeve surrounding the well casing that extends approximately 3 to 5 feet into the ground and usually extends above the ground surface approximately 2 to 3 feet. The protective casing protects the well casing.

1.9 Recharge – The addition of water to the zone of saturation.

1.10 Reference Mark – An easily located and clearly defined mark at the top of a well or borehole from which all water level measurements from that particular well are made. The reference mark should be as permanent as possible to provide consistency in measurements. Paducah EMEF document KY/EM-268 lists descriptions of the reference marks used and indicate which reference marks are to be used for each well or piezometer.

1.11 Static Water Level – The level of water in a well that is not influenced by well discharge or recharge.

1.12 Water Level Indicator – A portable device for measuring the depth from a fixed point at the ground surface or above the ground surface to the groundwater inside a well, borehole, or other underground opening.

Attachment A
Definitions and Acronyms
Page 2 of 2

1.13 **Well Casing** – A stainless steel or polyvinyl chloride (PVC) cylinder that extends into a borehole and is connected to the well screen or sealed at the bedrock surface in open-hole wells. The well casing is normally enclosed by an outer steel protective casing from 3 to 5 feet below land surface and 2 to 3 feet above land surface.

2.0 ACRONYMS

2.1 **AHA** – Activity Hazard Analysis

2.2 **GEO** – GEO Consultants, LLC

2.3 **PPE** – Personal Protective Equipment

2.4 **USEPA** – U.S. Environmental Protection Agency

Attachment B
Groundwater Level Measurements in Immiscible Fluids
Page 1 of 1

For wells containing immiscible contaminants, the sampler will use special procedures for the measurement of fluid levels. The procedure will depend upon whether layers are light immiscibles that form lenses floating on the top of the water table, or dense immiscibles that sink through the aquifer and form lenses over less permeable layers.

In the case of light immiscibles, measurements of immiscible fluid and water levels cannot be accomplished by using normal techniques. For example, an electric tape often will not respond to nonconducting immiscible fluids and the presence of the immiscible fluid will go undetected.

Techniques have been specially developed to measure fluid levels in wells containing immiscible fluids, particularly petroleum products. One method uses a special paste or gel which, when applied to the end of the steel tape and submerged in the well, will show the top of the oil as a wet line and the top of the water as a distinct color change. Another method is similar to the electric tape method. In this method an interface probe is used that can detect the presence of conducting and nonconducting fluids. Thus, if a well is contaminated with low density, nonconducting immiscible fluids such as gasoline, the probe will first detect the surface of the gasoline, but it will not register electrical conduction. However, when the probe is lowered deeper to contact water, it will detect electrical conduction. Normally, a variation in an audible signal indicates the difference between phases.

Both of these methods have disadvantages. These methods are less effective with heavier and less refined petroleum products because the product tends to stick to the tape or probe, giving a greater product thickness measurement than it should. Paste cannot be used when sampling for constituents present in the paste.

Another way of obtaining thicknesses of immiscible fluids is to use a "thief". A "thief" is a clear acrylic bailer that when lowered and retrieved from the well, can be used to obtain a fluid thickness. This method can be used when the presence of an immiscible fluid is suspected. The water level should be obtained before using the "thief". Care should be taken not to lower the "thief" too deeply into the water column as this may displace the immiscible fluid.

It is important to note that water levels obtained in this situation are not suitable without further interpretation for determining hydraulic gradients. To use those data for determining hydraulic gradients, the differences in density between the light immiscible and water have to be accounted for.

Measuring fluid levels in wells screened in lenses of dense immiscible resting on a low permeability formation is somewhat easier, provided the immiscible fluid is nonconducting. Simply using an electric tape can identify the top of the dense layer. As the electric probe passes from groundwater into the immiscible phase, the detection unit will deactivate because the fluid will no longer conduct electricity. A better method would be to use an interface probe as described above. The variation in the audible signal associated with the detection of differing phase liquids will also allow the user to obtain a groundwater depth and dense immiscible thickness measurement.

THIS PAGE INTENTIONALLY LEFT BLANK

GEO CONSULTANTS, LLC

A Geological Engineering and Environmental Services Company

Technical Operating Procedure

SUBSURFACE SOIL SAMPLING

GEO-TEC-015
Revision 2

Prepared by: Mike Bosch

Approved by: _____ / 1/23/12
Jeff Douthitt, P.E. – President Date

Effective Date: January 23, 2012

Record of Changes

Revision No.	Affected Page(s)	Effective date	Approval	Approval Date
0	All			
1	All	05/01/10	J. Boulton	
2	Title Page, Approval/Review Dates	01/23/12	J. Douthitt	1/23/12

Next review required no later than: January 23, 2013

TABLE OF CONTENTS

1.0 PURPOSE 3

2.0 SCOPE 3

3.0 PRECAUTIONS AND LIMITATIONS 3

4.0 TRAINING 3

5.0 OTHER DOCUMENTS NEEDED 3

6.0 APPROVALS, NOTIFICATIONS, AND LIMITING CONDITIONS 4

7.0 PRE-PERFORMANCE ACTIVITIES 4

8.0 SPECIAL TOOLS, EQUIPMENT, PARTS, AND SUPPLIES 4

9.0 WHAT TO DO
- 9.1 Collection of Subsurface Soil Samples – General Steps 5
- 9.2 Manual (Hand) Augering 6
- 9.3 Split-Spoon Sampling 7
- 9.4 Shelby Tube Sampling 10
- 9.5 Continuous Soil Sampler 12
- 9.6 Geoprobe™ or Drive Rod Sampling Tubes 13
- 9.7 Soil Subsampling with Microcorer for VOC Analysis 16

10.0 POST-PERFORMANCE ACTIVITIES 17

11.0 RECORDS 17
- 11.1 General Requirements 17
- 11.2 Quality Records 17
- 11.3 Non-Quality Records 17

12.0 SOURCE DOCUMENTS 17

13.0 ATTACHMENTS
- Attachment A - Definitions and Acronyms 18
- Attachment B - Summary of Sample Collection Methods 20

PURPOSE

1.1 This procedure describes the methods and equipment necessary for collecting subsurface soil samples from the unconsolidated zone. This procedure is intended to provide compliance with the requirements of the United States Environmental Protection Agency (EPA). Exceptions may be needed to comply with applicable State and local regulations.

SCOPE

2.1 This procedure applies to all personnel who perform work activities for GEO Consultants, LLC (GEO) and its subcontractors unless it is superseded by a customer's or partner's procedure that has been defined for use to support a specific contract or subcontract.

2.2 This procedure covers techniques that include the use of hand augers, Shelby tubes, Rotosonic samplers, and split-spoon samplers (including continuous auger flight split-spoon samplers, direct-push, and microcorer).

PRECAUTIONS AND LIMITATIONS

3.1 Environmental, Safety, and Health Precautions

3.1.1 GEO's policy is to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress that is consistent with the established standards of the Occupational Safety and Health Administration (OSHA) and other governing bodies.

3.1.2 Field personnel will be required to wear the protective clothing and safety equipment specified in the site-specific health and safety plan.

3.2 Work Environment Limitations

3.2.1 The immediate supervisor may determine whether work may or may not be performed due to safety hazards caused by adverse weather conditions or other work environment limitations.

TRAINING

4.1 Field personnel must be familiar with project-specific documents which include health and safety plan (H&S), quality assurance project plan (QAPP), site-specific sampling and analysis plan (SAP), and work plan (WP). A copy of each shall be available in the field office before the onset of any field activities. These documents should be consulted as necessary to obtain specific information regarding equipment and supplies, health and safety, sample collection and identification, sample packaging, decontamination, etc.

4.2 Field personnel must be knowledgeable of the latest version of the procedures included in the OTHER DOCUMENTS NEEDED section of this procedure before beginning any subsurface soil collection activities.

4.3 Collection of subsurface soil samples shall be limited to those individuals who are fully trained and knowledgeable of field procedures applicable to the collection of subsurface soil samples. Proper training and field surveillance will be completed to ensure that the requirements of this procedure are met.

OTHER DOCUMENTS NEEDED

5.1 GEO-TEC-004, *Quality Assured Data*

5.2 GEO-TEC-003, *Logbooks*

5.3 GEO-TEC-006, *Sample Chain of Custody*

5.4 GEO-TEC-009, *Collection of Field Quality Control Samples*

5.5 GEO-TEC-010, *Equipment Cleaning and Decontamination*

5.6 American Society for Testing and Materials (ASTM), ASTM D 1586-08, *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*

APPROVALS, NOTIFICATIONS, AND LIMITING CONDITIONS

Project Manager

6.1 Make appropriate notifications to the customer and/or other entity that governs the site locations where sampling activity will be conducted.

6.2 Arrange for the issuance of any required excavation or penetration permit(s) due to underground lines, utilities, etc.

6.3 Provisions for lithologic logging are not described or called for in this procedure. Should the project require lithologic logging, instructions for this activity should be described in a separate document.

PRE-PERFORMANCE ACTIVITIES

NOTE 1: Follow the site-specific HSP for guidelines for appropriate sample area setup.

NOTE 2: A brief summary of subsurface soil collection methods is included in Attachment B, "Summary of Sample Collection Methods."

7.1 Obtain the designated sample containers from the GEO or laboratory.

7.2 Don the appropriate personal protective clothing as dictated by the site-specific HSP.

7.3 Locate pre-surveyed and pre-staked sampling locations **and** determine appropriate sampling requirements.

7.4 Check the sampling locations against the excavation permit, if required.

7.5 Place clean plastic sheeting on a flat level surface near the sampling area, if possible.

7.6 Place decontaminated equipment to be used on the plastic.

7.7 Place the sample cooler(s) near the sampling area, if possible.

7.8 Cover all equipment and supplies with clean plastic sheeting when not in use.

7.9 Set up the decontamination line required by the site-specific SAP. The decontamination line should be staged on plastic sheeting.

SPECIAL TOOLS, EQUIPMENT, PARTS, AND SUPPLIES

8.1 Ensure that the following items are available for use and are in good condition (if necessary):

- Site-specific plans and procedures
- Field logbook
- Indelible black-ink pens and markers
- Measuring tape
- Deionized (DI) water

- Labels **and** appropriate formal documentation for sample collection including chain-of-custody forms, custody seals, sample labels, and sampling tools and equipment
- Pre-preserved sample containers
- Insulated cooler(s)
- Ice bags or "Blue Ice"
- Plastic zip-type bags
- Personal protective clothing and equipment
- Plastic sheeting
- Decontamination equipment and supplies
- Health and safety monitoring equipment (calibrated)
- Two-way radio and/or cellular telephone
- Containers for investigation-derived wastes as specified in the site-specific WMP
- Microcorer
- Analytical balance (calibrated)
- Material Data Safety Sheets (MSDS) for materials used in work site.

8.2 **IF** the manual (hand) augering method will be used,
THEN also ensure that the following items are available prior to initiating subsurface soil sampling activities:
- Hand auger: flighted-type, bucket-type, or tube-type auger as required by the site-specific project SAP
- Extension rods, as needed
- Tools – wrench(es) and pliers.

8.3 **IF** either a split-spoon or a Shelby tube will be used,
THEN also ensure that the following items are available prior to initiating subsurface soil sampling activities:
- Drilling equipment capable of providing a borehole to the required depth and enough drilling rods to reach the required depth.
- Drilling equipment capable of "driving" or "pushing" the split spoon or Shelby tube as required by the site-specific SAP.
- Sufficient numbers of split-spoon or Shelby-tube samplers so that at least one is always decontaminated and available for sampling.
- Teflon or acetate liners, as appropriate.

8.4 **IF** either a Geoprobe™ or drive rod sampling tube will be used,
THEN also ensure that the following items are available prior to initiating subsurface soil sampling activities:
- Drilling equipment and supplies used to hydraulically drive a probe into the ground to collect undisturbed soil samples.

WHAT TO DO

9.1 Collection of Subsurface Soil Samples – General Steps

Sampling Technician

NOTE: Follow these general steps when collecting any subsurface soil samples using any of the methods described in Sections 9.2 and 9.7.

9.1.1 **IF** sampling locations defined in the site-specific SAP cannot be sampled due to a physical obstruction,
THEN contact the GEO Project Manager, on-site engineer, or geologist.

Sampling Technician

9.1.2 **WHENEVER** approval is received from the project manager,

THEN move the sampling location
AND document the change in the field logbook
AND notify the GEO and customer project data coordinator.

9.1.3 Document the sampling events by recording the information in the designated field logbook as defined in GEO-TEC-005, *Logbooks.*

9.1.4 Clear away any vegetation or debris from the sampling location surface so that sod may be replaced.

9.1.5 Place plastic sheeting over boring location and place a plywood box around the auger, if possible, so that soil cuttings have minimal contact with the ground surface prior to containerization.

9.1.6 Place all decontaminated equipment on plastic sheeting.

9.1.7 Carefully remove the top ½ to ¾ in of exposed soil, sediment, or sludge before sample collection unless the site-specific SAP indicates otherwise.

9.1.8 First collect sample portions or aliquots for volatile analyses and/or for any other samples that would be degraded by aeration.

9.1.9 Follow applicable sampling requirements related to data quality as described in GEO-TEC-004, *Quality Assured Data.*

9.1.10 Complete chain of custody forms as described GEO-TEC-006, *Sample Chain of Custody.*

9.1.11 If applicable, collect quality control samples as defined in GEO-TEC-009, *Collection of Field Quality Control Samples*

9.2 Manual (Hand) Augering

Sampling Technician

NOTE: Follow these general steps when collecting hand-augered soil samples:

9.2.1 Auger to the depth required for sampling to obtain soil sample.

9.2.2 Remove excess cuttings from the borehole.

9.2.3 Place soil cuttings on plastic sheeting **or** containerize as required by the site-specific WMP or SAP.

9.2.4 Remove the auger from the borehole **and** complete field screening for any Volatile Organic Compounds (VOC) and radionuclides, if required, as specified in the site-specific HSP.

9.2.5 Place the soil into a decontaminated stainless steel bowl or plastic bag **and** homogenize using a decontaminated stainless steel spatula or other appropriate instrument.

9.2.6 Place the homogenized soil sample into the appropriately labeled sample container(s) using a decontaminated stainless steel spatula or other appropriate instrument.

9.2.7 Seal container(s) **and** affix custody seal(s) on each cooler.

Sampling Technician

9.2.8 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel to remove soil and/or moisture from the exterior of the container.

9.2.9 Place the sample container(s) into the sample cooler.

NOTE: Liners of different materials may be used.

9.2.10 **IF** a Teflon liner was used,
THEN remove the liner and sample from the auger bucket
AND immediately cap the ends of the tube using Teflon end-caps **OR** place plastic end caps over Teflon tape to separate the sample from the cup
AND seal the caps with waterproof tape
AND label the sealed liners as required in the site-specific SAP
AND mark the top and bottom of the sample on the outside of the liner, or top of the end caps.

9.2.11 Wipe the liner (if necessary) with a clean Kimwipe or paper towel to remove soil and moisture from the exterior of the liner.

9.2.12 Record the sample identification number, the depth from which the sample was taken, and the analysis requested in both the field logbook and on the appropriate forms.

9.2.13 Proceed with further sampling, as required.

9.2.14 **WHENEVER** sampling is complete,
THEN dispose of cuttings and plastic sheeting as specified in the site-specific WMP.

9.2.15 Decontaminate all equipment following GEO-TEC-010, *Equipment Cleaning and Decontamination*, as applicable.

9.2.16 Complete field logbook entries and boring logs before leaving the sampling site.

9.2.17 Properly package all samples for delivery to the laboratory **and** complete all necessary sample documentation as specified in GEO-TEC-006, *Sample Chain of Custody*.

9.3 Split-Spoon Sampling

Sampling Technician

NOTE: The following general steps must be followed when collecting split-spoon samples using a hollow stem auger (HSA). Other drilling methods may be used to reach desired sampling depths depending on subsurface conditions and requirements of the site-specific SAP.

9.3.1 Attach the lead HSA with cutting head to the drilling rig and insert drilling rod(s) with center plug.

9.3.2 Begin drilling **and** proceed to the first designated sample depth, adding auger flight(s) as necessary.

9.3.3 Rotate augers (without advancing) to remove cutting from the bottom of the borehole.

9.3.4 Remove the plug from the drilling rods.

Sampling Technician

9.3.5 Attach a decontaminated split spoon to the drilling rod(s).

9.3.6 **IF** sampling for VOC's,
THEN insert Teflon or acetate liners into the barrel of the split spoon
AND insert the rod(s) and split spoon through the HSA.

9.3.7 **IF** ASTM Method D-1586-84 is to be followed,
THEN attach the drive-weight assembly to the rod
AND lightly tap the rods to seat the drive shoe into the undisturbed soil.

9.3.8 **IF** ASTM Method D-1586-84 is **NOT** specified in the site-specific SAP **AND** conditions warrant,
THEN push the split spoon using the drill rig hydraulics or an automatic drive hammer.

9.3.9 Mark the drilling rod in 6-inch increments from the top of the auger flight(s), if required.

9.3.10 Drive the split spoon with the hammer using a full 30-inch drop as specified in ASTM Method D-1586-84, if required.

9.3.11 **IF** ASTM Method D-1586-84 is **NOT** used,
THEN advance to Step 15, if required.

9.3.12 Record the number of blows required to drive the spoon through each 6-inch increment, if required.

9.3.13 Cease driving when the full length of the spoon has been advanced or upon refusal, if required. ("Refusal" occurs when 50 blows are used for a single 6-inch increment or a total of 100 blows are applied.)

9.3.14 Pull the spoon free to loosen the sampler **and** pull out the rod and spoon with the winch.

9.3.15 Unscrew the split spoon assembly from the drilling rod(s) **and** place it on the plastic-covered sampling table.

9.3.16 Remove the drive shoe and head assembly.

9.3.17 With the drive shoe and head assembly removed, open (split) the spoon, being careful **not** to disturb the sample.

9.3.18 Complete field screening for VOC's and radionuclides as specified in the site-specific HSP.

9.3.19 Remove the acetate sleeve with soil from the sample tube.

9.3.20 Mark the sleeve with the appropriate depths.

9.3.21 **IF** VOC samples are **NOT** to be collected,
THEN advance to Step 9.3.30.

9.3.22 **IF** non-preserved VOC samples are to be collected,

THEN advance to step 9.3.30

Sampling Technician

9.3.23 Cut the sleeve into one-foot sections using a safety blade **and** immediately use a Photo Ionization Detector (PID) to take measurements at the exposed surface.

9.3.24 Cut one-foot sleeve sections lengthwise.

9.3.25 Collect the soil plug with a microcorer (approx. 5 grams of soil).

9.3.26 Eject the plug into an appropriately labeled 40 milliliter (mL) Volatile Organic Analysis (VOA) vial, which had been prepared with 5 mL hexane or methanol and 5 mL of DI water.

9.3.27 Repeat Steps 9.3.25 and 9.3.26 for multiple vials as required.

9.3.28 Seal the container(s) **and** affix custody seal(s).

9.3.29 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel **and** place sample vial(s) immediately into a cooler maintained at 4°C.

9.3.30 Place the remaining soil into a decontaminated stainless steel bowl or plastic bag **and** homogenize using a decontaminated stainless steel spatula or other appropriate instrument.

9.3.31 Place the homogenized soil sample into the appropriately labeled container(s) using a decontaminated stainless steel spatula or other suitable instrument.

9.3.32 Seal the container(s) **and** affix custody seal(s).

9.3.33 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel to remove excess moisture and/or soil from the exterior of the sample container.

9.3.34 **IF** the sample is a non-preserved VOC sample,
THEN place sample vial(s) immediately into a cooler maintained at 4°C.

9.3.35 Record the sample identification number, the depth, and the analyses to be performed on the sample in both the field logbook and on the appropriate forms.

9.3.36 Continue to advance the borehole to the next sampling point.

9.3.37 Collect additional samples as outlined above.

9.3.38 **WHENEVER** sampling is complete,
THEN dispose of the soil cuttings and plastic sheeting as specified in the site-specific WMP or SAP.

9.3.39 Decontaminate all equipment following GEO-TEC-010, *Equipment Cleaning and Decontamination*, as applicable.

9.3.40 Complete field logbook entries and boring logs before leaving the site.

9.3.41 Properly package all samples for delivery to the laboratory **and** complete all necessary sample documentation as specified in GEO-TEC-006, *Sample Chain of*

Custody.

9.4 Shelby Tube Sampling

Sampling Technician

NOTE: Follow these general steps when collecting Shelby tube samples using HSA. Other drilling methods may be used to reach desired sampling depths depending on subsurface conditions and requirements of the site-specific SAP.

9.4.1 Attach the lead HSA with cutting head to the drilling rig **and** insert drilling rod(s) with plug.

9.4.2 Begin drilling **and** proceed to the first designated sample depth, adding auger flight(s) as necessary.

9.4.3 Rotate augers (without advancing) to remove cutting from the bottom of the borehole.

9.4.4 Remove the plug from the drilling rods.

9.4.5 Attach a decontaminated Shelby tube to the drilling rod(s).

9.4.6 Lower the Shelby tube down to the top of the sampling interval **and** make sure to leave at least 30 inches of drilling rod above the lowest point of the hydraulic piston's extension.

9.4.7 Use the drilling rig's hydraulic drive to push the Shelby tube into undisturbed soil with a steady force.

9.4.8 **WHENEVER** the Shelby tube has been advanced to its full length or to refusal,
THEN back off the hydraulic pressure
AND attach a hoisting plug to the upper drilling rod
AND twist to break off the sample
AND pull the apparatus out of the HSA with the rig winch.

9.4.9 Detach the Shelby tube from the drilling rod(s) **and** remove the head assembly.

9.4.10 Complete field screening for VOC's and radionuclides as specified in the site-specific HSP.

9.4.11 **IF** the intent of the Shelby-tube sampling is for geotechnical purposes **AND** an undisturbed sample is required,
THEN cap tube ends **and** seal them with wax to prevent moisture loss
AND mark the top and bottom ends of the tube
AND transport the tube to the laboratory in a vertical position
AND advance to Step 9.4.29.

9.4.12 Use the hydraulic extruder to extrude the acetate sleeve from the Shelby tube onto a clean piece of plastic sheeting.

9.4.13 Mark the sleeve with the appropriate depths.

9.4.14 **IF** VOC samples are **NOT** to be collected,
THEN proceed to Step 9.4.23

9.4.15 **IF** non-preserved VOC samples are to be collected,
THEN proceed to Step 9.4.23.

Sampling Technician

9.4.16 Cut the sleeve into one-foot sections using a safety blade **and** immediately use a PID to take measurements at the exposed surface.

9.4.17 Cut the one-foot sleeve sections lengthwise.

9.4.18 Collect the soil plug with a microcorer (approx. 5 grams of soil).

9.4.19 Eject the plug into an appropriately labeled 40 mL VOA vial, which had been prepared with 5 mL hexane or methanol and 5 mL of DI water.

9.4.20 Repeat Steps 9.4.18 and 9.4.19 for multiple vials.

9.4.21 Seal the container(s) **and** affix custody seal(s).

9.4.22 Wipe the exterior of each sample container clean (if necessary) with a Kimwipe or paper towel **and** place sample vials immediately into a cooler maintained at 4°C.

9.4.23 Place the remaining soil into a decontaminated stainless steel bowl or plastic bag **and** homogenize using a decontaminated stainless steel spatula or other appropriate instrument.

9.4.24 Place the homogenized soil sample into the appropriately labeled container(s) using a decontaminated stainless steel spatula or other appropriate instrument.

9.4.25 Seal the container(s) **and** affix custody seal(s).

9.4.26 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel to remove excess moisture and/or soil from the exterior of the sample container.

9.4.27 **IF** the sample is a non-preserved VOC sample,
THEN place sample vial(s) immediately into a cooler maintained at 4°C.

9.4.28 Record the sample identification number, the depth, and the analyses to be performed on the sample in both the field logbook and on the appropriate forms.

9.4.29 Continue to advance the borehole to the next sampling point.

9.4.30 Collect additional samples as outlined above.

9.4.31 **WHENEVER** sampling is complete,
THEN dispose of the soil cuttings and plastic sheeting as specified in the site-specific WMP or SAP.

9.4.32 Decontaminate all equipment according to GEO-TEC-010, *Equipment Cleaning and Decontamination*, as applicable.

9.4.33 Complete field logbook entries and boring logs before leaving the site.

9.4.34 Properly package all samples for delivery to the laboratory **and** complete all necessary sample documentation as specified in GEO-TEC-006, *Sample Chain of Custody.*

Sampling Technician

9.5 Continuous Soil Sampler

NOTE: Follow these general steps when collecting continuous split-spoon samples with HSA.

9.5.1 Insert the 5-foot sampler into the HSA flight (typical HSA flights are 5 feet in length).

9.5.2 Attach the HSA and sampler to the drill stem.

9.5.3 Begin normal HSA drilling.

9.5.4 **WHENEVER** the first 5-foot interval is complete,
THEN detach the drill rig from the HSA
AND withdraw the sampler.

9.5.5 Unscrew the sampler from the drilling rod(s) **and** place it on the sample table.

9.5.6 Remove the drive shoe and head assembly.

9.5.7 Remove the acetate sleeve with soil from the sample tube.

9.5.8 Mark the sleeve with the appropriate depths.

9.5.9 Open (split) the spoon, being careful **not** to disturb the sample.

9.5.10 Complete field screening for VOC's and radionuclides as specified in the site-specific HSP **and** mark the sleeve with the appropriate depths.

9.5.11 **IF** VOC samples are **NOT** to be collected,
THEN advance to Step 9.5.20.

9.5.12 **IF** non-preserved VOC samples are to be collected,
THEN advance to Step 9.5.20.

9.5.13 Cut the sleeve into one-foot sections using a safety blade **and** immediately use a PID to take measurements at the exposed surface.

9.5.14 Cut the one-foot sleeve sections lengthwise.

9.5.15 Collect the soil plug with a microcorer (approx. 5 grams of soil).

9.5.16 Eject the plug into an appropriately labeled 40 mL VOA vial, which had been prepared with 5 mL hexane or methanol and 5 mL of DI water.

9.5.17 Repeat Steps 9.5.15 and 9.5.16 for multiple vials.

9.5.18 Seal the container(s) **and** affix custody seal(s).

9.5.19 Wipe the exterior of each sample container (if necessary) clean with a Kimwipe or paper towel **and** place sample vial(s) immediately into a cooler maintained at 4°C.

9.5.20 Place the remaining soil into a decontaminated stainless steel bowl **and** homogenize

using a decontaminated stainless steel spatula or other appropriate instrument.

Sampling Technician

9.5.21 Place the soil sample into the appropriately labeled container(s) using decontaminated stainless steel spatula or other suitable instrument.

9.5.22 Seal the container(s) **and** affix custody seal(s).

9.5.23 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel to remove excess moisture and/or soil from the exterior of the sample container.

9.5.24 **IF** the sample is a non-preserved VOC sample,
THEN place sample vial(s) immediately into a cooler maintained at 4°C.

9.5.25 Record the sample identification number, the depth, and the analyses to be performed on the sample in both the field logbook and on the appropriate forms.

9.5.26 Continue sampling as outlined above until the final borehole depth is reached.

9.5.27 **WHENEVER** sampling is complete,
THEN dispose of the soil cuttings and plastic sheeting as specified in the site-specific WMP or SAP.

9.5.28 Decontaminate all equipment following GEO-TEC-010, *Equipment Cleaning and Decontamination*, as applicable.

9.5.29 Complete field logbook entries and boring logs before leaving the site.

9.5.30 Properly package all samples for delivery to the laboratory **and** complete all necessary sample documentation as specified in GEO-TEC-006, *Sample Chain of Custody.*

9.6 Geoprobe™ or Drive Sampling Tubes

Drill Rig Operator/
Sampling Technician

9.6.1 Prepare the Geoprobe™ for sampling.

9.6.2 Lift the latch **and** insert the hammer anvil into the Geoprobe™.

9.6.3 Push the latch back in order to hold in the hammer anvil.

NOTE: In certain conditions, such as hard soils, a drive point may be used instead of a soil sample tube as described below.

9.6.4 Assemble the soil sample tube in the following way:

9.6.4.1 Insert the acetate liner into the soil sample tube

9.6.4.2 Assemble the soil sample tube with the acetate liner and

9.6.4.3 Thread the shoe onto the soil sample tube
.

9.6.5 Prepare the rods for sampling in the following way:

9.6.5.1 Thread a section of probe rod onto the sample tube **and** install the drive cap.

9.6.5.2 Position the sampling rod assembly below the hammer anvil.

Drill Rig Operator/ Sampling Technician

9.6.5.3 Lower the drive rod and sub until the hammer anvil makes contact with the drive cap.

9.6.5.4 Push the sampling rod assembly into the ground **and** increase the hydraulic pressure and/or the hydraulic hammer as needed.

9.6.5.5 Raise the drive rod and sub **and** connect a second Geoprobe™ rod.

9.6.5.6 Continue with this procedure until the desired depth is reached.

9.6.6 Extract the piston stop pin in the following way:

9.6.6.1 Slide the drill rig mast forward to allow more working room, if possible.

9.6.6.2 Remove the drive cap.

9.6.6.3 Using the necessary sections of threaded extension rods; remove the sampler piston stop pin by rotating the extension rods until the pin is free.

9.6.7 Collect the soil sample **and** remove it from the ground in the following way:

9.6.7.1 Slide the drill rig mast back over the probe rods.

9.6.7.2 Replace the drive cap **and** advance the Geoprobe™ rods the length of the sampler less 3 inches (7.6 cm) to compensate for the length of the sampler adapter and the piston point.

9.6.7.3 Raise the drive rod **and** remove the hammer anvil.

9.6.7.4 Thread the probe rod puller cap onto the probe rod.

9.6.7.5 Lower the drive rod so that it is sitting directly on top of the rod puller cap.

9.6.7.6 Latch the drive rod to the puller cap.

9.6.7.7 Stack wooden blocks under the derrick feet **or** lower the "outriggers" on the Geoprobe™ rig, if needed.

9.6.7.8 Slowly raise the drive rod **and** pull the probe rods from the ground.

9.6.7.9 Unthread each probe rod **and** lay each to the side to avoid tripping hazard.

9.6.7.10 Install the probe rod puller cap.

9.6.7.11 Repeat the ten steps above until the sample tube has been retrieved to the surface.

9.6.8 Collect the sample in the following way:

9.6.8.1 Remove the sample tube from the probe rods.

9.6.8.2 Remove the piston rod, point, and sample tube adapter from the sample tube.

Drill Rig Operator/ Sampling Technician

9.6.8.3 Extract the sample from the sample tube using a ¾ inch (1.0 centimeter) diameter steel rod or wooden dowel and the drive rod from the Geoprobe™ rig. (Other methods for extruding the sample may be used.)

Sampling Technician

9.6.9 Complete field screening for VOC's and radionuclides as specified in site-specific HSP.

9.6.10 **IF** VOC samples are **NOT** to be collected,
THEN advance to Step 9.6.17.

9.6.11 **IF** non-preserved VOC samples are to be collected,
THEN advance to Step 9.6.17.

9.6.12 Collect the soil plug with a microcorer (approx. 5 grams of soil).

9.6.13 Eject the plug into an appropriately labeled 40 mL VOA vial, which had been prepared with 5 mL hexane or methanol and 5 mL of DI water.

9.6.14 Repeat Steps 9.6.12 and 9.6.13 for multiple vials.

9.6.15 Seal the container(s) **and** affix custody seal(s).

9.6.16 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel **and** place sample vial(s) immediately into a cooler maintained at 4°C.

9.6.17 Place the remaining soil sample into the appropriately labeled container(s) using a decontaminated stainless steel spatula or other suitable instrument.

9.6.18 Seal the container(s) **and** affix custody seal(s).

9.6.19 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel to remove excess moisture and/or soil from the exterior of the sample container.

9.6.20 **IF** the sample is a non-preserved VOC sample,
THEN place sample vial(s) immediately into a cooler maintained at 4°C.

9.6.20 Record the sample identification number, the depth, and the analyses to be performed on the sample in both the field logbook and on the appropriate forms.

9.6.21 Continue sampling as outlined above until the final borehole depth is reached.

9.6.22 **WHENEVER** sampling is complete,
THEN dispose of the soil cuttings and plastic sheeting as specified in the site-specific WMP or SAP.

9.6.23 Decontaminate all equipment following GEO-TEC-010, *Equipment Cleaning and Decontamination*, as applicable.

9.6.24 Complete field logbook entries and boring logs before leaving the site.

9.6.25 Properly package all samples for delivery to the laboratory **and** complete all necessary sample documentation as specified in GEO-TEC-006, *Sample Chain of*

Custody.

9.7 Sub-Sampling with Microcorer for VOC Analysis

Sampling Technician

9.7.1 Clean **and** decontaminate all equipment and materials that will be used during sampling according to GEO-TEC-010, *Equipment Cleaning and Decontamination.*

9.7.2 Determine an appropriate sampling point for VOC's as directed by the site-specific SAP or the Project Manager.

9.7.3 **IF** non-preserved VOC samples are to be collected,
THEN advance to Step 9.7.7

9.7.4 Introduce 5 mL of hexane or methanol and 5 mL of DI water using a pipette into a precleaned 40 mL glass vial, depending upon what is called for in the site-specific SAP.

9.7.5 Cap **and** weigh the vial.

9.7.6 Record the weight on the vial label and/or chain of custody form as directed by the site-specific SAP or the Project Manager.

9.7.7 Set the microcorer for the desired sample size in the following way:

NOTE: Each line inscribed on the barrel indicates approximately 1 gram, depending upon the soil type to be sampled.

9.7.7.1 Loosen the set screw.

9.7.7.2 Slide the stop to the desired line.

9.7.7.3 Tighten the screw.

9.7.8 Insert the microcorer into the soil to be sampled, ensuring that soil fills the barrel to the stop.

9.7.9 Extrude the soil from the microcorer into the appropriately labeled 40 mL VOA vial or non-preserved vial (if non-preserved VOC samples are collected).

9.7.10 **IF** the sample is a non-preserved VOC sample,
THEN weigh vial and soil only.

9.7.11 **IF** the sample is a non-preserved VOC sample,
THEN weigh the vial, including hexane or methanol, DI water, and soil.

9.7.12 Record the weight on the vial label and/or chain of custody form.

9.7.13 Wipe the exterior of each sample container (if necessary) with a Kimwipe or paper towel to remove excess moisture and/or soil from the exterior of the sample container.

9.7.14 **IF** the sample is a non-preserved VOC sample,
THEN place sample vial(s) immediately into a cooler maintained a 4°C.

9.7.15 Decontaminate the microcorer according to GEO-TEC-010, *Equipment Cleaning and*

Decontamination.

POST-PERFORMANCE ACTIVITIES

10.1 Handle **and** secure logbooks and field forms according to GEO-TEC-005, *Logbooks* and GEO-TEC-003, *Records Management,* or the other project-specific plans.

10.2 Dispose of excess sample media, personnel protective equipment, plastic, and other waste materials as specified by the site-specific WMP, Statement of Work, or other applicable documents.

RECORDS

11.1 General Requirements

Records generated as a result of this procedure shall be processed and maintained in accordance with requirements in GEO-TEC-003, *Records Management.*

11.2 Quality Records

11.2.1 Field Logbook

11.2.2 Boring logs

11.2.3 Chain-of-Custody form

11.3 Non-Quality Records

None

SOURCE DOCUMENTS

12.1 Environmental Protection Agency, *A Compendium of Superfund Field Operations Methods,* EPA/540/P-87/001, OSWER Directive 9355.0-14, December 1987

12.2 U. S. Environmental Protection Agency, *Field Branches Quality System and Technical Procedures*

12.3 *Hazardous Waste Remedial Actions Program, Standard Operating Procedures for Site Characterization,* DOE/HWP-100, July 1990

12.4 U. S. Department of Energy, *Environmental Survey Manual,* DOE/EH-00053, October 1987

12.5 American Society for Testing and Materials (ASTM) Standard Method D 1587-08, *Standard Practice for Thin Walled Tube Sampling of Soils for Geotechnical Purposes.*

Attachment A
Definitions and Acronyms
Page 1 of 2

1.0 Definitions

1.1 Extension Rods – Rods that fit inside the probe rods, the ends of which tread into piston stop pins, allowing the pin to be removed at the proper sample depth.

1.2 Geoprobe™ – A commonly used brand of a direct push technology system for hydraulically driving rods and various sampling devices into the subsurface.

1.3 Geoprobe™ Adapter Assembly – A device that adapts the drive rod to the Geoprobe™ system.

1.4 Grab Sample – A discrete portion or aliquot taken from a specific location at a given point in time.

1.5 Hammer Anvil – A device that fits into the Geoprobe™ adapter assembly and is used for pushing and hammering rods into the ground.

1.6 Hand Auger – A stainless steel cylinder (bucket) approximately 3 to 4 inches in diameter and 1 ft in length. Open at both ends, and with the bottom edge designed to twist into the soil and cut out a cylinder. The bucket collects the soil sample. The auger has a T-shaped handle (for hand operations), which is attached to the top of the bucket by an extendable stainless steel rod.

1.7 Latch – A device that attaches to the adapter assembly to pull the Geoprobe™ rod out of the ground.

1.8 Microcorer – A small hand-held sampler used to collect a soil sample that will fit inside a 40 mL glass vial.

1.9 Piston Rod and Point – A point and attached rod that slides into the soil sample tube. When held in place by the piston stop in, the point and rod slide up into the sampling tube allowing soil to enter the tube.

1.10 Piston Stop Pin – A pin that threads (reverse) into the sample tube adapter and holds the piston rod and point in place.

1.11 Sample Tube Auger – An adapter from soil sample tube to probe rods

1.12 Shelby Tube – A cylindrical sampling device, generally made of stainless steel or brass, which is pushed into the subsurface soil. Once the tube is retrieved, the sample may be removed by a rig-mounted extruder or capped and sealed for extrusion in the laboratory before analysis.

1.13 Split Spoon – A cylindrical sampling device of varying diameters and lengths, generally made of stainless steel. The spoon is hinged lengthwise, which allows the sample to be retrieved by opening ("splitting") the spoon. The most common split-spoon samplers have a 2 inch to 5 inch outer diameter and a length of 2 feet or 5 feet.

1.14 Subsurface Soil – The material that exists deeper than approximately 1 foot (30 centimeters) from the surface, but above bedrock or any other consolidated material.

1.15 Unconsolidated Zone – The layer of material above bedrock that exists in a relatively loose (non-cemented) state.

Attachment A
Definitions and Acronyms
Page 2 of 2

2.0 Acronyms

2.1 **ASTM** – American Society for Testing and Materials

2.2 **DI** – Deionized

2.3 **GEO** – GEO Consultants, LLC

2.4 **HSP** – Health and Safety Plan

2.5 **HSA** – Hollow Stem Auger

2.6 **MSDA** – Material Safety Data Sheet

2.7 **mL** – Milliliters

2.8 **OSHA** – Occupational Safety and Health Administration

2.9 **PID** – Photo Ionization Detector

2.10 **SAP** – Sampling and Analysis Plan

2.11 **SPT** – Standard Penetration Test

2.12 **QAPP** – Quality Assurance Program Plan

2.13 **USEPA** – United States Environmental Protection Agency

2.14 **VOA** – Volatile Organic Analysis

2.15 **VOC** – Volatile Organic Compound

2.16 **WMP** – Waste Management Plan

Attachment B
Summary of Sample Collection Methods

A variety of sampling devices are available for subsurface soil sampling including bucket augers, split-barrel samplers, Shelby-tube samplers and solid-barrel samplers. Each of these sampling devices comes in a variety of diameters and lengths. Typically, the site geologic conditions, drilling methods, and sample needs determine which sampling method is best for a given project. All of the listed sampling devices may be used to obtain physical, chemical, or radiological data. All sampling equipment used to collect environmental samples for chemical or radiological testing must be constructed of stainless steel. Teflon liners may also be required for insertion into the sampling device. The most commonly used subsurface soil sample collection methods are described below.

Hand Auger

The hand auger consists of a stainless steel cylinder or bucket, approximately 3 to 4 inches in diameter and 1 foot in length, open at both ends, with the bottom edge designed to twist into the soil and cut out a soil core. The auger has a T-shaped handle for manual operation attached to the top of the bucket by an extendable stainless steel rod. Additional sections or flights can be attached to the auger to extend the length, as necessary.

Hand augers are designed to collect surface or shallow subsurface soil samples. The use of hand augers is applicable to a variety of soil conditions including sands, clays, and silts. The use of hand augers in soils having substantial quantities of rock or gravel is limited. Hand auger buckets are available tin diameters ranging from 1.75 by 12 inches to 4 by 12 inches. There are several different styles of hand augers that are suitable for coring in different soil types. Two of these styles are illustrated in Figure 1 (see page 3of 5 in this atachment).

Hand augers have some advantages over other subsurface sampling devices. Hand augering does not require expensive drilling equipment to advance a borehole to the desired sampling depth, and hand augers are relatively inexpensive. For sampling areas with limited access (including sites with trees, buildings, and subsurface utilities), hand augering may be the only viable option.

There are several disadvantages to hand augering. The maximum sampling depth is limited, regardless of subsurface conditions. Typically 20 ft below ground surface is the maximum obtainable with a hand auger. Hand augering also provides a soil sample that can be very disturbed, increasing the potential of VOC loss. Hand augering is NOT to be used for the collection of VOC samples, although a hand auger may be used to advance the hole. A slide hammer or other similar device can be used to drive the sampling rod into the ground for the collection of a soil sample.

Split-Barrel Sample Spoons

The split-barrel sample spoon or "split-spoon" consists of a carbon or stainless steel cylindrical barrel and a hardened steel drive shoe, and ball check valve head which thread on to either end of the barrel. The barrel is split longitudinally. The ball check valve head is threaded for attachment to the drilling rods. Split-spoon samplers come in a variety of diameters and lengths. Diameters range from 2 in to 4.5 inches in outer diameter, and in lengths from 18 to 60 inches. The 2-foot long, 2-inch diameter split spoon samplers are the most commonly used, but all sizes have advantages depending on sample needs. A split spoon is illustrated in Figure 2 (see page 4 of 5 in this attachment).

Split spoons can be used in a variety of subsurface soil sample acquisitions. They can be used in sands, clays, silts, and gravels. They are also useful for obtaining samples in semi consolidated deposits and from very soft rocks where traditional rock coring methods with water tend to wash away the sample.

The most commonly used method for obtaining soil samples using a split-spoon is the Standard Penetration Test (SPT). Originally conceived for use in geotechnical engineering, the SPT has recently been used in conjunction with subsurface environmental investigations. The method requires that the split spoon be driven using a 140 $\pm$ 2 pounds hammer falling 30 inches. The blow counts are recorded for each 6-inch advancement of the split spoon. This information is used to determine general density and compactness of the media being sampled.

Split spoons can also be pushed. This method of sample acquisition is generally confined to use in clay, silt, and fine sand deposits. There is an advantage to pushing split spoons, when possible, because sampling time can be shortened. Some advantages of subsurface soil sampling using split spoons include:

- Increased sampling depths
- Dependent on sampling media, relatively undisturbed sample can be obtained
- Several different sizes of split spoons are available for use depending on sampling requirements
- Teflon liners can be inserted in the split spoon barrel to minimize VOC loss
- Split spoons are very durable

Some disadvantages of subsurface soil sampling using split spoons include:

- The method can be expensive because drilling equipment is needed to advance boreholes to required sampling depth, and sampling time is increased requiring more professional hours
- Use of drilling equipment limits sampling activities to areas with easy access

Shelby Thin-Walled Tube Samplers (Shelby Tubes)

The Shelby tube consists of a thin-walled solid cylinder that is threaded to a sampler head containing a check valve. The sampler head is then connected to the drilling rods. The Shelby tube can be made of brass, carbon steel, or stainless steel. Like split spoons, Shelby tubes come in a variety of diameters and lengths, the most common being 3-inch diameter, 2 feet long. A Shelby tube is illustrated in Figure 3 (see page 5 of 5 in this attachment).

Shelby tubes are most often used for obtaining "undisturbed" soil samples for in-situ permeability testing or other physical soil testing. Under the right circumstances, Shelby tubes can be used as a general subsurface soil sampler. Unlike split spoons, Shelby tubes are generally pushed to minimize disturbance to the sample.

Some advantages of subsurface soil sampling using Shelby tubes include:

- Increased sample depths
- "Undisturbed" soil samples may be obtained
- Different sizes are available for use depending on sampling requirements
- Teflon liners can be inserted in the Shelby tube to minimize VOC loss.

Some disadvantages of subsurface soil sampling using Shelby tubes include:

- Shelby tube use is limited to fine-grained and cohesive deposits (clay and silt)
- Shelby tubes are **not** very durable and are typically used only once
- Shelby tubes can be expensive because drilling equipment is needed to advance boreholes to the required sampling depth
- Use of drilling equipment limits sampling activities to areas with easy access.

Daily Safety Tailgate Meeting Form

Job Name: _____ Number: _____ Date: _____

Start Time: _____ Completed: _____ Site Location: _____

SAFETY ISSUES

Tasks (this shift) _____

Protective Clothing/Equipment _____

Chemical Hazards _____

Physical Hazards _____

Control Methods _____

Special Equipment/Techniques _____

Hazard Communication Overview _____

Nearest Phone _____

Nearest Fire Extinguisher _____

Name/Address _____

(incidents, actions taken, etc.) _____

ATTENDEES

Print Name	Sign Name

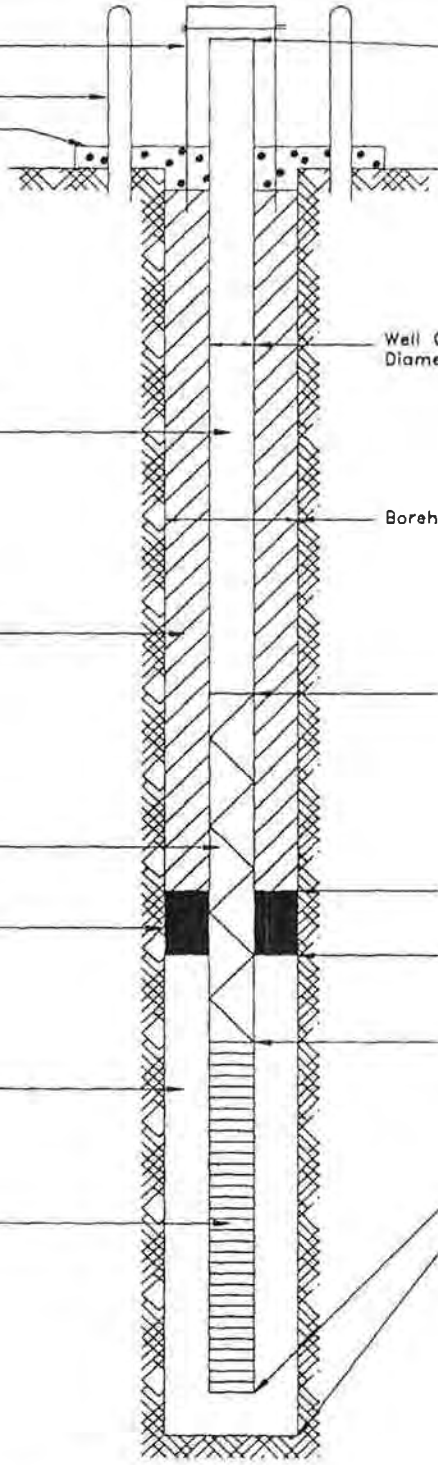
Meeting Conducted by: _____

APPENDIX D

MONITORING WELL CONSTRUCTION DIAGRAMS

THIS PAGE INTENTIONALLY LEFT BLANK

DRAWING NUMBER	301317-A16
	10-1-91
	LAS
CHECKED BY / APPROVED BY	
DRAWN BY	Soren Johnson 10/01/91



	Depth (ft)	Elevation (ft)
Top of Riser	2.27	915.09
Ground Surface	0	912.82
Well Casing Diameter 2" ID		
Borehole Diameter 6.25"		
Top of Stainless Steel Riser	30.20	
Top of Bentonite Seal	46.00	
Top of Sand	48.00	
Top of Screen	50.20	
Bottom of Screen	60.20	852.62
Bottom of Borehole	63.00	849.82

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

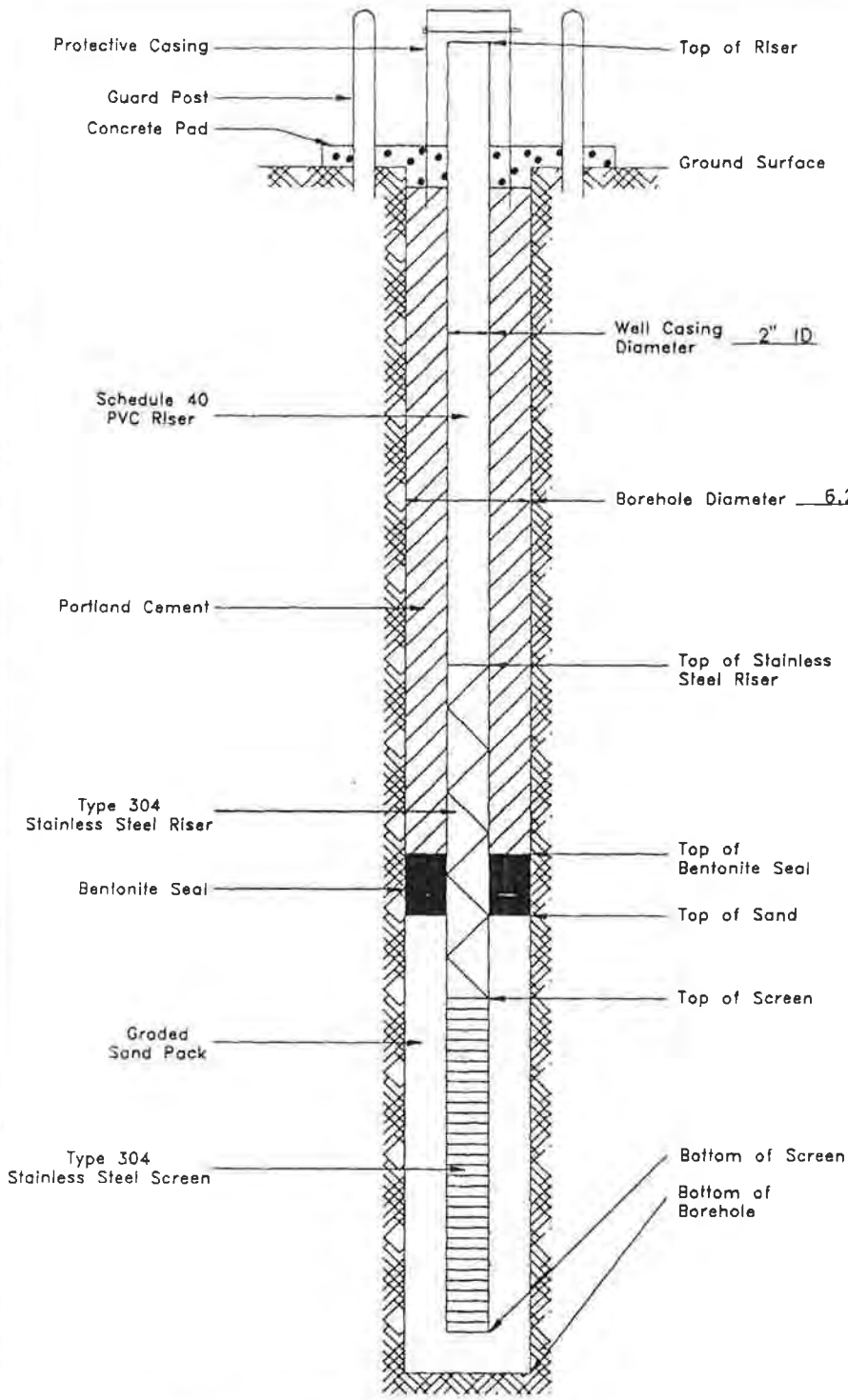
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-B1-MW05
Well No. : MW05

Eng./Geo.: EEM Date: 09/09/90
Start Date: 09/09/90 End Date: 09/09/90

Centralizers : 50.2 ft and 25.2 ft
(Depth below sfc)

IT ... Creating a Safer Tomorrow

DRAWN BY	Soeren Johnson 10/01/91	CHECKED BY / APPROVED BY	LAS 10-1-91	DRAWING NUMBER 301317-A17



	Depth (ft)	Elevation (ft)
Top of Riser	2.35	908.96
Ground Surface	0	906.61
Top of Stainless Steel Riser	35.20	
Top of Bentonite Seal	41.00	
Top of Sand	43.00	
Top of Screen	45.20	
Bottom of Screen	55.20	851.41
Bottom of Borehole	58.00	848.61

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-TPAD-MW06
Well No. : MW06

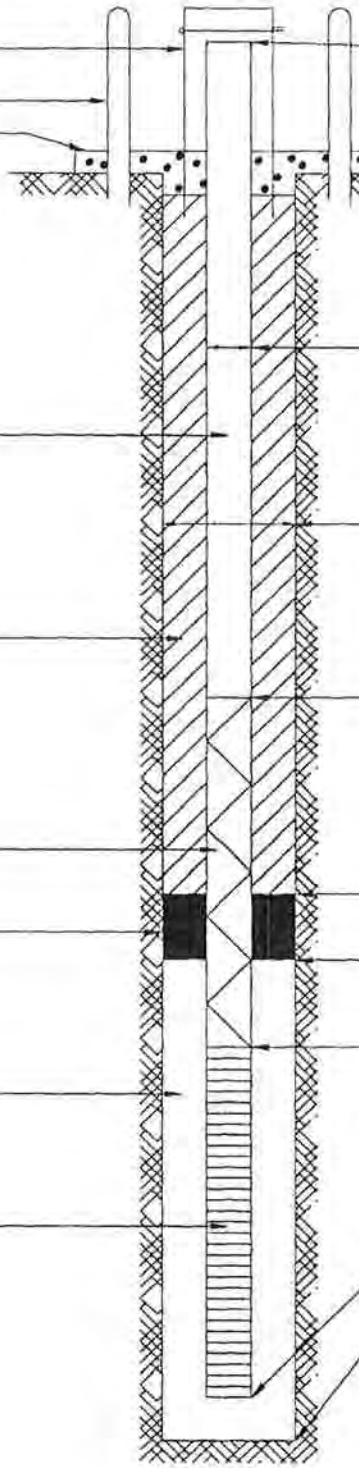
Eng./Geo.: EEM Date: 09/10/90
Start Date: 09/10/90 End Date: 09/10/90

Centralizers : 45.2 ft and 20.2 ft
(Depth below sfc)

IT

... Creating a Safer Tomorrow

DRAWN BY	Soeren Johnson	CHECKED BY	LAS	DRAWING NUMBER	301317-A18
	10/01/91	APPROVED BY	10-1-91		



	Depth (ft)	Elevation (ft)
Top of Riser	2.20	906.83
Ground Surface	0	904.63
Well Casing Diameter 2" ID		
Borehole Diameter 6.25"		
Top of Stainless Steel Riser	35.00	
Top of Bentonite Seal	41.00	
Top of Sand	43.00	
Top of Screen	45.00	
Bottom of Screen	55.00	849.63
Bottom of Borehole	58.00	846.63

Monitoring Well Construction Log

prepared for

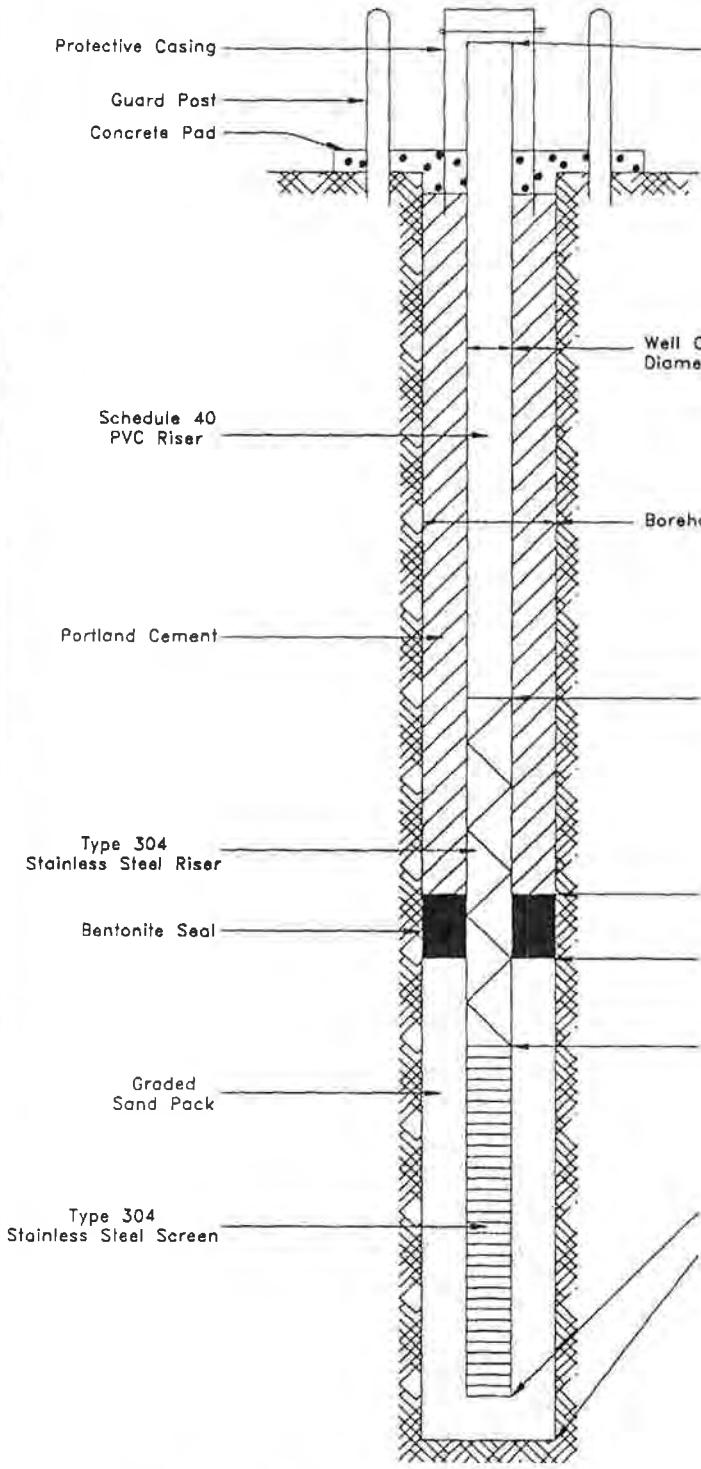
Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

Project Name: BOMARC Eng./Geo.: EEM Date: 09/11/90
Project No. : 301317
Boring No. : BOM-C4-MW07 Start Date: 09/11/90 End Date: 09/11/90
Well No. : MW07

Centralizers : 45 ft and 20 ft
(Depth below sfc)

IT ... Creating a Safer Tomorrow

DRAWN BY	Soeren Johnson	10/01/91	CHECKED BY	LAS	10-1-91	DRAWING NUMBER	301317-A19
			APPROVED BY				



	Depth (ft)	Elevation (ft)
Top of Riser	2.20	905.59
Ground Surface	0	903.39
Top of Stainless Steel Riser	24.60	
Top of Bentonite Seal	58.00	
Top of Sand	62.50	
Top of Screen	64.60	
Bottom of Screen	74.60	828.79
Bottom of Borehole	75.00	828.39

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

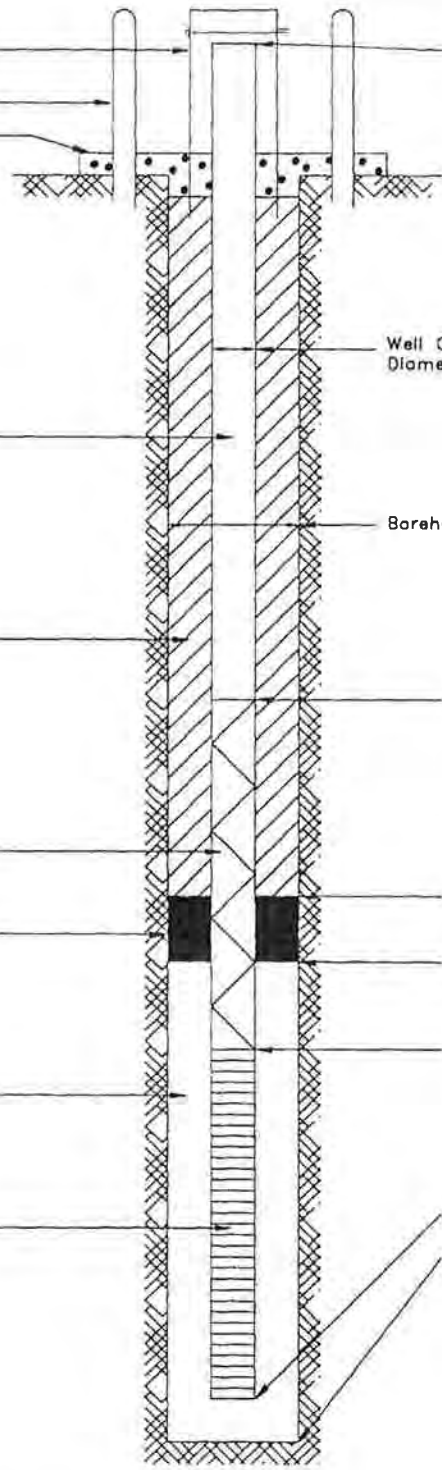
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-RG3-MW08
Well No. : MW08

Eng./Geo.: EEM Date: 09/22/90
Start Date: 09/12/90 End Date: 09/22/90

Centralizers : 64.6 ft, 34.6 ft and 19.6 ft
(Depth below sfc)

IT ... Creating a Safer Tomorrow

DRAWING NUMBER	301317-A20
	10-1-91
	LAS
CHECKED BY	
APPROVED BY	
Soeren Johnson	10/01/91
DRAWN BY	



	Depth (ft)	Elevation (ft)
Top of Riser	2.40	903.15
Ground Surface	0	900.75
Well Casing Diameter 2" ID		
Borehole Diameter 6.25"		
Top of Stainless Steel Riser	26.00	
Top of Bentonite Seal	32.00	
Top of Sand	34.00	
Top of Screen	36.00	
Bottom of Screen	46.00	854.75
Bottom of Borehole	48.00	852.75

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

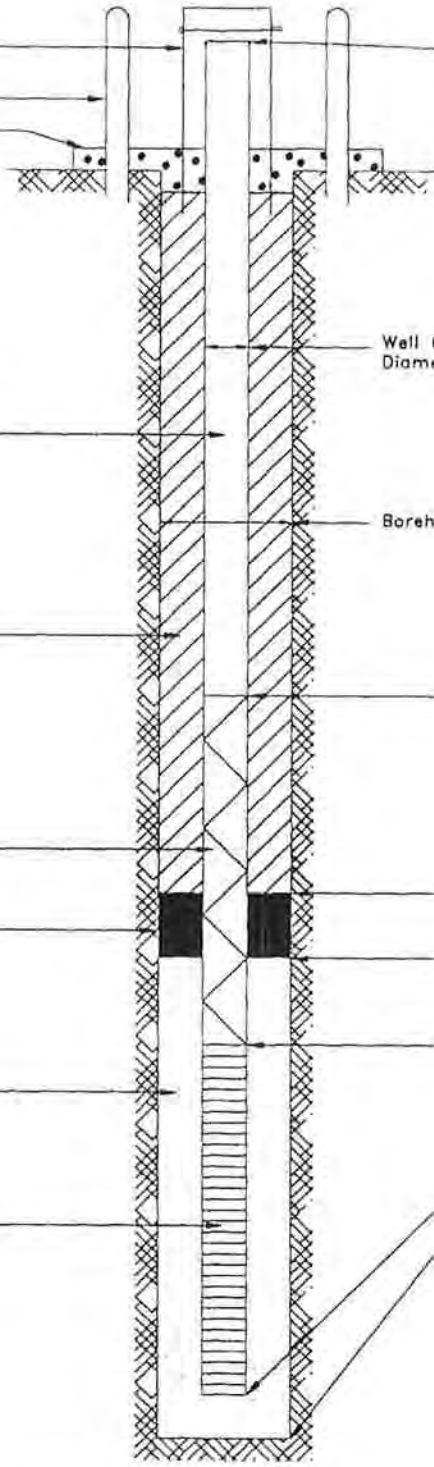
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-NER-MW09
Well No. : MW09

Eng./Geo.: EEM Date: 09/18/90
Start Date: 09/18/90 End Date: 09/18/90

Centralizers : 36 ft and 21 ft
(Depth below sfc)

IT ... Creating a Safer Tomorrow

DRAWN BY	Soeren Johnson 10/01/91	CHECKED BY	LAS 10-1-91	DRAWING NUMBER	301317-A21
		APPROVED BY			



	Depth (ft)	Elevation (ft)
Protective Casing / Top of Riser	2.20	903.87
Ground Surface	0	901.67
Well Casing Diameter 2" ID		
Schedule 40 PVC Riser		
Borehole Diameter 6.25"		
Portland Cement		
Top of Stainless Steel Riser	25.00	
Type 304 Stainless Steel Riser		
Top of Bentonite Seal	31.00	
Bentonite Seal		
Top of Sand	33.00	
Top of Screen	35.00	
Graded Sand Pack		
Type 304 Stainless Steel Screen		
Bottom of Screen	45.00	858.87
Bottom of Borehole	48.00	855.87

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

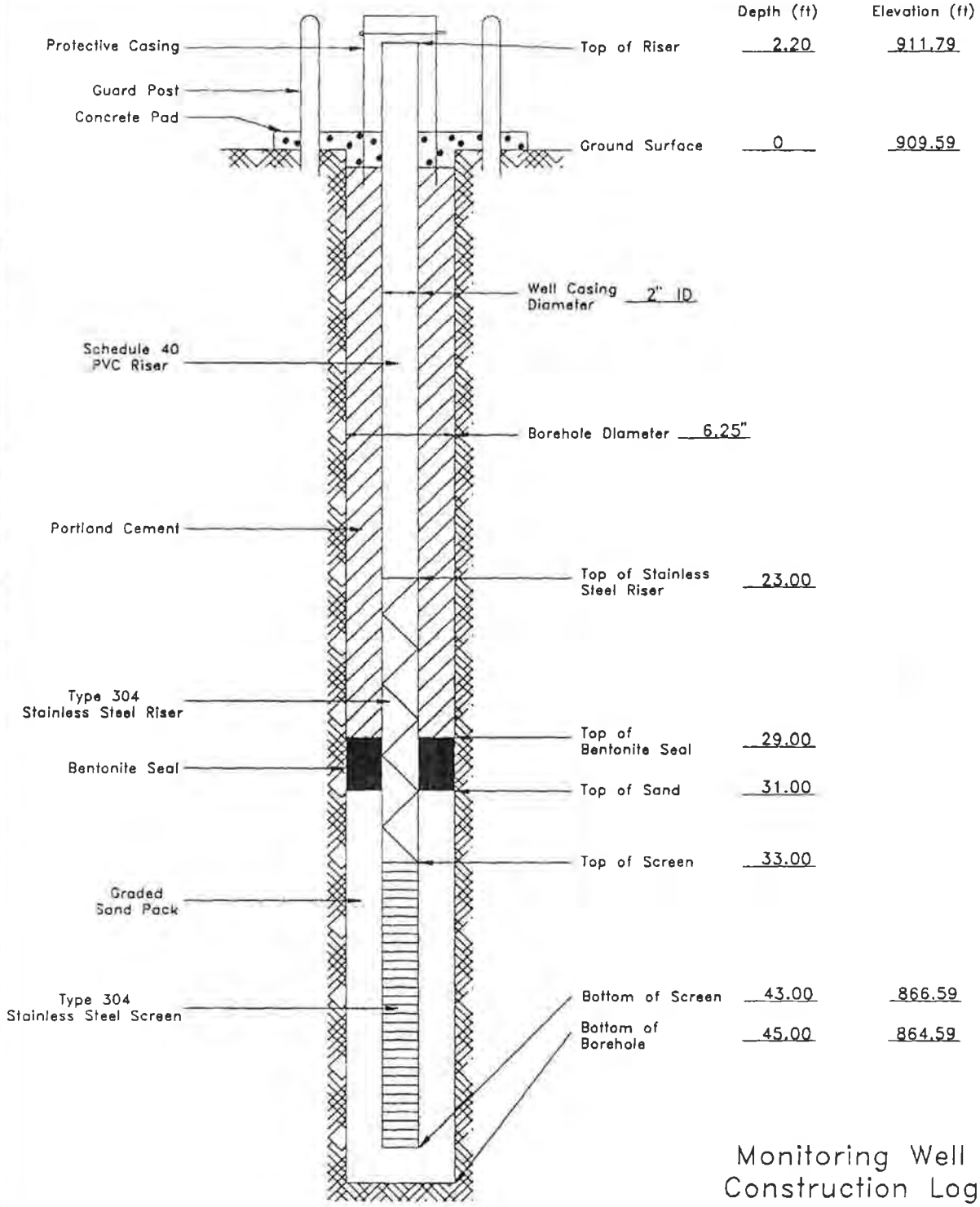
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-CTE-MW10
Well No. : MW10

Eng./Geo.: EEM Date: 09/19/90
Start Date: 09/19/90 End Date: 09/19/90

Centralizers : 35 ft and 20 ft
(Depth below sfc)

... Creating a Safer Tomorrow

DRAWN BY	Soeren Johnson 10/01/91	CHECKED BY / APPROVED BY	LAS 10-1-91	DRAWING NUMBER	301317-A22



Monitoring Well Construction Log

prepared for

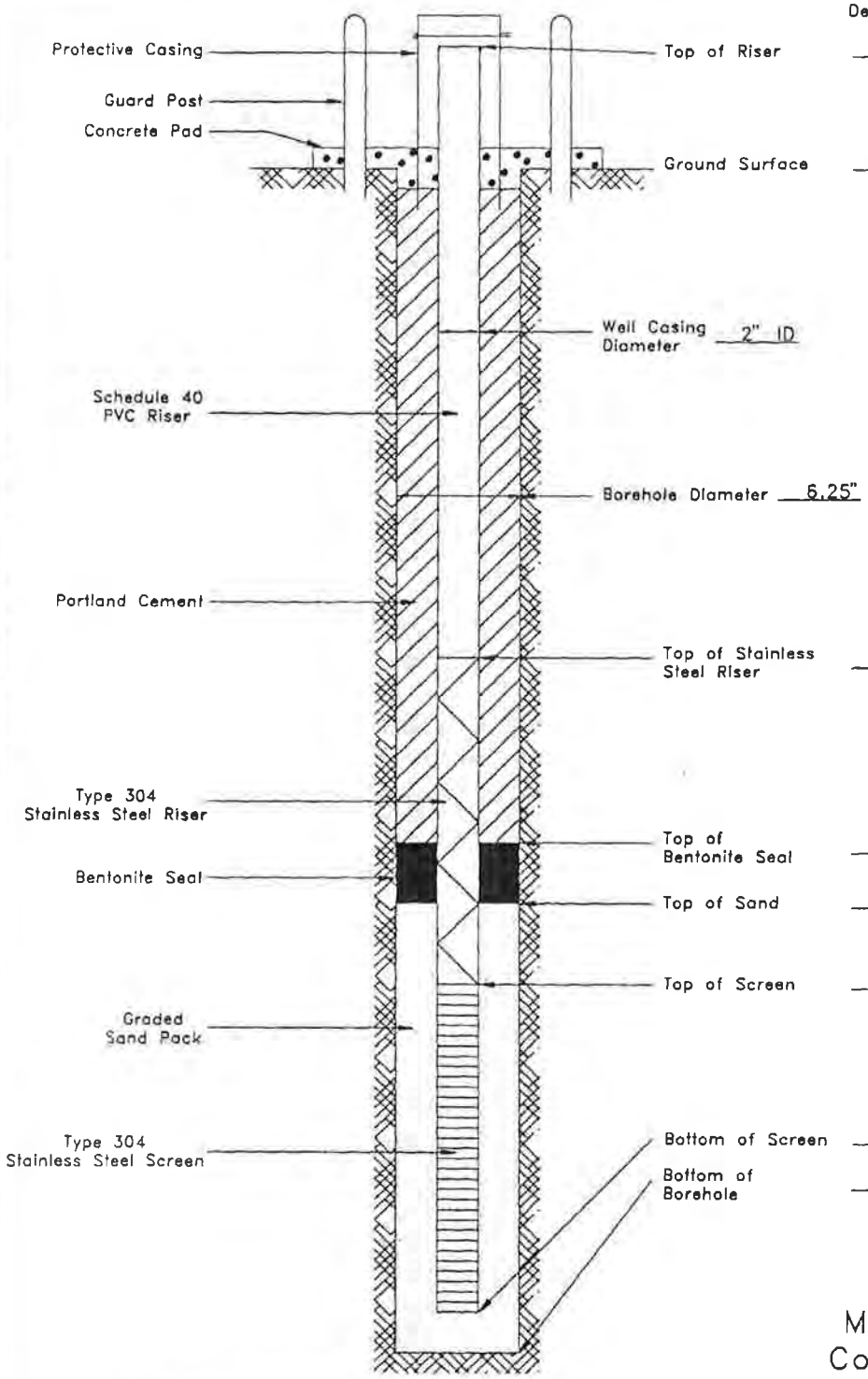
Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

Project Name: BOMARC Eng./Geo.: EEM Date: 09/20/90
Project No. : 301317
Boring No. : BOM-FD1-MW11 Start Date: 09/19/90 End Date: 09/20/90
Well No. : MW11

Centralizers : 33 ft and 18 ft
(Depth below sfc)

... Creating a Safer Tomorrow

DRAWN BY	Soeren Johnson 10/01/91	CHECKED BY	LAS	10-1-91	DRAWING NUMBER	301317-A23
		APPROVED BY				



	Depth (ft)	Elevation (ft)
Top of Riser	2.20	906.60
Ground Surface	0	904.40
Top of Stainless Steel Riser	21.00	
Top of Bentonite Seal	27.00	
Top of Sand	29.00	
Top of Screen	31.00	
Bottom of Screen	41.00	863.40
Bottom of Borehole	43.00	861.40

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

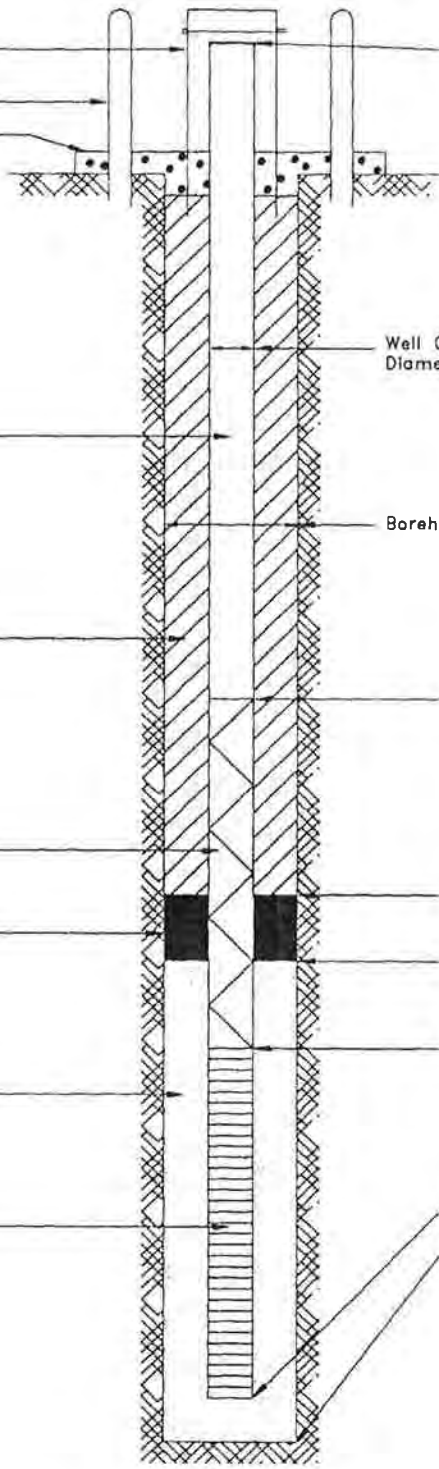
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-FD2-MW12
Well No. : MW12

Eng./Geo.: EEM Date: 09/20/90
Start Date: 09/20/90 End Date: 09/20/90

Centralizers : 31 ft and 16 ft
(Depth below sfc)

... Creating a Safer Tomorrow

DRAWING NUMBER	301317-A35
	10-1-91
CHECKED BY	LAS
APPROVED BY	
DRAWN BY	Soeren Johnson 10/01/91



	Depth (ft)	Elevation (ft)
Top of Riser	2.0	911.66
Ground Surface	0	909.66
Well Casing Diameter 2" ID		
Borehole Diameter 6.25"		
Top of Stainless Steel Riser	22.20	
Top of Bentonite Seal	28.00	
Top of Sand	30.00	
Top of Screen	32.20	
Bottom of Screen	42.60	867.06
Bottom of Borehole	43.00	866.66

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

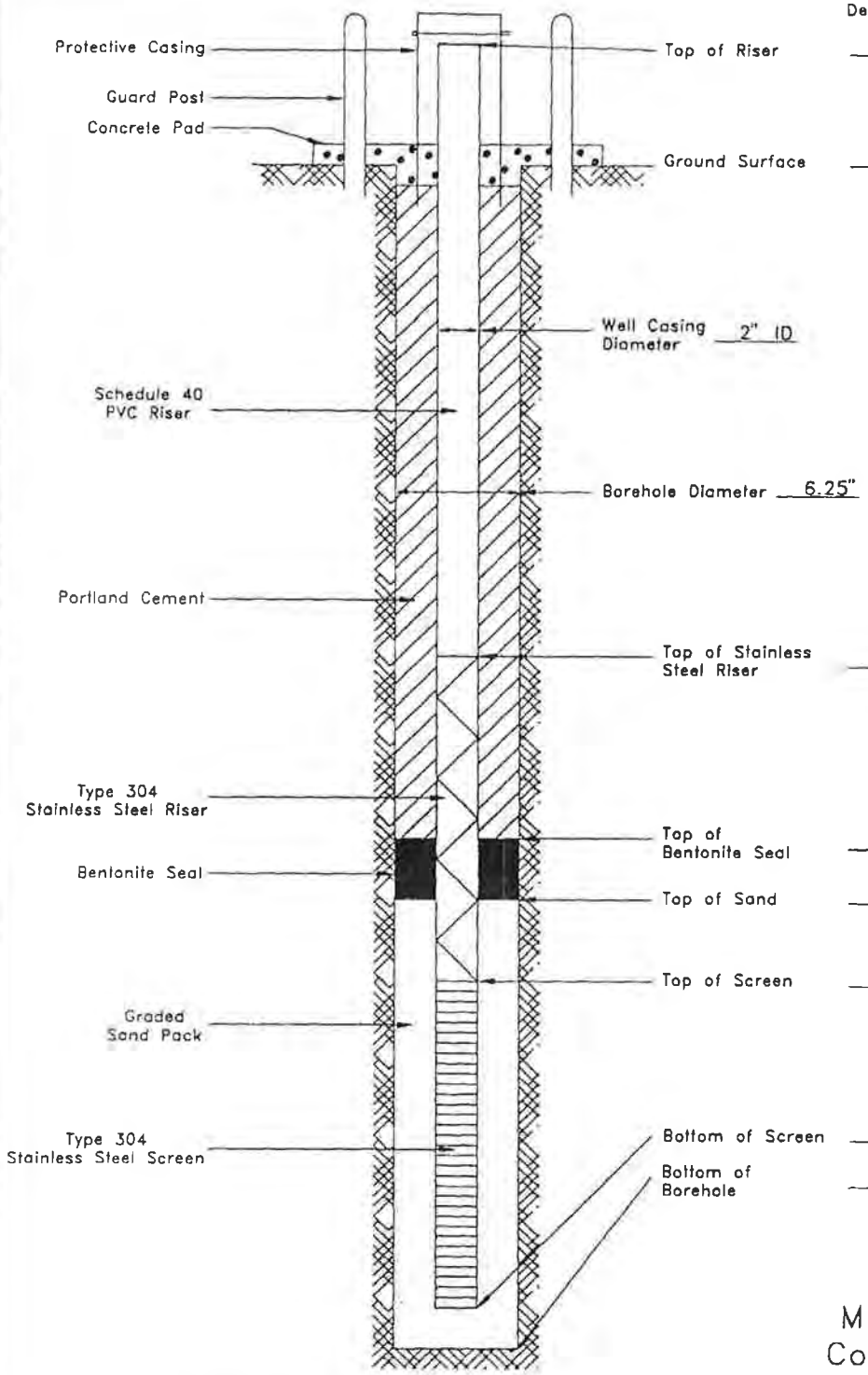
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-FD-MW13
Well No. : MW13

Eng./Geo.: TML Date: 06/29/91
Start Date: 06/29/91 End Date: 06/29/91

Centralizers : None
(Depth below sfc)

... Creating a Safer Tomorrow

DRAWING NUMBER	3013T/-A36
	10-1-91
	LAS
CHECKED BY	
APPROVED BY	
Soren Johnson	
10/01/91	
DRAWN BY	



	Depth (ft)	Elevation (ft)
Top of Riser	2.0	909.54
Ground Surface	0	907.54
Top of Stainless Steel Riser	37.00	
Top of Bentonite Seal	42.80	
Top of Sand	45.00	
Top of Screen	47.00	
Bottom of Screen	57.40	850.14
Bottom of Borehole	58.00	849.54

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

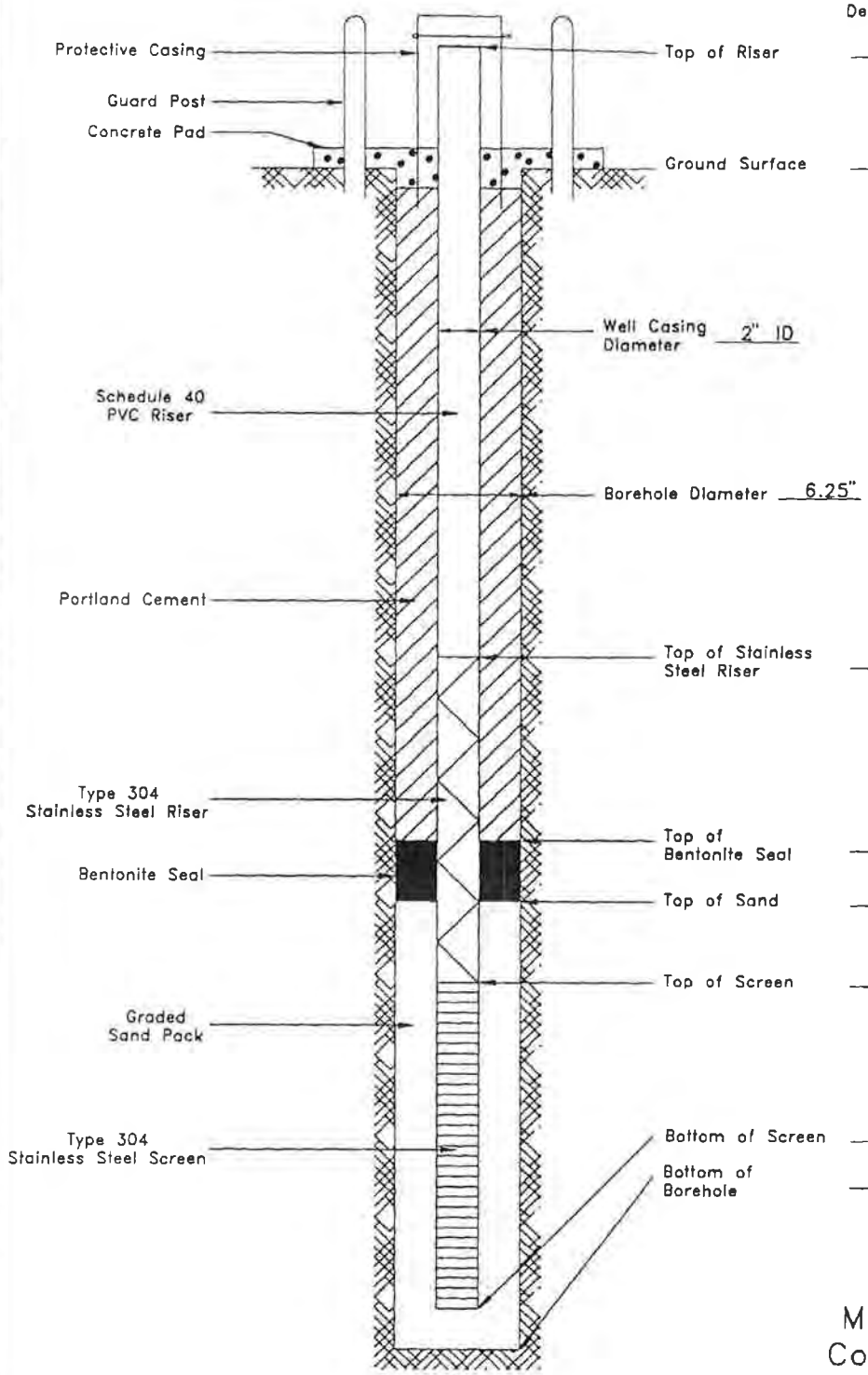
Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-SDB-MW14
Well No. : MW14

Eng./Geo.: TML
Date: 06/30/91
Start Date: 06/30/91
End Date: 06/30/91

Centralizers : None
(Depth below sfc)

IT ... Creating a Safer Tomorrow

DRAWING NUMBER	3013T/-A37
	10-1-91
	LAS
CHECKED BY	
APPROVED BY	
Soeren Johnson	10/01/91
DRAWN BY	



	Depth (ft)	Elevation (ft)
Top of Riser	2.0	906.86
Ground Surface	0	904.86
Top of Stainless Steel Riser	32.20	
Top of Bentonite Seal	38.00	
Top of Sand	40.00	
Top of Screen	42.20	
Bottom of Screen	52.60	852.26
Bottom of Borehole	55.00	849.86

Monitoring Well Construction Log

prepared for

Former Raco Airfield
and
BOMARC Missile Site
Raco, Michigan

Project Name: BOMARC
Project No. : 301317
Boring No. : BOM-TPAD-SB16
Well No. : MW15

Eng./Geo.: TML
Date: 07/02/91
Start Date: 07/02/91 End Date: 07/02/91

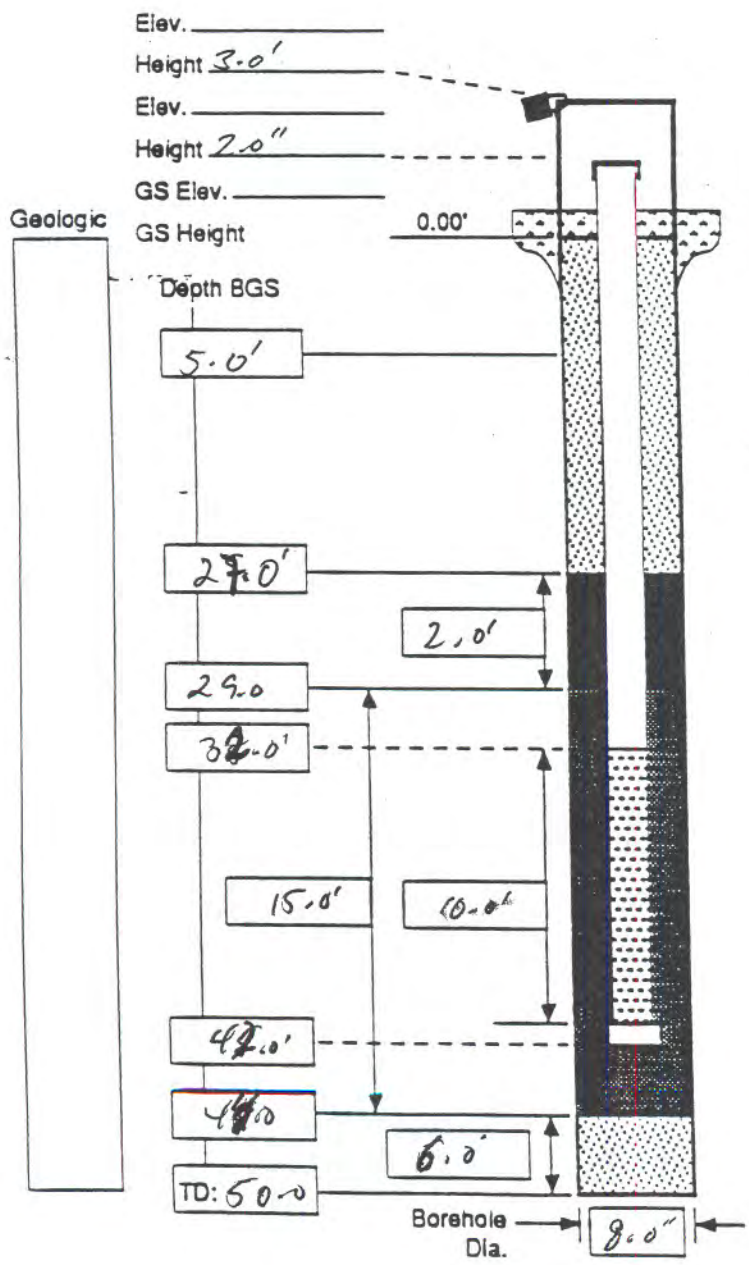
Centralizers : None
(Depth below sfc)

IT ... Creating a Safer Tomorrow

EARTH TECH
A tyco INTERNATIONAL LTD COMPANY

Monitoring Well Construction Log - Above Ground

Project Name: Raco	Project Number: 61367	Date: 09/16/03
Well MW16	Well ID: MW16	Sheet 1 of ___
Driller: Kevin Mike Mueller	Borehole Diameter (in): 8"	Total Depth (ft): 50.0
Drilling Agency: Boart Longyear	Date Started: 09/16/03	Depth to Water (ft): 38.0'
Drilling Equipment: Mobile B-57	Date Finished:	Elevation and Datum: —
Drilling Method: 4 1/4 Auger	Logged by: not logged	Checked by:
Drilling Fluid: none	Number of Samples: —	Date:



PROTECTIVE CSG
Material / Type: Steel
Diameter: 4"
Depth BGS: ___ ~~Weep Hole (Y~~

GUARD POSTS (Y) / N)
No.: ~~3~~ 4 Type: Steel

SURFACE PAD
Composition and Size: Cement 2x2

RISER PIPE
Type: PVC Sch 40
Diameter: 2"
Total Length (TOC to TOS): 40.0'
Ventilated Cap (Y) ~~N~~

GROUT
Composition and Proportions: Cemex Type IA
6.5 sks - 50 lb bags.
Tremied (Y) / N) 94
Interval BGS: ___

CENTRALIZERS
Depth(s) —

SEAL
Type: Bentonite
Source: Enviro plug
Setup / Hydration Time: TR30 Vol. Fluid Added ___
Tremied (Y / (N))

FILTER PACK
Type: Sand
Amt. Used: 9 - 50 lbs
Tremied (Y) / N)
Source: Badger Mining Co.
Gr. Size Dist.: 45-55

SCREEN
Type: Johnson
Diameter: 2.0"
Slot Size and Type: 0.01
Interval BGS: ___

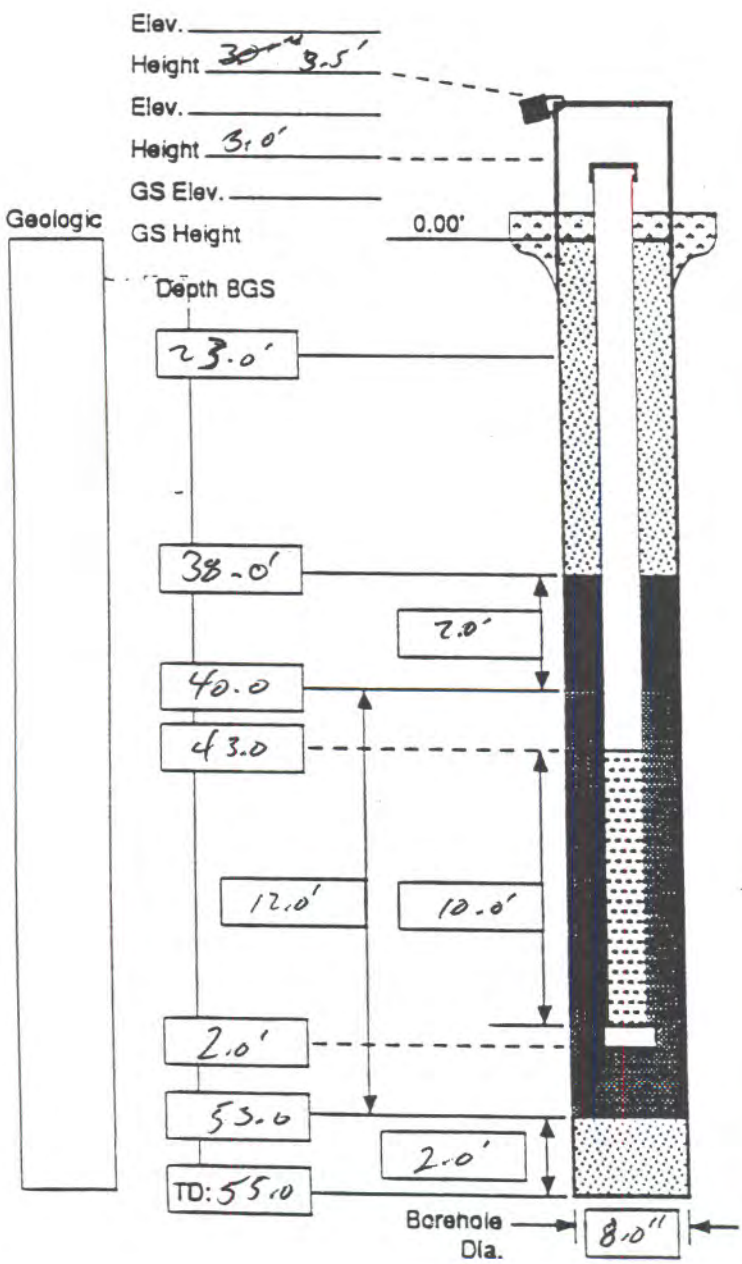
WELL FOOT ~~(Y) / N)~~
Interval BGS: ___ Length ___
Bottom Cap (Y) / N)

BACKFILL PLUG
Material: ~~Bentonite~~ no
Setup / Hydration Time: —

EARTH TECH
A tyco INTERNATIONAL LTD COMPANY

Monitoring Well Construction Log - Above Ground

Project Name: Raco	Project Number: 61367.03	Date: 09/17/03
Well MW17	Well ID: MW17	Sheet 1 of ___
Driller: Mike Mueller	Borehole Diameter (in): 8.0"	Total Depth (ft): 55.0'
Drilling Agency: Boart Longyear	Date Started: 09/17/03	Depth to Water (ft): 47
Drilling Equipment: Mobile B-57 ATV	Date Finished:	Elevation and Datum: —
Drilling Method: 4 1/4 Auger	Logged by: —	Checked by:
Drilling Fluid: none	Number of Samples: —	Date:



PROTECTIVE CSG
Material / Type: steel
Diameter: 4.0"
Depth BGS: —
Weep Hole (Y)

GUARD POSTS (Y/N)
No.: 4 Type: steel

SURFACE PAD
Composition and Size: Concrete 2x2

RISER PIPE
Type: PVC Sch 40
Diameter: 2.0"
Total Length (TOC to TOS): 53.0'
Ventilated Cap (Y/N)

GROUT
Composition and Proportions: Cemex Type IA
Tremied (Y/N)
Interval BGS: ~1.0 ft

CENTRALIZERS
Depth(s) —

SEAL
Type: Enviroplug
Source: 1/4 pellets
Setup / Hydration Time: 30 min Vol. Fluid Added 1 Bgal
Tremied (Y/N)

FILTER PACK
Type: Sand
Amt. Used: 9 - 50lbs bags
Tremied (Y/N)
Source: Badger Mining Corp
Gr. Size Dist.: 45-55

SCREEN
Type: Stainless Steel
Diameter: 2.0"
Slot Size and Type: 0.01
Interval BGS: 43-53.0'

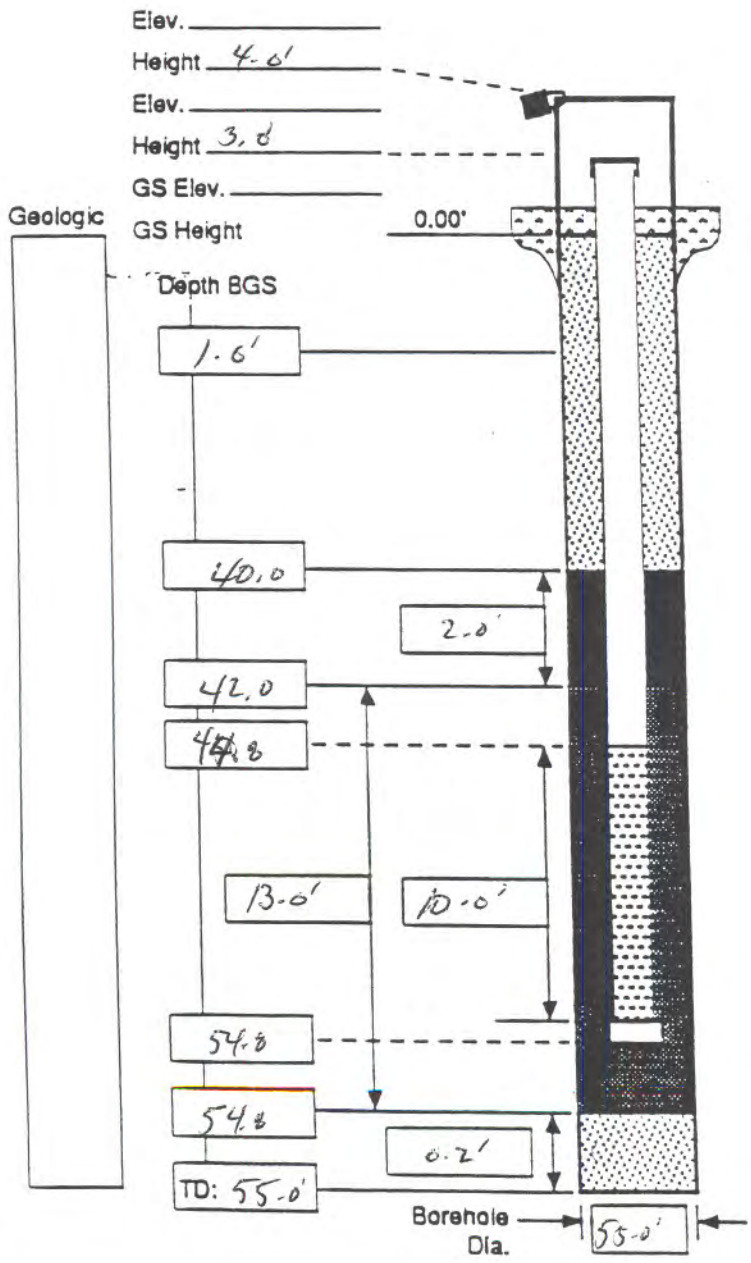
WELL FOOT (Y/N)
Interval BGS: — Length 2.0'
Bottom Cap (Y / N) —

BACKFILL PLUG
Material: ~~—~~ Formation Material
Setup / Hydration Time: —

EARTH TECH
A tyco INTERNATIONAL LTD. COMPANY

Monitoring Well Construction Log - Above Ground

Project Name: Raco	Project Number: 61367.03	Date: 09/17/03
Well MW18	Well ID: MW18	Sheet 1 of ___
Driller: ~~Leon~~ Mike Mueller	Borehole Diameter (in): 8.0"	Total Depth (ft): 55.0'
Drilling Agency: Boart Longyear	Date Started: 09/17/03	Depth to Water (ft): 48.8
Drilling Equipment: Mobile B-57	Date Finished: 09/18/03	Elevation and Datum: —
Drilling Method: 4¼ Hollowstem augers	Logged by: —	Checked by:
Drilling Fluid: none	Number of Samples: —	Date:



PROTECTIVE CSG
Material / Type: Steel
Diameter: 4.0"
Depth BGS: —
Weep Hole (Y

GUARD POSTS (Y / N)
No.: 4 Type: steel

SURFACE PAD
Composition and Size: Circular 2.0' r

RISER PIPE
Type: Sch 40 PVC
Diameter: 2.0"
Total Length (TOC to TOS): 58.0'
Ventilated Cap (Y / N)

GROUT
Composition and Proportions: Portland Type IA

Tremied (Y / N)
Interval BGS: ≥ 1.0'

CENTRALIZERS
Depth(s)

SEAL
Type: Bentonite ¼
Source: Enviroplug
Setup / Hydration Time: 30" overnight Vol. Fluid Added —
Tremied (Y N)

FILTER PACK
Type: 45-55 Sand
Amt. Used: 8 bags - 50 lbs
Tremied (Y / N)
Source: Badger Drilling
Gr. Size Dist.: —

SCREEN
Type: Stainless steel
Diameter: 2.0'
Slot Size and Type: 0.01
Interval BGS: 55-45

WELL FOOT (Y / N)
Interval BGS: — Length
Bottom Cap (Y / N)

BACKFILL PLUG
Material: Formation material
Setup / Hydration Time: —

EARTH TECH
A tyco INTERNATIONAL LTD COMPANY

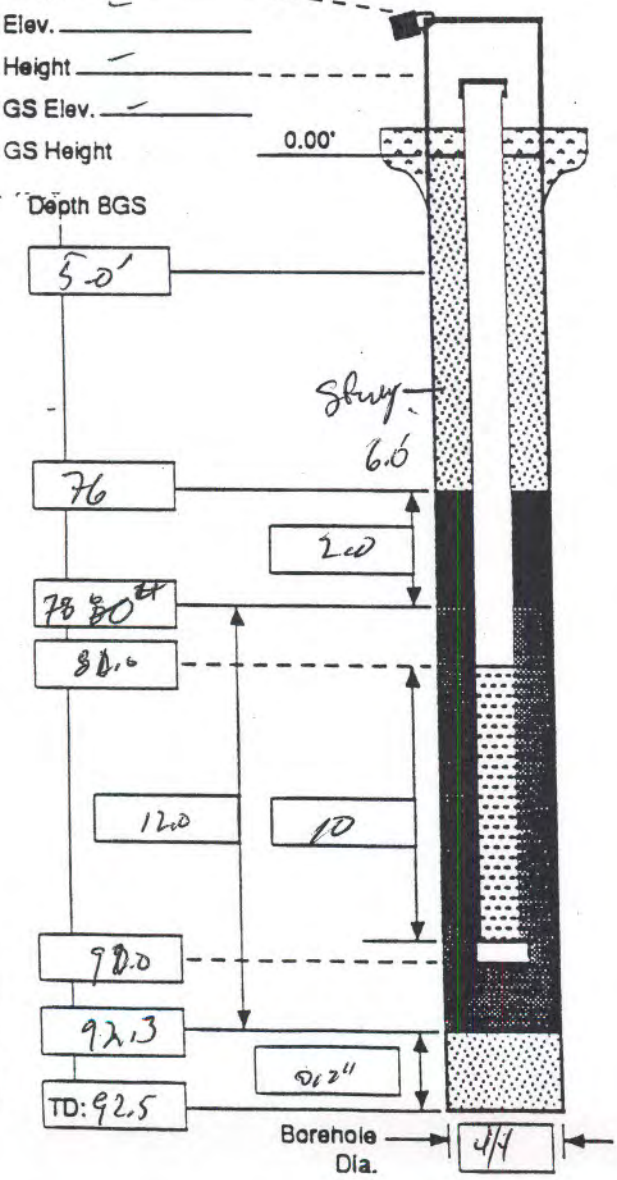
Monitoring Well Construction Log - Above Ground

Project Name: Paco	Project Number: 61367	Date: 10/18/04
Well MW19	Well ID: MW19	Sheet 1 of 1
Driller: Gary Jones	Borehole Diameter (in): 4 1/4	Total Depth (ft): 92.5
Drilling Agency: Boart	Date Started: 10/18/04	Depth to Water (ft): 50.0
Drilling Equipment: Mobile B-57	Date Finished: 10/19/04	Elevation and Datum: —
Drilling Method: Mud Rotary	Logged by: [illegible]	Checked by:
Drilling Fluid: Mud	Number of Samples:	Date:

Elev. N/A
Height —
Elev. —
Height —
GS Elev. —
GS Height 0.00'

Geologic

Depth BGS

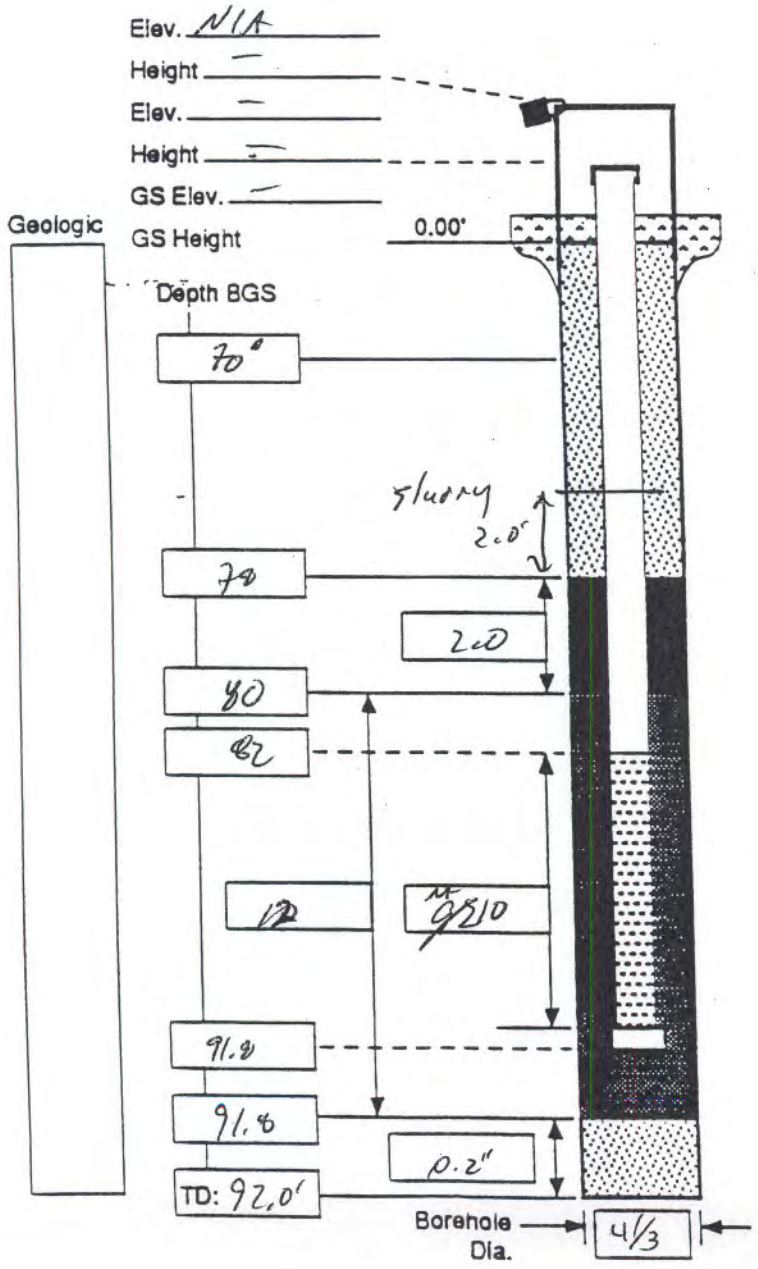


PROTECTIVE CSG
Material / Type: steel, stick up
Diameter: 3.0"
Depth BGS: 3.0' Weep Hole (Y
GUARD POSTS (Y/N)
No.: 4 Type: steel
SURFACE PAD
Composition and Size: Conc 3x3
RISER PIPE
Type: Sch 40 PVC
Diameter: 2.0"
Total Length (TOC to TOS): 82'
Ventilated Cap (Y/N)
GROUT
Composition and Proportions: Type IA
Tremied (Y/N)
Interval BGS: —
CENTRALIZERS
Depth(s) —
SEAL
Type: Slurry
Source: —
Setup / Hydration Time: — Vol. Fluid Added
Tremied (Y/N)
FILTER PACK
Type: Sand
Amt. Used: 5 bags
Tremied (Y/N)
Source: —
Gr. Size Dist.: —
SCREEN
Type: Sch 40 PVC
Diameter: 2.0"
Slot Size and Type: 0.010
Interval BGS: 92.5 - 82.5
WELL FOOT (Y/N)
Interval BGS: — Length
Bottom Cap (Y/N)
BACKFILL PLUG
Material: —
Setup / Hydration Time: —

EARTH TECH
A tyco INTERNATIONAL LTD COMPANY

Monitoring Well Construction Log - Above Ground

Project Name: Raco	Project Number: 61367	Date: 10/17/04
Well MW-20	Well ID: MW-20	Sheet 1 of 1
Driller: Gary Jones	Borehole Diameter (in): 4 1/4	Total Depth (ft): 92.0'
Drilling Agency: Boart	Date Started: 10/17/04	Depth to Water (ft): 50.0
Drilling Equipment: B-57 Mobile	Date Finished: 10/18/04	Elevation and Datum: —
Drilling Method: Mud Rotary	Logged by: [illegible]	Checked by:
Drilling Fluid: Drilling Mud	Number of Samples: —	Date:



PROTECTIVE CSG
Material / Type: steel stickup
Diameter: 3.0"
Depth BGS: 3.0' Weep Hole (Y

GUARD POSTS (Y/N)
No.: 4 Type: steel

SURFACE PAD
Composition and Size: Conc. 3X3

RISER PIPE
Type: Sch 40 PVC
Diameter: 2.0"
Total Length (TOC to TOS): ~ 82.0'
Ventilated Cap (Y/N)

GROUT
Composition and Proportions: Type IA
Tremied (Y/N)
Interval BGS: —

CENTRALIZERS
Depth(s) —

SEAL
Type: Slurry
Source: —
Setup / Hydration Time: N/A Vol. Fluid Added
Tremied (Y/N)

FILTER PACK
Type: #1 Sand
Amt. Used: 5 bags
Tremied (Y/N)
Source: —
Gr. Size Dist.:

SCREEN
Type: Sch 40 PVC
Diameter: 2.0"
Slot Size and Type: 0.010
Interval BGS: 92 - 82

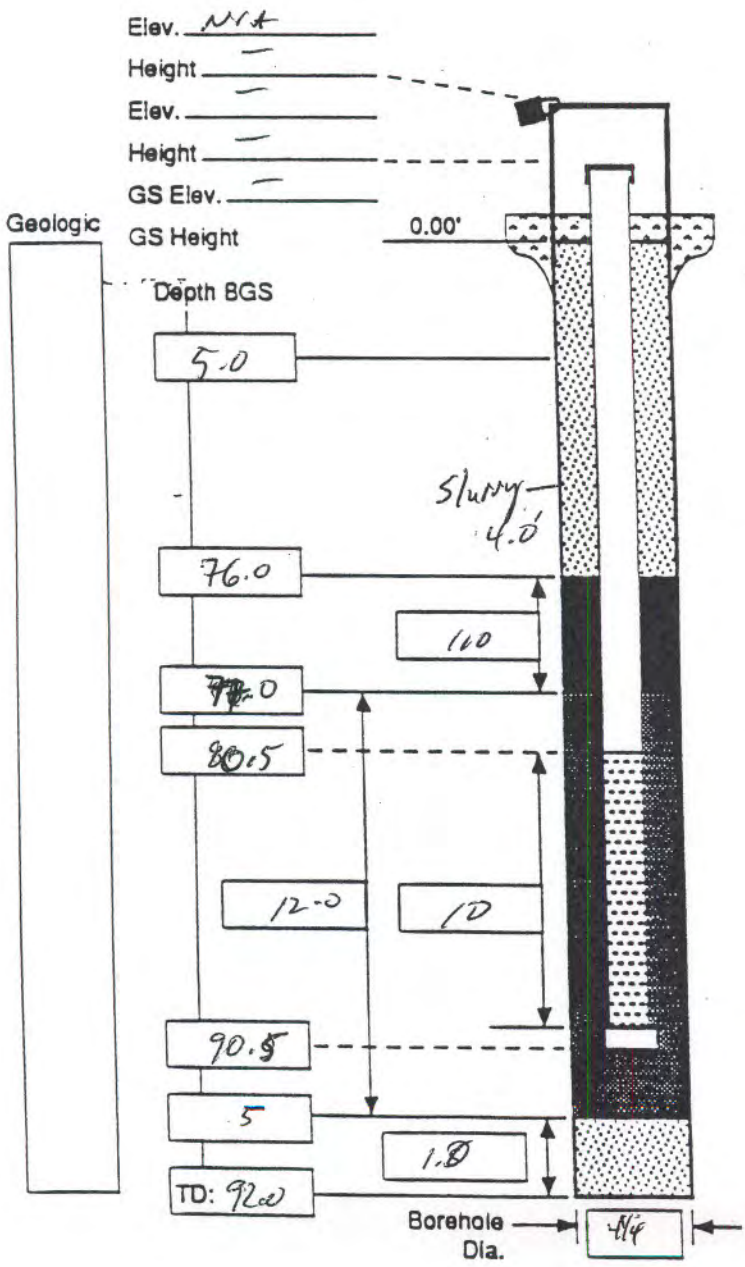
WELL FOOT (Y/N)
Interval BGS: — Length
Bottom Cap (Y/N)

BACKFILL PLUG
Material: —
Setup / Hydration Time: —

EARTH TECH
A tyco INTERNATIONAL LTD COMPANY

Monitoring Well Construction Log - Above Ground

Project Name: Raco	Project Number: 61367	Date: 10/19/04
Well MW-21	Well ID: MW-21	Sheet 1 of 1
Driller: Gary Jones	Borehole Diameter (in): 4 1/4	Total Depth (ft): 92.0
Drilling Agency: Boart	Date Started: 10/19/04	Depth to Water (ft): 50.0
Drilling Equipment: Mobile B-57	Date Finished: 10/19/04	Elevation and Datum: —
Drilling Method: Mud Rotary	Logged by: LT	Checked by:
Drilling Fluid: Mud	Number of Samples: —	Date:



PROTECTIVE CSG
Material / Type: Steel Stick up
Diameter: 3.0"
Depth BGS: 3.0' Weep Hole (Y

GUARD POSTS (Y/N)
No.: 4 Type: Steel

SURFACE PAD
Composition and Size: Conc 3x3

RISER PIPE
Type: Sch 40 PVC
Diameter: 2.0"
Total Length (TOC to TOS): ~82.0'
Ventilated Cap (Y/N)

GROUT
Composition and Proportions: Type IA
Tremied (Y/N)
Interval BGS: —

CENTRALIZERS
Depth(s) —

SEAL
Type: Slurry
Source: —
Setup / Hydration Time: — Vol. Fluid Added
Tremied (Y/N)

FILTER PACK
Type: Sand
Amt. Used: 5 bags
Tremied (Y/N)
Source: —
Gr. Size Dist.: —

SCREEN
Type: Sch 40 PVC
Diameter: 2.0"
Slot Size and Type: 0.010
Interval BGS: 90 - 80

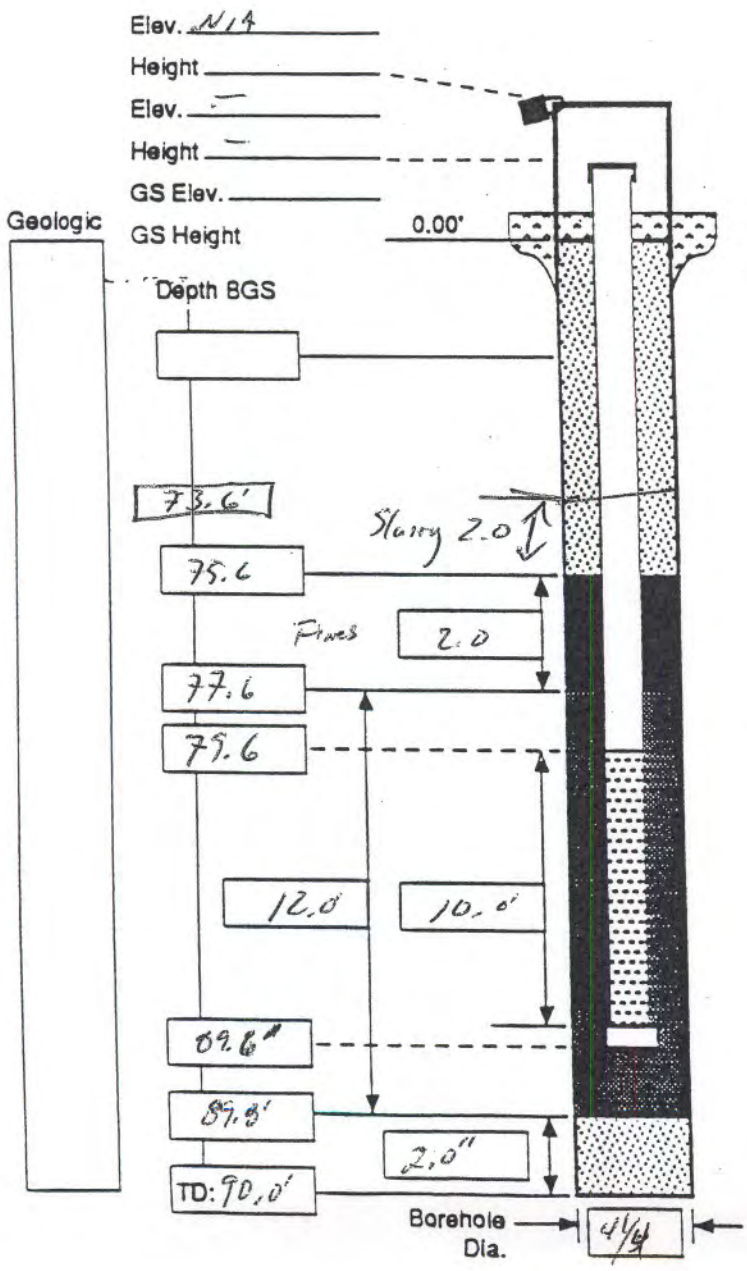
WELL FOOT (Y/N)
Interval BGS: — Length
Bottom Cap (Y/N)

BACKFILL PLUG
Material: —
Setup / Hydration Time: —

EARTH TECH
A tyco INTERNATIONAL LTD. COMPANY

Monitoring Well Construction Log - Above Ground

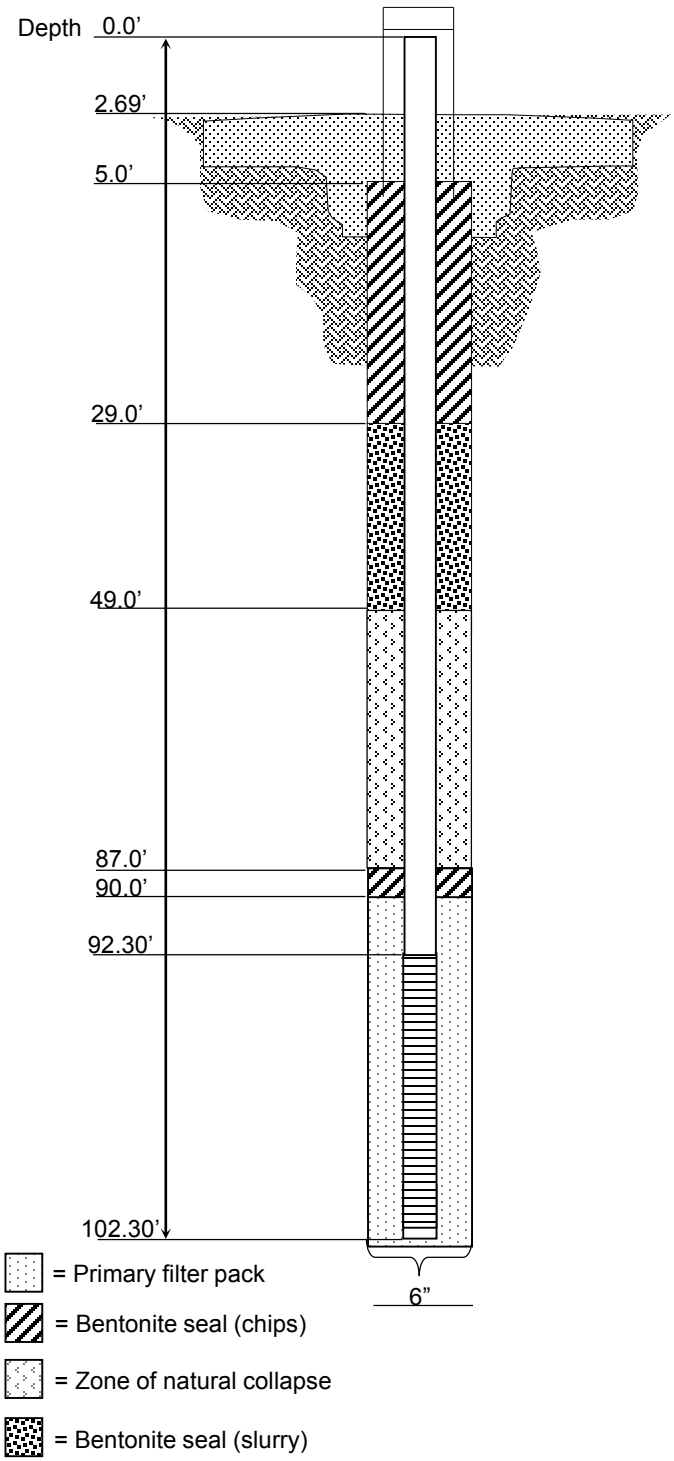
Project Name: Pace	Project Number: 61367	Date: 10/14/04
Well MW22	Well ID: MW22	Sheet 1 of 1
Driller: Gary Jones	Borehole Diameter (in): 4 1/3	Total Depth (ft): 90'
Drilling Agency: Boart	Date Started: 10/14/04	Depth to Water (ft): ≈50'
Drilling Equipment: BK-66	Date Finished: 10/15/04	Elevation and Datum: —
Drilling Method: Hollow Stem Auger	Logged by: N/A	Checked by:
Drilling Fluid:	Number of Samples: N/A	Date:



PROTECTIVE CSG
Material / Type: Steel, stickup
Diameter: 3.0"
Depth BGS: 3.0' Weep Hole (Y
GUARD POSTS (Y / N)
No.: 4 Type: steel
SURFACE PAD
Composition and Size:
RISER PIPE
Type: Sch 40 PVC
Diameter: 2.0'
Total Length (TOC to TOS):
Ventilated Cap (Y / N)
GROUT
Composition and Proportions: Type IA
Tremied (Y / N)
Interval BGS:
CENTRALIZERS
Depth(s) —
SEAL
Type: Slurry
Source:
Setup / Hydration Time: N/A Vol. Fluid Added 2
Tremied (Y / N)
FILTER PACK
Type: Sand
Amt. Used:
Tremied (Y / N)
Source:
Gr. Size Dist.:
SCREEN
Type: Sch 40 PVC
Diameter: 2.0"
Slot Size and Type: 0.010
Interval BGS:
WELL FOOT (Y / N)
Interval BGS: Length
Bottom Cap (Y / N)
BACKFILL PLUG
Material:
Setup / Hydration Time:

Site: Raco Army Airfield and Bomarc Missile Site	Installation: Above Ground Completion	Well No. MW-23
Client: USACE– Louisville District	Contract No./Task Order No.: W912QR-08-D-0014/0007	
Contractor: GEO Consultants, LLC	Drill Contractor: Boart Longyear	
Start Date: 9/26/09 End Date: 9/26/09	Datum: Michigan State Plane North (NAD 83)	
	Coordinates: N 578527.867	
	E 26801410.690	

NOT TO SCALE



Protective Casing
Material Type: Steel
Diameter: 4 inch square
Depth BGS: 2.0ft Weep Hole? (Y / N): No
Guard Posts (Y / N): Yes - 4
No: 4 Type: 4 inch steel

Surface Pad
Composition and Size: 3 ft x 3 ft Concrete

Riser Pipe
Type: SCH 40 PVC
Diameter: 2 inch
Length (TOC to TOS): 92.30'
Ventilated Cap (Y / N): No

Bentonite Seal (Chips)
Type: ¼ in. bentonite chips
Source: Gold Seal
Amt. Used: 200#
Depth BTOC: 5.0' – 29' and 87.0' – 90.0'
Setup/Hydration Time: 1.5 hour Vol. Fluid Added: 60 gal
Tremied (Y / N): No

Bentonite Seal (Slurry)
Type: Portland Cement and Holeplug Gel
Source: Gold Seal
Depth BTOC: 29.0' - 49.0'
Tremied (Y / N): Yes

Zone of Natural Collapse
Type: Sand with trace gravel
Depth BTOC: 49.0' - 87.0'
Setup/Hydration Time: 1.5 hour
Tremied (Y / N): No

Primary Filter Pack
Graduation Designation: 10/20 mesh
Grain Size: #5
Source: Global Drilling Supplies
Amt. Used: 300#
Tremied (Y / N): No

Screen
Type: Type 301 Stainless Steel
Diameter: 2 in.
Length: 10 ft
Slot Size and Type: 0.010 inch wire wrap
Interval Below TOC: 92.30' – 102.30'

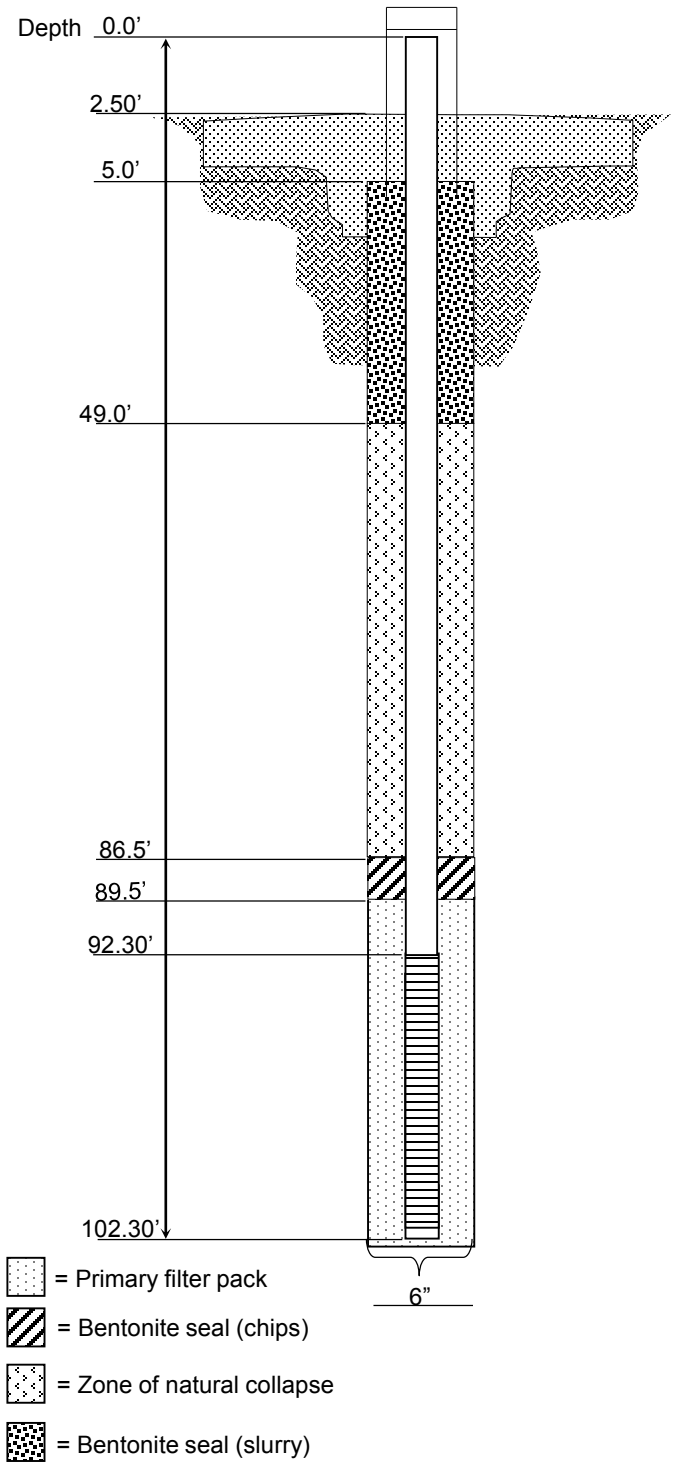
U.S. Army Corps of Engineers
Louisville District

MW-23 Monitoring Well Construction Log

GEO Consultants, LLC
A Geological Engineering and Environmental Services Company
Kevil, Kentucky

Site: Raco Army Airfield and Bomarc Missile Site	Installation: Above Ground Completion	Well No. MW-24
Client: USACE– Louisville District	Contract No./Task Order No.: W912QR-08-D-0014/0007	
Contractor: GEO Consultants, LLC	Drill Contractor: Boart Longyear	
Start Date: 9/30/09 End Date: 9/30/09	Datum: Michigan State Plane North (NAD 83)	
	Coordinates: N 578443.124	
	E 26801510.552	

NOT TO SCALE



Protective Casing
Material Type: Steel
Diameter: 4 inch square
Depth BGS: 2.0ft Weep Hole? (Y / N): No
Guard Posts (Y / N): Yes
No: 4 Type: 4 inch steel
Surface Pad
Composition and Size: 3 ft x 3 ft Concrete
Riser Pipe
Type: SCH 40 PVC
Diameter: 2 inch
Length (TOC to TOS): 92.30'
Ventilated Cap (Y / N): No
Bentonite Seal (Slurry)
Type: Portland Cement and Holeplug Gel
Source: Gold Seal
Depth BTOC: 5.0ft to 49.0ft
Tremied (Y / N): Yes
Zone of Natural Collapse
Type: Sand with trace gravel
Depth BTOC: 49.0' – 86.5'
Setup/Hydration Time: 1.5 hour
Tremied (Y / N): No
Bentonite Seal (Chips)
Type: ¼ in. bentonite chips
Source: Gold Seal
Amt. Used: 50#
Depth BGS: 86.5' – 89.5'
Setup/Hydration Time: 0.5 hour Vol. Fluid Added: 0.0 gal
Tremied (Y / N): No
Primary Filter Pack
Graduation Designation: 10/20 mesh
Grain Size: #5
Source: Global Drilling Supplies
Amt. Used: 300#
Tremied (Y / N): No
Screen
Type: Type 301 Stainless Steel
Diameter: 2 in.
Length: 10 ft
Slot Size and Type: 0.010 inch wire wrap
Interval Below TOC: 92.30' – 102.30'

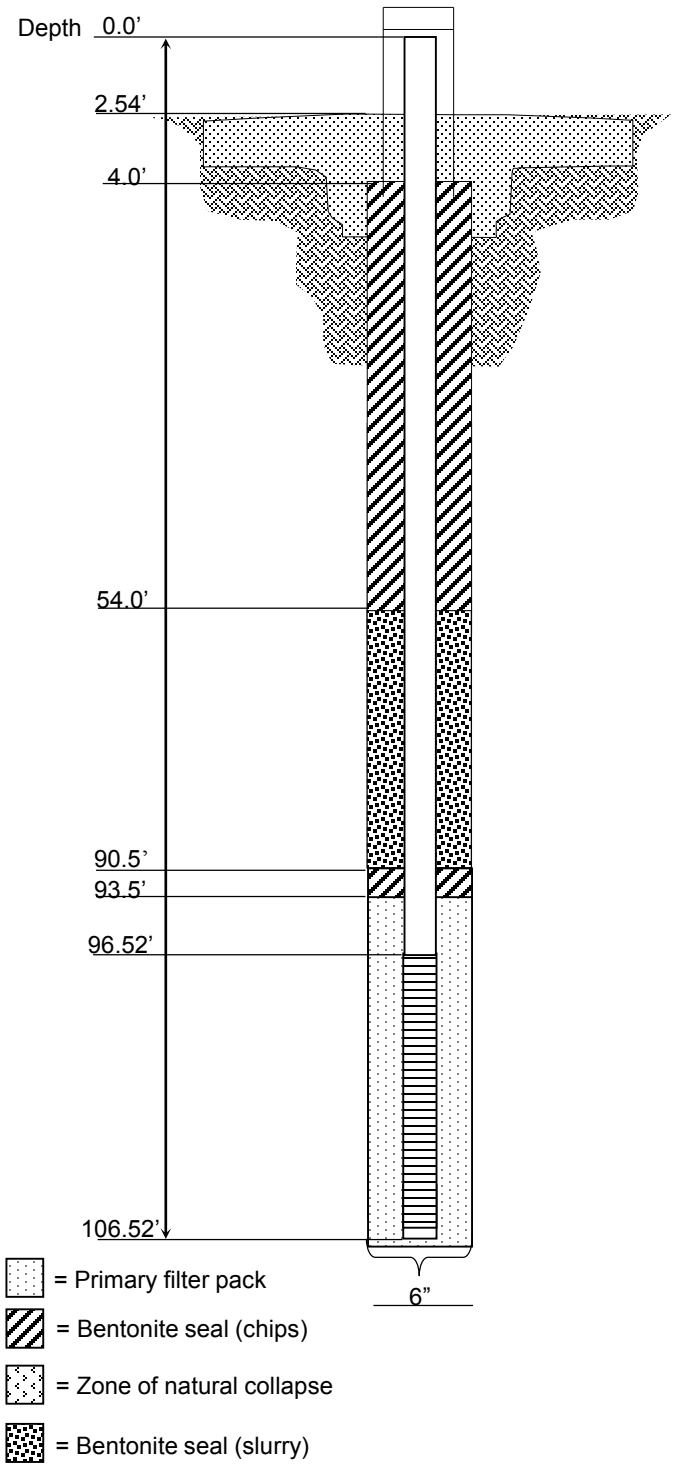
U.S. Army Corps of Engineers
Louisville District

MW-24 Monitoring Well Construction Log

GEO Consultants, LLC
A Geological Engineering and Environmental Services Company
Kevil, Kentucky

Site: Raco Army Airfield and Bomarc Missile Site	Installation: Above Ground Completion	Well No. MW-25
Client: USACE– Louisville District	Contract No./Task Order No.: W912QR-08-D-0014/0007	
Contractor: GEO Consultants, LLC	Drill Contractor: Boart Longyear	
Start Date: 10/6/09 End Date: 10/6/09	Datum: Michigan State Plane North (NAD 83)	
	Coordinates: N 578579.614	
	E 26801602.395	

NOT TO SCALE



Protective Casing
Material Type: Steel
Diameter: 4 inch square
Depth BGS: 2.0ft Weep Hole? (Y / N): No
Guard Posts (Y / N): Yes
No: 4 Type: 4 inch steel

Surface Pad
Composition and Size: 3 ft x 3 ft Concrete

Riser Pipe
Type: SCH 40 PVC
Diameter: 2 inch
Length (TOC to TOS): 96.52'
Ventilated Cap (Y / N): No

Bentonite Seal (Chips)
Type: ¼ in. bentonite chips
Source: Gold Seal
Amt. Used: 650#
Depth BTOC: 4.0ft to 54.0ft and 90.5' – 93.5'
Setup/Hydration Time: 1 hour Vol. Fluid Added: 60 gal
Tremied (Y / N): No

Bentonite Seal (Slurry)
Type: Portland Cement and Holeplug Gel
Source: Gold Seal
Amt. Used: 282# Portland Cement, 50# Holeplug Gel
Depth BTOC: 54.0' - 90.5'
Tremied (Y / N): Yes

Primary Filter Pack
Graduation Designation: 10/20 mesh
Grain Size: #5
Source: Global Drilling Supplies
Amt. Used: 300#
Tremied (Y / N): No

Screen
Type: Type 301 Stainless Steel
Diameter: 2 in.
Length: 10 ft
Slot Size and Type: 0.010 inch wire wrap
Interval Below TOC: 96.52' – 106.52'

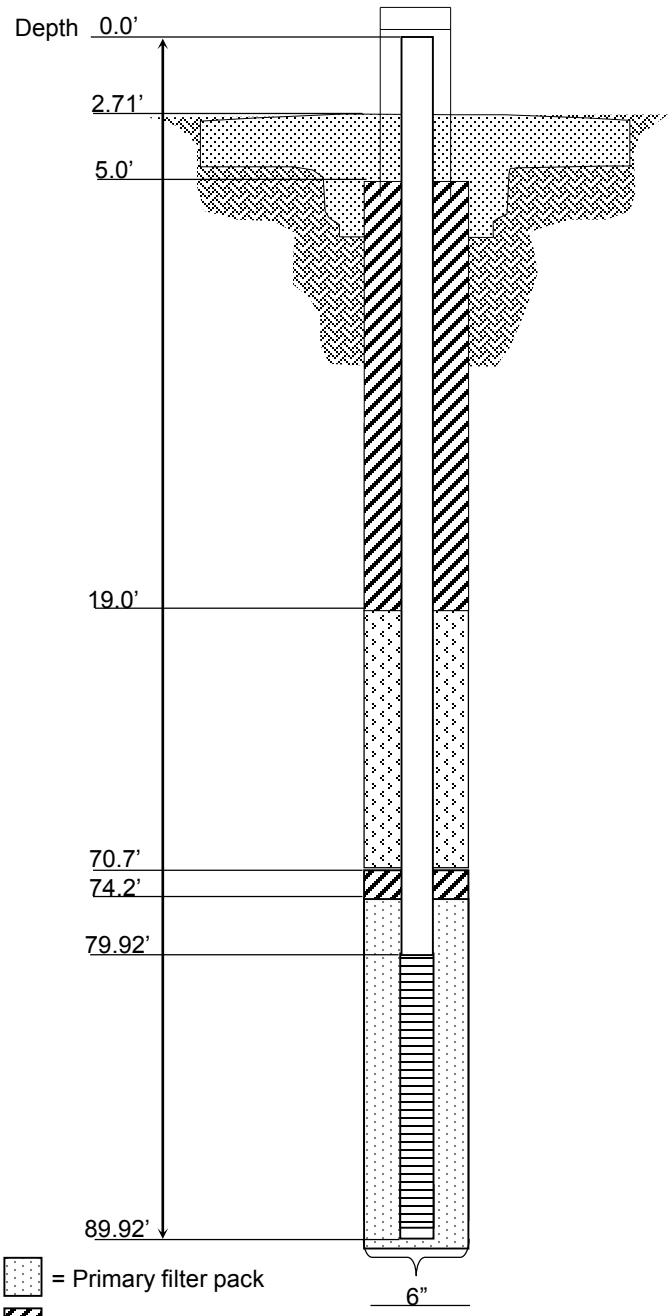
U.S. Army Corps of Engineers
Louisville District

GEO Consultants, LLC
A Geological Engineering and Environmental Services Company
Kevil, Kentucky

MW-25 Monitoring Well Construction Log

Site: Raco Army Airfield and Bomarc Missile Site	Installation: Above Ground Completion	Well No. MW-26
Client: USACE– Louisville District	Contract No./Task Order No.: W912QR-08-D-0014/0007	
Contractor: GEO Consultants, LLC	Drill Contractor: Boart Longyear	
Start Date: 10/9/09 End Date: 10/9/09	Datum: Michigan State Plane North (NAD 83)	
	Coordinates: N 578518.488	
	E 26801291.213	

NOT TO SCALE



= Primary filter pack

= Bentonite seal (chips)

= Zone of natural collapse

= Bentonite seal (slurry)

Protective Casing
Material Type: Steel
Diameter: 4 inch square
Depth BGS: 2.0ft Weep Hole? (Y / N): No
Guard Posts (Y / N): Yes
No: 4 Type: 4 inch steel

Surface Pad
Composition and Size: 3 ft x 3 ft Concrete

Riser Pipe
Type: SCH 40 PVC
Diameter: 2 inch
Length (TOC to TOS): 79.92'
Ventilated Cap (Y / N): No

Bentonite Seal (Chips)
Type: ¼ in. bentonite chips
Source: Gold Seal
Amt. Used: 300#
Depth BTOC: 5.0' - 19.0' and 70.7' - 74.2'
Setup/Hydration Time: 1 hour Vol. Fluid Added: 25 gal
Tremied (Y / N): No

Zone of Natural Collapse
Type: Sand with trace gravel
Depth BTOC: 19.0' – 70.7'
Tremied (Y / N): No

Primary Filter Pack
Graduation Designation: 10/20 mesh
Grain Size: #5
Source: Global Drilling Supplies
Amt. Used: 300#
Tremied (Y / N): No

Screen
Type: Type 301 Stainless Steel
Diameter: 2 in.
Length: 10 ft
Slot Size and Type: 0.010 inch wire wrap
Interval Below TOC: 79.92' – 89.92'

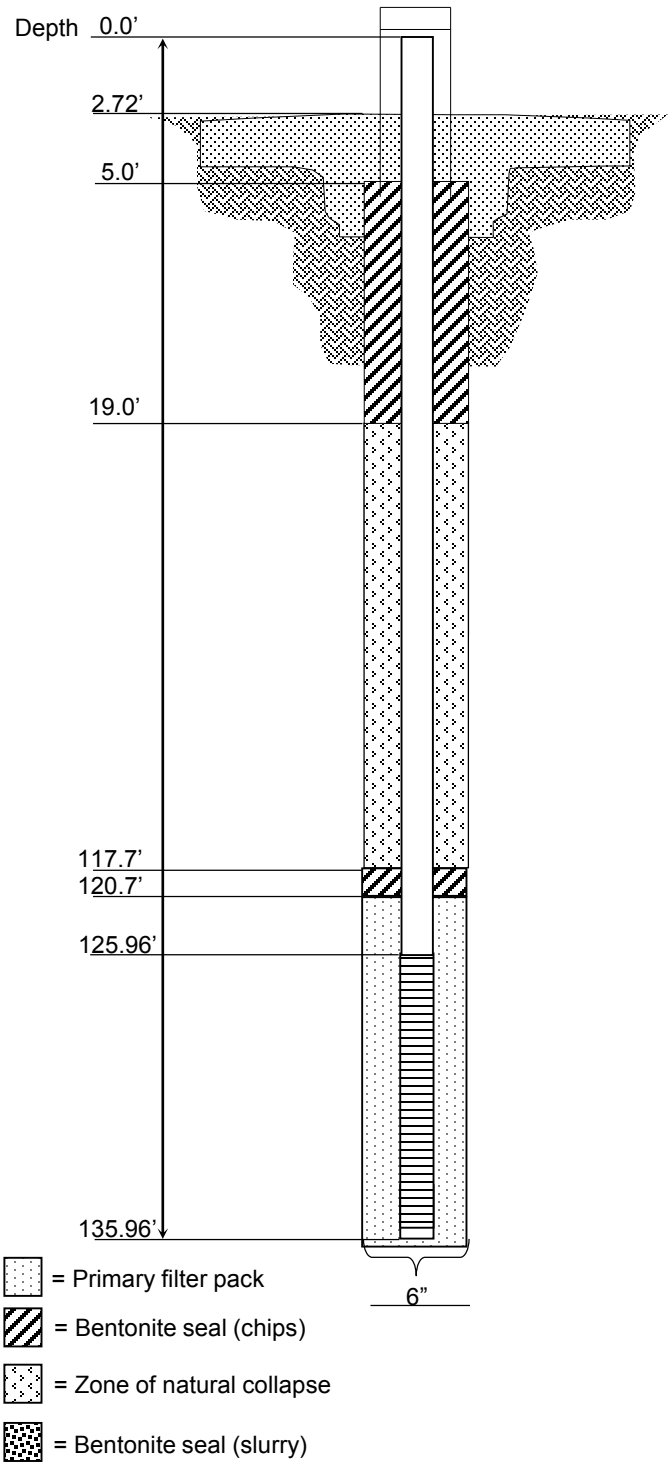
U.S. Army Corps of Engineers
Louisville District

GEO Consultants, LLC
A Geological Engineering and Environmental Services Company
Kevil, Kentucky

MW-26 Monitoring Well Construction Log

Site: Raco Army Airfield and Bomarc Missile Site	Installation: Above Ground Completion	Well No. MW-27
Client: USACE– Louisville District	Contract No./Task Order No.: W912QR-08-D-0014/0007	
Contractor: GEO Consultants, LLC	Drill Contractor: Boart Longyear	
Start Date: 10/9/09 End Date: 10/9/09	Datum: Michigan State Plane North (NAD 83)	
	Coordinates: N 578488.993	
	E 26801675.609	

NOT TO SCALE



Protective Casing
Material Type: Steel
Diameter: 4 inch square
Depth BGS: 2.0ft Weep Hole? (Y / N): No
Guard Posts (Y / N): Yes
No: 4 Type: 4 inch steel

Surface Pad
Composition and Size: 3 ft x 3 ft Concrete

Riser Pipe
Type: SCH 40 PVC
Diameter: 2 inch
Length (TOC to TOS): 125.96'
Ventilated Cap (Y / N): No

Bentonite Seal (Chips)
Type: ¼ in. bentonite chips
Source: Gold Seal
Amt. Used: 600#
Depth BTOC: 5.0' - 19.0' and 117.7' - 120.7'
Setup/Hydration Time: 1.5 hour Vol. Fluid Added: 25 gal
Tremied (Y / N): No

Zone of Natural Collapse
Type: Sand with trace gravel
Depth BTOC: 19.0' – 117.7'
Tremied (Y / N): No

Primary Filter Pack
Graduation Designation: 10/20 mesh
Grain Size: #5
Source: Global Drilling Supplies
Amt. Used: 300#
Tremied (Y / N): No

Screen
Type: Type 301 Stainless Steel
Diameter: 2 in.
Length: 10 ft
Slot Size and Type: 0.010 inch wire wrap
Interval Below BTOC: 125.96' – 135.96'

U.S. Army Corps of Engineers
Louisville District

GEO Consultants, LLC
A Geological Engineering and Environmental Services Company
Kevil, Kentucky

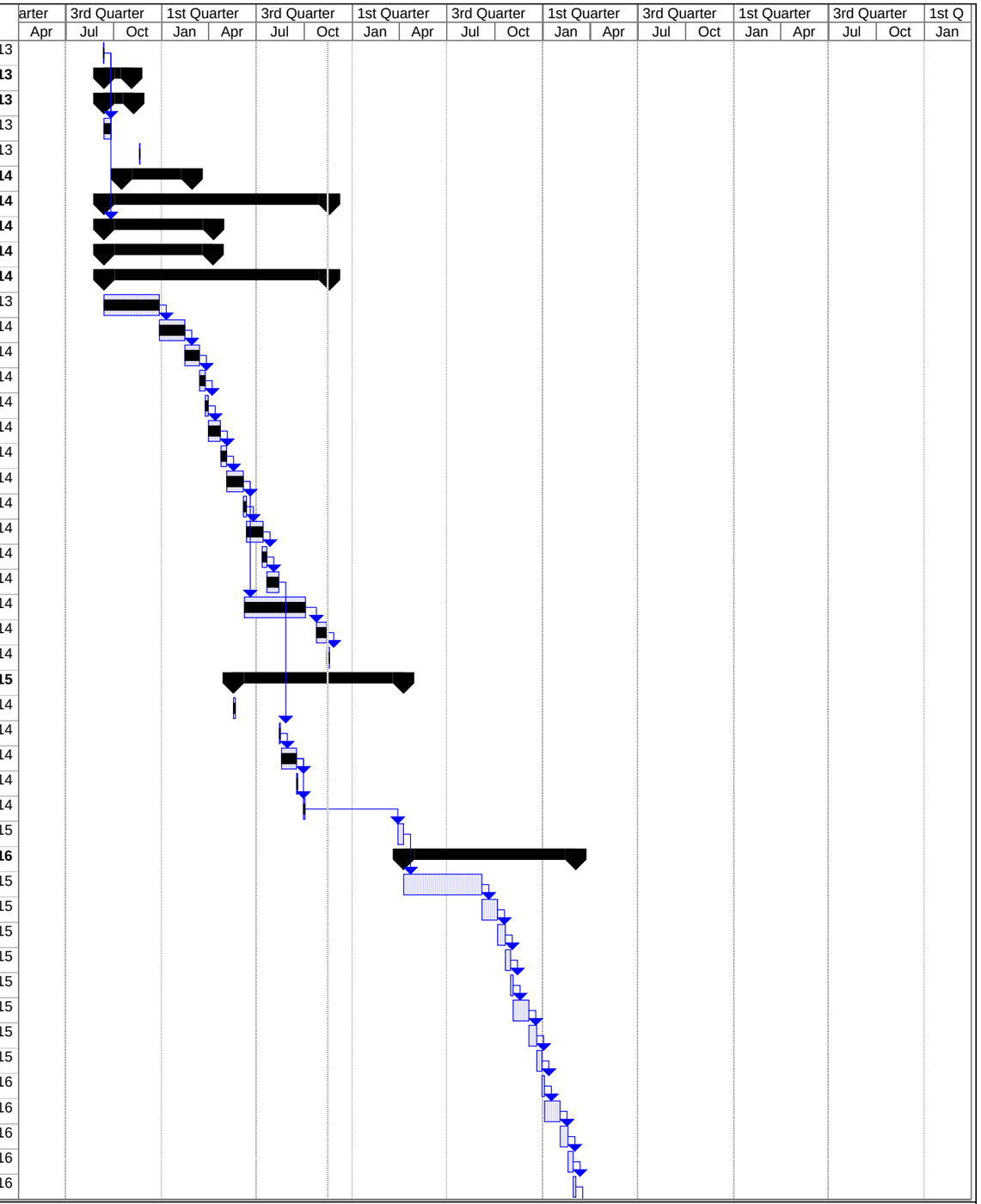
MW-27 Monitoring Well Construction Log

APPENDIX E

PROJECT SCHEDULE

THIS PAGE INTENTIONALLY LEFT BLANK

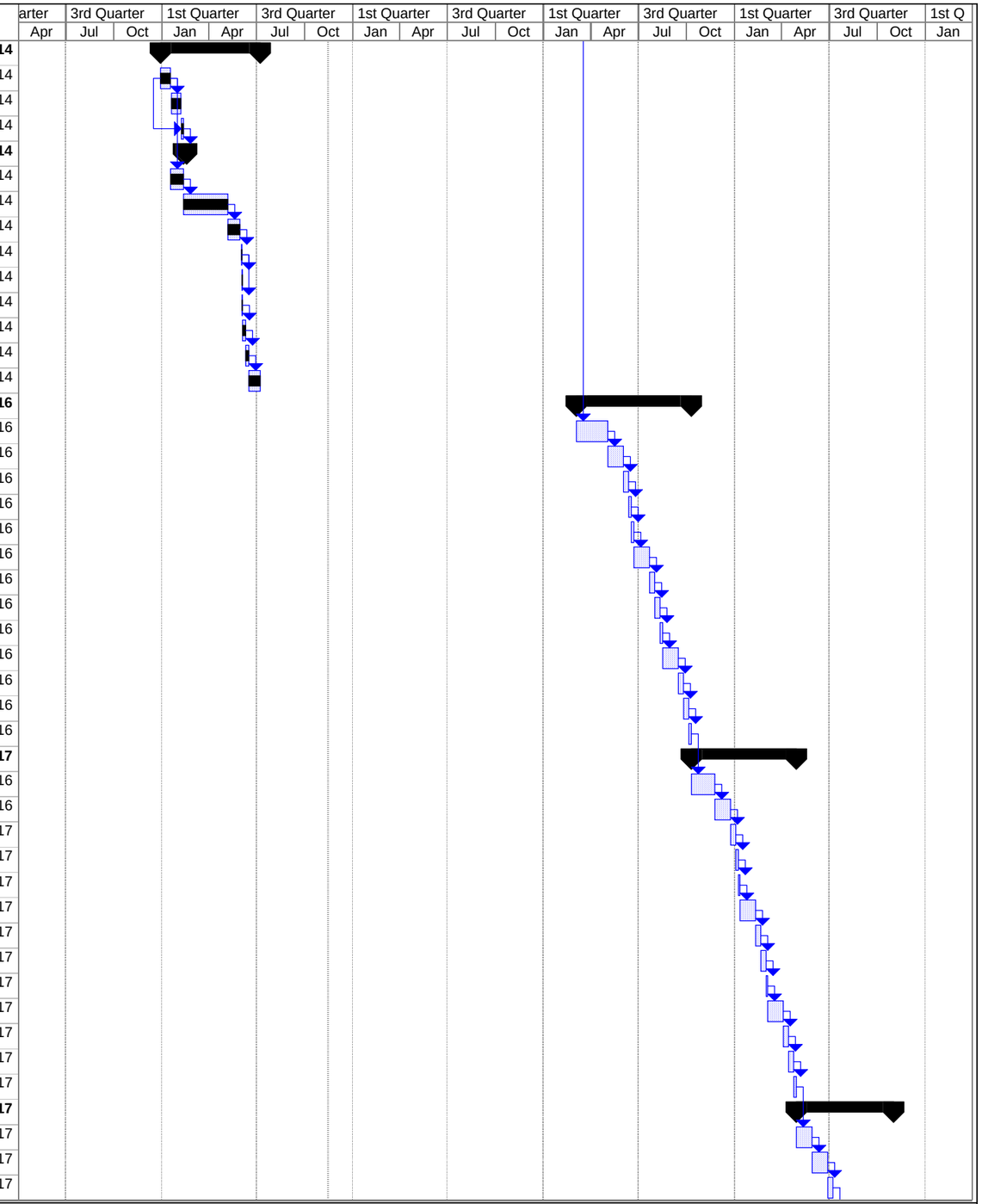
ID		Task Name	% Complete	Duration	Start	Finish
1	✓	Notice to Proceed	100%	1 day	Thu 9/12/13	Thu 9/12/13
2	✓	**Quality Control Plan (QCP)**	**100%**	**37 days**	**Thu 9/12/13**	**Mon 11/4/13**
9	✓	**Quality Assurance Project Plan (QASP)**	**100%**	**41 days**	**Thu 9/12/13**	**Fri 11/8/13**
15	✓	**Project Kickoff Meeting**	100%	14 edays	Thu 9/12/13	Thu 9/26/13
16	✓	TPP Meeting	100%	1 day	Wed 11/20/13	Wed 11/20/13
17		**Archive Search**	**92%**	**97 days**	**Wed 10/16/13**	**Sat 3/1/14**
29	✓	**Planning Documents (WP, QAPP, SAP, SSHP)**	**100%**	**308 days**	**Thu 9/12/13**	**Tue 11/18/14**
30	✓	**Planning Documents (Abbreviated WP - Verification Sampling Event)**	**100%**	**150 days**	**Fri 9/13/13**	**Thu 4/10/14**
40	✓	**Planning Documents (SSHP)**	**100%**	**149 days**	**Thu 9/12/13**	**Thu 4/10/14**
50	✓	**Planning Documents (WP, QAPP, SAP)**	**100%**	**308 days**	**Thu 9/12/13**	**Tue 11/18/14**
51	✓	Preparation and Submittal of Pre-Draft Planning Documents	100%	106 edays	Thu 9/12/13	Fri 12/27/13
52	✓	USACE Review of Pre-Draft Planning Documents	100%	49 edays	Fri 12/27/13	Fri 2/14/14
53	✓	Contractor RTC of Pre-Draft Planning Documents	100%	28 edays	Fri 2/14/14	Fri 3/14/14
54	✓	USACE Concurrence of RTCs of Pre-Draft Planning Documents	100%	11 edays	Fri 3/14/14	Tue 3/25/14
55	✓	Submittal of Draft Planning Documents	100%	6 edays	Tue 3/25/14	Mon 3/31/14
56	✓	USACE, CX Review of Draft Planning Documents	100%	23 edays	Mon 3/31/14	Wed 4/23/14
57	✓	Contractor RTC of Draft Planning Documents	100%	11 edays	Thu 4/24/14	Mon 5/5/14
58	✓	USACE, CX Concurrence of Draft Planning Documents	100%	24 days	Tue 5/6/14	Fri 6/6/14
59	✓	Submittal of Draft-Final Planning Documents	100%	6 edays	Fri 6/6/14	Thu 6/12/14
60	✓	MDEQ review of Draft-Final Planning Documents (field work)	100%	32 edays	Thu 6/12/14	Mon 7/14/14
61	✓	Contractor RTC of Draft-Final Planning Documents (field work)	100%	9 edays	Sat 7/12/14	Mon 7/21/14
62	✓	Submittal of Draft-Final R1 Planning Documents for Field Work	100%	17 days	Tue 7/22/14	Wed 8/13/14
63	✓	MDEQ Review of RTCs of Draft-Final Planning Documents (non-field work)	100%	85 days	Mon 6/9/14	Fri 10/3/14
64	✓	Contractor RTC of Draft-Final Planning Documents (non-field work)	100%	20 edays	Fri 10/24/14	Thu 11/13/14
65	✓	Submittal of Final Planning Documents	100%	5 edays	Thu 11/13/14	Tue 11/18/14
66		**Remedial Investigation (RI) Field Work**	**78%**	**234 days**	**Mon 5/19/14**	**Thu 4/9/15**
67	✓	Mobilize, conduct and demobilize - Verification Sampling	100%	4 edays	Mon 5/19/14	Fri 5/23/14
68	✓	Mobilize RI field work (Draft-Final R1 Planning Documents)	100%	2 edays	Thu 8/14/14	Sat 8/16/14
69	✓	Conduct RI field work	100%	29 edays	Mon 8/18/14	Tue 9/16/14
70	✓	Demobilize RI field work	100%	2 edays	Tue 9/16/14	Thu 9/18/14
71	✓	Mobilize, conduct and demobilize - Quarterly Sampling Event 1	100%	3 edays	Mon 9/29/14	Thu 10/2/14
72		Mobilize, conduct and demobilize - Quarterly Sampling Event 2	0%	11 edays	Sun 3/29/15	Thu 4/9/15
73		**RI Report**	**0%**	**236 days**	**Thu 4/9/15**	**Fri 3/4/16**
74		Preparation and Submittal of Pre-Draft RI Report	0%	150 edays	Thu 4/9/15	Sun 9/6/15
75		USACE Review of Pre-Draft RI Report	0%	30 edays	Sun 9/6/15	Tue 10/6/15
76		Contractor RTC of Pre-Draft RI Report	0%	15 edays	Tue 10/6/15	Wed 10/21/15
77		USACE Concurrence of RTCs of Pre-Draft RI Report	0%	10 edays	Wed 10/21/15	Sat 10/31/15
78		Submittal of Draft RI Report	0%	5 edays	Sat 10/31/15	Thu 11/5/15
79		USACE, CX, OC, USAPHC Review of Draft RI Report	0%	30 edays	Thu 11/5/15	Sat 12/5/15
80		Contractor RTC of Draft RI Report	0%	15 edays	Sat 12/5/15	Sun 12/20/15
81		USACE, CX Concurrence of Draft RI Report	0%	10 edays	Sun 12/20/15	Wed 12/30/15
82		Submittal of Draft-Final RI Report	0%	5 edays	Wed 12/30/15	Mon 1/4/16
83		MDEQ review of Draft-Final RI Report	0%	30 edays	Mon 1/4/16	Wed 2/3/16
84		Contractor RTC of Draft-Final RI Report	0%	15 edays	Wed 2/3/16	Thu 2/18/16
85		MDEQ Review of RTCs of Draft-Final RI Report	0%	10 edays	Thu 2/18/16	Sun 2/28/16
86		Submittal of Final RI Report	0%	5 edays	Sun 2/28/16	Fri 3/4/16



Project: Raco_2014_11-14
Date: Fri 11/14/14

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

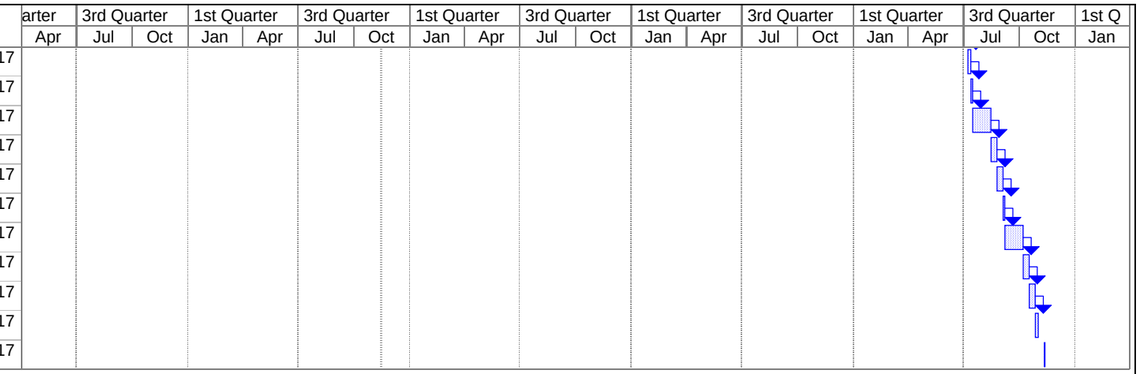
ID		Task Name	% Complete	Duration	Start	Finish
87	✓	**Public Involvement**	**100%**	**137 days**	**Mon 12/30/13**	**Tue 7/8/14**
88	✓	Community Survey	100%	15 days	Mon 12/30/13	Fri 1/17/14
89	✓	Submit Fact Sheet to Survey Respondants	100%	14 days	Mon 1/20/14	Thu 2/6/14
90	✓	Establish Administrative Record	100%	4 edays	Fri 2/7/14	Tue 2/11/14
91	✓	**Public Notice of Administrative Record**	**100%**	**4 days**	**Wed 2/12/14**	**Mon 2/17/14**
94	✓	Preparation and Submittal of Pre-Draft Public Information Plan (PIP)	100%	25 edays	Fri 1/17/14	Tue 2/11/14
95	✓	USACE Review of Pre-Draft PIP	100%	85 edays	Tue 2/11/14	Wed 5/7/14
96	✓	Contractor RTC of Pre-Draft PIP	100%	17 days	Thu 5/8/14	Fri 5/30/14
97	✓	USACE Concurrence of RTCs of Pre-Draft PIP	100%	1 eday	Mon 6/2/14	Tue 6/3/14
98	✓	Submittal of Draft PIP	100%	1 eday	Tue 6/3/14	Wed 6/4/14
99	✓	USACE Review of Draft PIP	100%	1 day	Wed 6/4/14	Wed 6/4/14
100	✓	Contractor RTC of Draft PIP	100%	6 edays	Wed 6/4/14	Tue 6/10/14
101	✓	USACE Concurrence of Draft PIP	100%	6 edays	Tue 6/10/14	Mon 6/16/14
102	✓	Submittal of Final PIP	100%	16 days	Tue 6/17/14	Tue 7/8/14
103		**Feasibility Study (FS)**	**0%**	**156 days**	**Fri 3/4/16**	**Mon 10/10/16**
104		Preparation and Submittal of Pre-Draft FS Report	0%	60 edays	Fri 3/4/16	Tue 5/3/16
105		USACE Review of Pre-Draft FS Report	0%	30 edays	Tue 5/3/16	Thu 6/2/16
106		Contractor RTC of Pre-Draft FS Report	0%	10 edays	Thu 6/2/16	Sun 6/12/16
107		USACE Concurrence of RTCs of Pre-Draft FS Report	0%	5 edays	Sun 6/12/16	Fri 6/17/16
108		Submittal of Draft FS Report	0%	5 edays	Fri 6/17/16	Wed 6/22/16
109		USACE, CX, OC, USAPHC Review of Draft FS Report	0%	30 edays	Wed 6/22/16	Fri 7/22/16
110		Contractor RTC of Draft FS Report	0%	10 edays	Fri 7/22/16	Mon 8/1/16
111		USACE, CX Concurrence of Draft FS Report	0%	10 edays	Mon 8/1/16	Thu 8/11/16
112		Submittal of Draft-Final FS Report	0%	5 edays	Thu 8/11/16	Tue 8/16/16
113		MDEQ review of Draft-Final FS Report	0%	30 edays	Tue 8/16/16	Thu 9/15/16
114		Contractor RTC of Draft-Final FS Report	0%	10 edays	Thu 9/15/16	Sun 9/25/16
115		MDEQ Review of RTCs of Draft-Final FS Report	0%	10 edays	Sun 9/25/16	Wed 10/5/16
116		Submittal of Final FS Report	0%	5 edays	Wed 10/5/16	Mon 10/10/16
117		**Proposed Plan (PP)**	**0%**	**144 days**	**Mon 10/10/16**	**Sat 4/29/17**
118		Preparation and Submittal of Pre-Draft PP Report	0%	45 edays	Mon 10/10/16	Thu 11/24/16
119		USACE Review of Pre-Draft PP Report	0%	30 edays	Thu 11/24/16	Sat 12/24/16
120		Contractor RTC of Pre-Draft PP Report	0%	10 edays	Sat 12/24/16	Tue 1/3/17
121		USACE Concurrence of RTCs of Pre-Draft PP Report	0%	5 edays	Tue 1/3/17	Sun 1/8/17
122		Submittal of Draft PP Report	0%	3 edays	Sun 1/8/17	Wed 1/11/17
123		USACE, CX, OC, USAPHC Review of Draft PP Report	0%	30 edays	Wed 1/11/17	Fri 2/10/17
124		Contractor RTC of Draft PP Report	0%	10 edays	Fri 2/10/17	Mon 2/20/17
125		USACE, CX Concurrence of Draft PP Report	0%	10 edays	Mon 2/20/17	Thu 3/2/17
126		Submittal of Draft-Final PP Report	0%	3 edays	Thu 3/2/17	Sun 3/5/17
127		MDEQ review of Draft-Final PP Report	0%	30 edays	Sun 3/5/17	Tue 4/4/17
128		Contractor RTC of Draft-Final PP Report	0%	10 edays	Tue 4/4/17	Fri 4/14/17
129		MDEQ Review of RTCs of Draft-Final PP Report	0%	10 edays	Fri 4/14/17	Mon 4/24/17
130		Submittal of Final PP Report	0%	5 edays	Mon 4/24/17	Sat 4/29/17
131		**Decision Document (DD)**	**0%**	**133 days**	**Sat 4/29/17**	**Wed 11/1/17**
132		Preparation and Submittal of Pre-Draft DD Report	0%	30 edays	Sat 4/29/17	Mon 5/29/17
133		USACE Review of Pre-Draft DD Report	0%	30 edays	Mon 5/29/17	Wed 6/28/17
134		Contractor RTC of Pre-Draft DD Report	0%	10 edays	Wed 6/28/17	Sat 7/8/17



Project: Raco_2014_11-14
Date: Fri 11/14/14

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

ID		Task Name	% Complete	Duration	Start	Finish
135		USACE Concurrence of RTCs of Pre-Draft DD Report	0%	5 edays	Sat 7/8/17	Thu 7/13/17
136		Submittal of Draft DD Report	0%	3 edays	Thu 7/13/17	Sun 7/16/17
137		USACE, CX, OC, USAPHC Review of Draft DD Report	0%	30 edays	Sun 7/16/17	Tue 8/15/17
138		Contractor RTC of Draft DD Report	0%	10 edays	Tue 8/15/17	Fri 8/25/17
139		USACE, CX Concurrence of Draft DD Report	0%	10 edays	Fri 8/25/17	Mon 9/4/17
140		Submittal of Draft-Final DD Report	0%	3 edays	Mon 9/4/17	Thu 9/7/17
141		MDEQ review of Draft-Final DD Report	0%	30 edays	Thu 9/7/17	Sat 10/7/17
142		Contractor RTC of Draft-Final DD Report	0%	10 edays	Sat 10/7/17	Tue 10/17/17
143		MDEQ Review of RTCs of Draft-Final DD Report	0%	10 edays	Tue 10/17/17	Fri 10/27/17
144		Submittal of Final DD Report	0%	5 edays	Fri 10/27/17	Wed 11/1/17
145		End Period of Performance	0%	1 day	Sun 11/12/17	Sun 11/12/17



Project: Raco_2014_11-14
Date: Fri 11/14/14

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

APPENDIX F

GEOGRAPHIC INFORMATION SYSTEMS FILES AND DATA

(ELECTRONIC ONLY ON CD AT FRONT OF DOCUMENT)

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX G

TECHNICAL MEMORANDUM, GREEN AND SUSTAINABLE REMEDIATION

THIS PAGE INTENTIONALLY LEFT BLANK

FINAL TECHNICAL MEMORANDUM

GREEN AND SUSTAINABLE REMEDIATION
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
TCE GROUNDWATER PLUME
FORMER RACO ARMY AIRFIELD AND MISSILE SITE
CHIPPEWA COUNTY, MICHIGAN

DERP-FUDS SITE NO. E05MI0026
Contract No. W912BV-10-D-2000, Delivery Order CY01

Prepared for:

U.S. Army Corps of Engineers,
Louisville District

Prepared by:

GEO Consultants, LLC
325 Kentucky Avenue, Kevil, KY 42053

November 2014

THIS PAGE INTENTIONALLY LEFT BLANK

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Notice is hereby given that an Independent Technical Review (ITR) has been conducted that is appropriate to the level of risk and complexity inherent in the project for the Green and Sustainable Remediation Technical Memorandum for the Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05M10026. During the ITR, compliance with established policy, principles, and procedures was verified. This included review of procedures to be used to create a product that meets the customer's needs, consistent with law and existing U.S. Army Corps of Engineers (USACE) policy.

Larry Copeland, P.E. Project Manager	11/05/14 Date
Craig Rightmire, P.G. ITR Team Member	11/05/14 Date
Kim Morris Quality Assurance Reviewer	11/10/14 Date

Significant concerns and the explanation of the resolution are as follows:

None.

As noted above, all concerns resulting from the independent technical review of the document have been considered.

Paul Lewers ITR Team Leader, GEO Consultants, LLC	11/09/14 Date

THIS PAGE INTENTIONALLY LEFT BLANK

1. INTRODUCTION

This memorandum identifies and evaluates progress in incorporating green and sustainable remediation (GSR) practices into the Remedial Investigation (RI)/Feasibility Study (FS), trichloroethene (TCE) Groundwater Plume, at the Former Raco Army Airfield and Missile Site located in Chippewa County, Michigan (FUDS Property No. E05MI0026). This work is being completed under Contract No. W912BV-10-D-2000, Delivery Order CY01 and includes the RI and RI Report, with optional FS (if required), Proposed Plan, Decision Document, and public involvement tasks (USACE 2013).

1.1 SITE DESCRIPTION

Raco occupies approximately one square mile and is located 18 air miles southwest of Sault Ste. Marie, Michigan, in the Hiawatha National Forest (Figure 1 and Figure 2, all figures located at the end of the document). The topography at Raco is relatively flat with elevations ranging from 900 to 920 feet above mean sea level. Groundwater flow trends toward the east in the TCE groundwater plume area.

1.2 SITE HISTORY

The Department of Defense (DoD) used the site as an airfield for 21 years and as a missile base for approximately 13 years, ending in 1972. The site consisted of a triangular-shaped airfield with 5000 foot runways and a Bomarc Missile Site containing 28 missile silos and associated support facilities (Figure 3). The site has been intermittently controlled by the DoD and its predecessor agencies since 1895. The airfield covers approximately 640 acres and was constructed between 1942 and 1943. Around 1960, the missile base was constructed on 153.54 acres of land southeast of the airfield. On January 19, 1964, the Air Force released the airfield property to the U.S. Forest Service (USFS) but retained the acreage covering the missile area. On June 30, 1973 the missile area was released to the USFS.

Since 1973, the USFS has entered into several permit agreements with outside interests. They are summarized below (Woodruff and Pearce 1989].

- 1973 – a sawmill was operated by a local Indian Tribe resulting in accumulation of a large pile (approximately 5000 cubic yards) of sawdust, wood waste, and other debris.
- 1978 – the sale and removal of seven of the base buildings, the water tower, and 28 missile silo shelters.
- 1981 and 1984 – the dumping of broken concrete and waste construction materials into the silos. This debris apparently resulted from road repair operations on Route M-28 and was used to reduce the hazard potential of public travel near open missile silos.
- Present – the airfield runways and other portions of the site are currently used during the winter months for automobile tire testing by Smithers Scientific Services, Inc. (Smithers). The buildings and water supply wells located on the northeast portion of Raco were added by Smithers. The circular tracks in the Missile Battery Area (MBA) were also added by Smithers.

With the exception of the runways and some associated tarmac/hardstands, the original structures have all been removed, and the silos have been filled in and covered. The airfield runways and other portions of the site are currently used during the winter months for automobile tire testing. The remainder of the site is vacant.

A TCE groundwater plume exists at the site and is the subject of this RI/FS. A Contamination Evaluation Study first discovered TCE in groundwater at the property in 1987. The April 2005 Site Investigation Report confirmed that a TCE plume existed in the groundwater beneath the MBA (Earth Tech 2005). A Report of Findings was completed in September 2010 indicating that there is an eastward and downward migration of the TCE plume, which is not completely delineated (GEO 2010).

1.3 PURPOSE

The purpose of the RI/FS at Raco is to investigate the potential threat to human health and the environment that may be posed by the on-site TCE groundwater plume. Based on previous investigation results and the Performance Work Statement, the sampling to be conducted as part of the RI/FS will focus on delineating the TCE groundwater plume to 5 micrograms per liter (µg/L) and collecting data of sufficient quality for completion of a Monitored Natural Attenuation (MNA) evaluation and FS.

GSR practices will be implemented when and where they are applicable. GSR employs the following strategies throughout the remedial process (USACE 2013):

- Reduce the environmental footprint of project activities
- Maximize sustainability
- Reduce waste
- Reduce energy and water usage
- Increase energy efficiency and minimize the use of non-renewable energy
- Conserve and efficiently manage resources and materials
- Promote carbon neutrality
- Reduce direct and indirect greenhouse gas and other emissions
- Promote reuse and recycling
- Fostering green and healthy communities and working landscapes which balance ecological, economic, and social goals
- Integrate the remedy with the end use where possible and encouraging green and sustainable redevelopment
- Maximize habitat value and create habitat when possible
- Protect and preserve land resources
- Minimize or eliminate pollution at its source

GSR remediation practices will be considered and implemented where practicable based on economic and social benefits and costs. In the FS, remedial alternatives will be evaluated to ensure they are efficient, are economically and fiscally sound, consider sustainable practices, and reduce the footprint of remediation systems on the environment.

This Technical Memorandum is included as an Appendix to the Work Plan (USACE 2014) and identifies GSR practices. Project tasks considered for GSR implementation are: Reports/Documents, Field Work, and Remedial Alternatives. This memorandum and will be updated and submitted after completion of the RI, FS, Proposed Plan, and Decision Document phases, as applicable.

2. GREEN AND SUSTAINABLE REMEDIATION STRATEGY

The GSR strategy for this project includes implementing sustainable considerations through best management practices (BMPs) and footprint evaluations. As a minimum, the following GSR practices and Innovative Technologies on this project include the following:

- The TRIAD approach to project planning, work strategies, and sampling and analytical technologies.
- The Site-Wise™ Tool, during the FS (if required) to quantify the environmental footprints of remedial alternatives and possibly assess the footprint of different investigation technologies during the RI planning stages.
- Completion of BMP Checklists (USACE 2012).

2.1 BEST MANAGEMENT PRACTICES

BMPs are actions or considerations that are expected to improve the environmental, social, or economic aspects of the remedial process. GSR BMPs have been developed that apply to soil, sediment, and groundwater remediation activities. Improvements for GSR can be achieved by considering BMPs and implementing those that apply to the project specific remedial process or potentially implementing alternate GSR practices identified while considering BMPs (USACE 2011).

BMPs are divided into the following categories:

A. Planning
B. Characterization of the Remedy Approach
C. Energy/Emission - Transportation
D. Energy/Emissions - Equipment Use
E. Materials and Offsite Services
F. Water Resource Use
G. Waste Generation, Disposal, and Recycling
H. Land Use, Ecosystems, and Cultural Resources
I. Safety and Community
J. Other Site-Specific BMPs

Table 1 (all tables located at the end of the document) lists the BMPs and discusses the applicability and progress made towards the BMPs. Table 2 summarizes BMP applicability and implementation.

2.2 ENVIRONMENTAL FOOTPRINT

The term 'environmental footprint' refers to the quantification of GSR parameters, such as the amount of energy used, amount of greenhouse gases emitted, and amount of potable water consumed. The environmental footprint will be evaluated as part of the FS (if prepared), Proposed Plan, and Decision Document, for remedial alternatives with active treatment and remedy selection. The SiteWise™ tool will be utilized to evaluate the environmental footprint, unless the remedial alternatives are shown to have a small footprint that is not cost-effectively analyzed by a quantitative footprint evaluation.

THIS PAGE INTENTIONALLY LEFT BLANK

3. REFERENCES

DoD (Department of Defense) 2012. Department of Defense Annual Number 4715.20, *Defense Environmental Restoration Program Management.* March.

Earth Tech (Earth Tech, Inc.) 2005. *Draft Site Investigation and Associated Activities Report.* April.

GEO (GEO Consultants, LLC 2010. *Report of Findings, Raco Army Air Force Base and Bomarc Missile Site, Remedial Investigation/Feasibility Study Activities, Hiawatha National Forest, Raco, Michigan.*

USACE (U.S. Army Corps of Engineers) 2011. *Process for Consideration and Incorporation of Process of Green and Sustainable (GSR) Practices in Army Environmental Remediation*. (Prepared by Tetra Tech EC, Inc.) May.

USACE (U.S. Army Corps of Engineers) 2012. *Detailed Approach for Evaluating GSR on Army Environmental Projects.*

USACE (U.S. Army Corps of Engineers) 2013. *Performance Work Statement for Raco TCE Groundwater Plume*. Revised August.

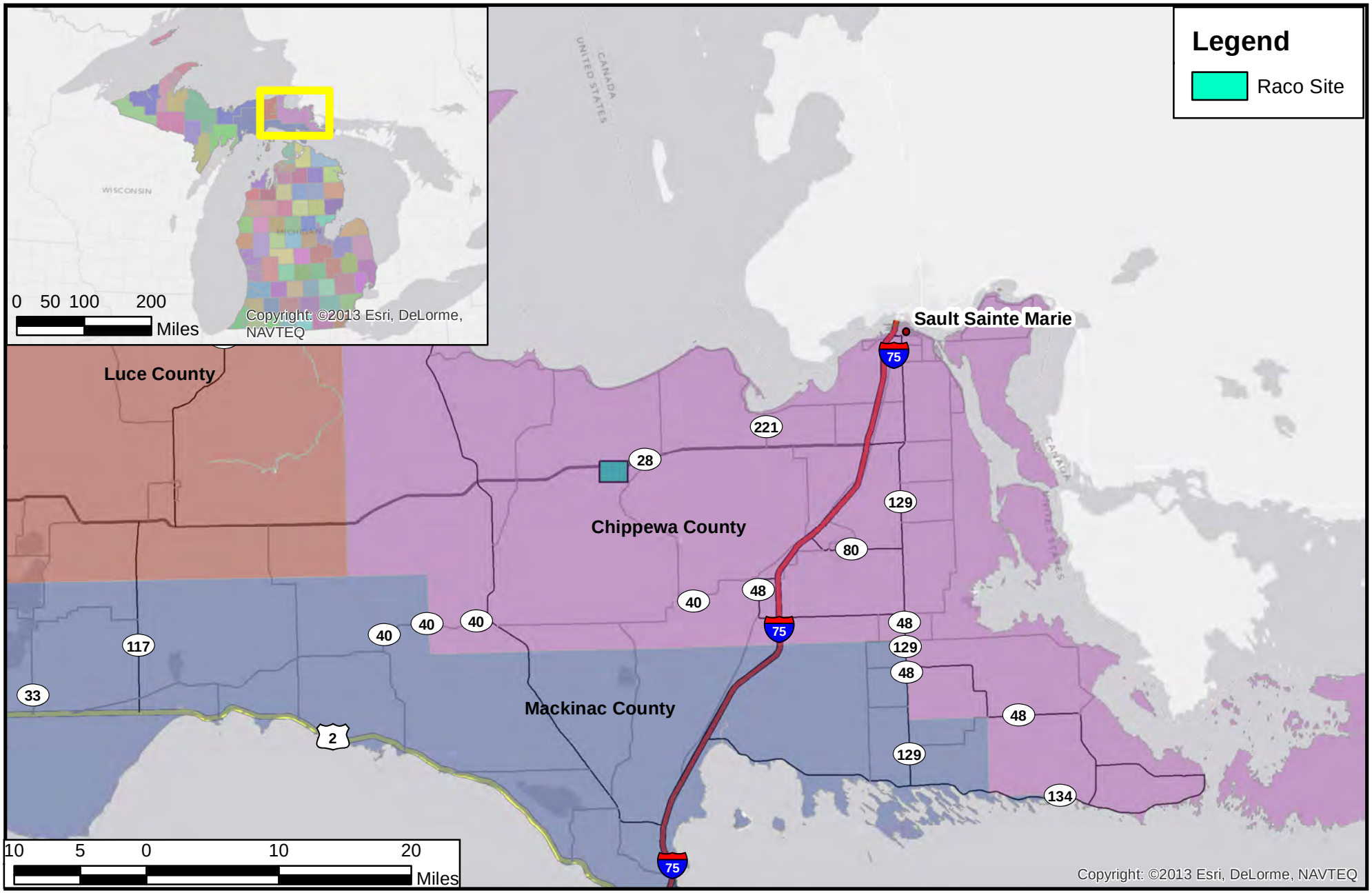
USACE (U.S. Army Corps of Engineers) 2014. Work Plan, Remedial Investigation/Feasibility Study, TCE Groundwater Plume, Former Raco Army Airfield and Missile Site, Chippewa County, Michigan, FUDS Property No. E05MI0026. Draft-Final, May.

Woodruff, C.L. and Pearce, R. 1989. *Raco, A Case Study*. USACE Detroit District and Ronald Pearce, Sault Ste. Marie Area Office, USACE Detroit District, undated but post 1989 (Case Study)]

THIS PAGE INTENTIONALLY LEFT BLANK

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK



Base map source - ©2012 ESRI, DeLorme, NAVTEQ

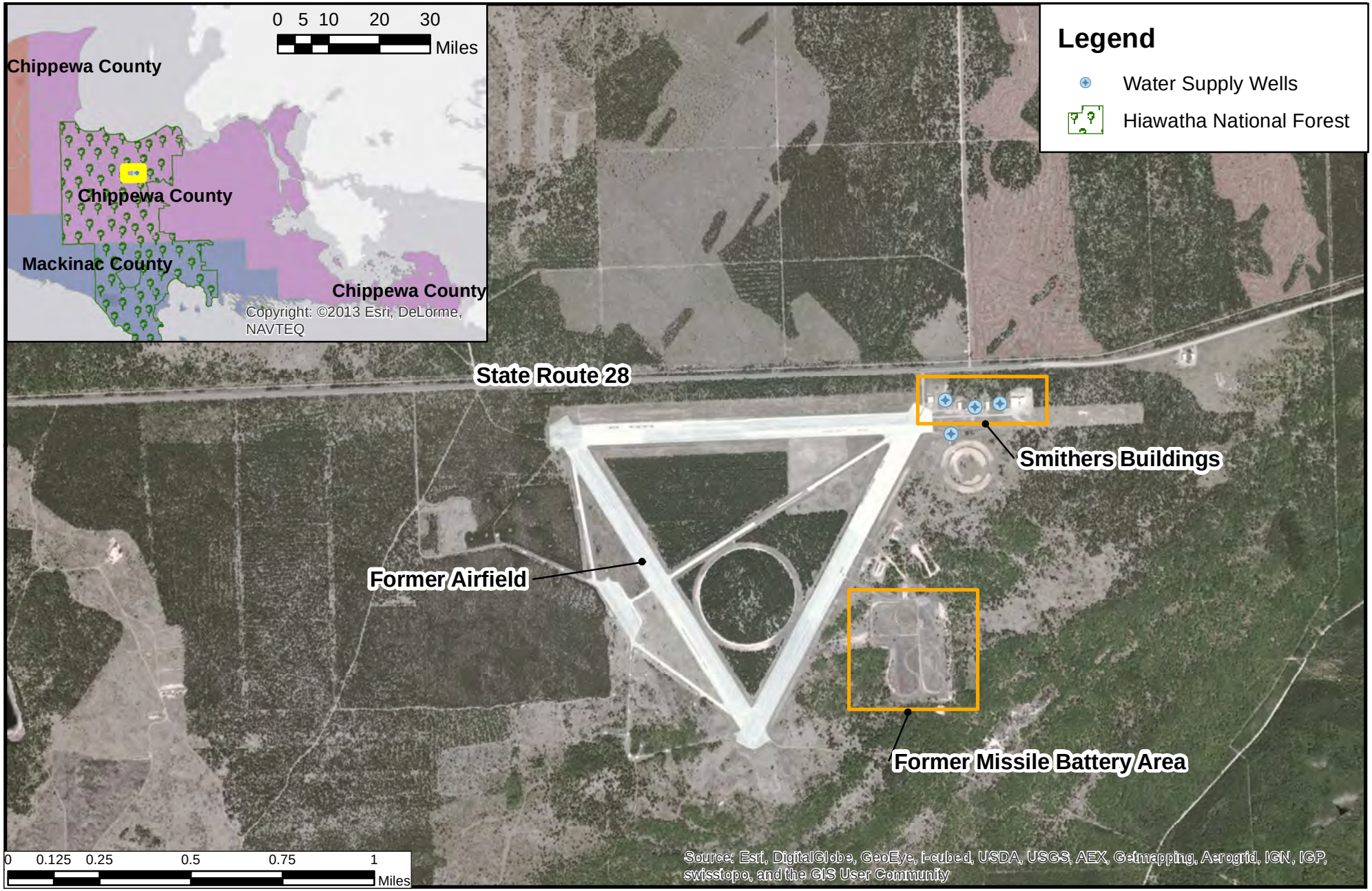
Figure 1.
Site location

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: January 2014



Base map source - ©2012 ESRI, DeLorme, NAVTEQ

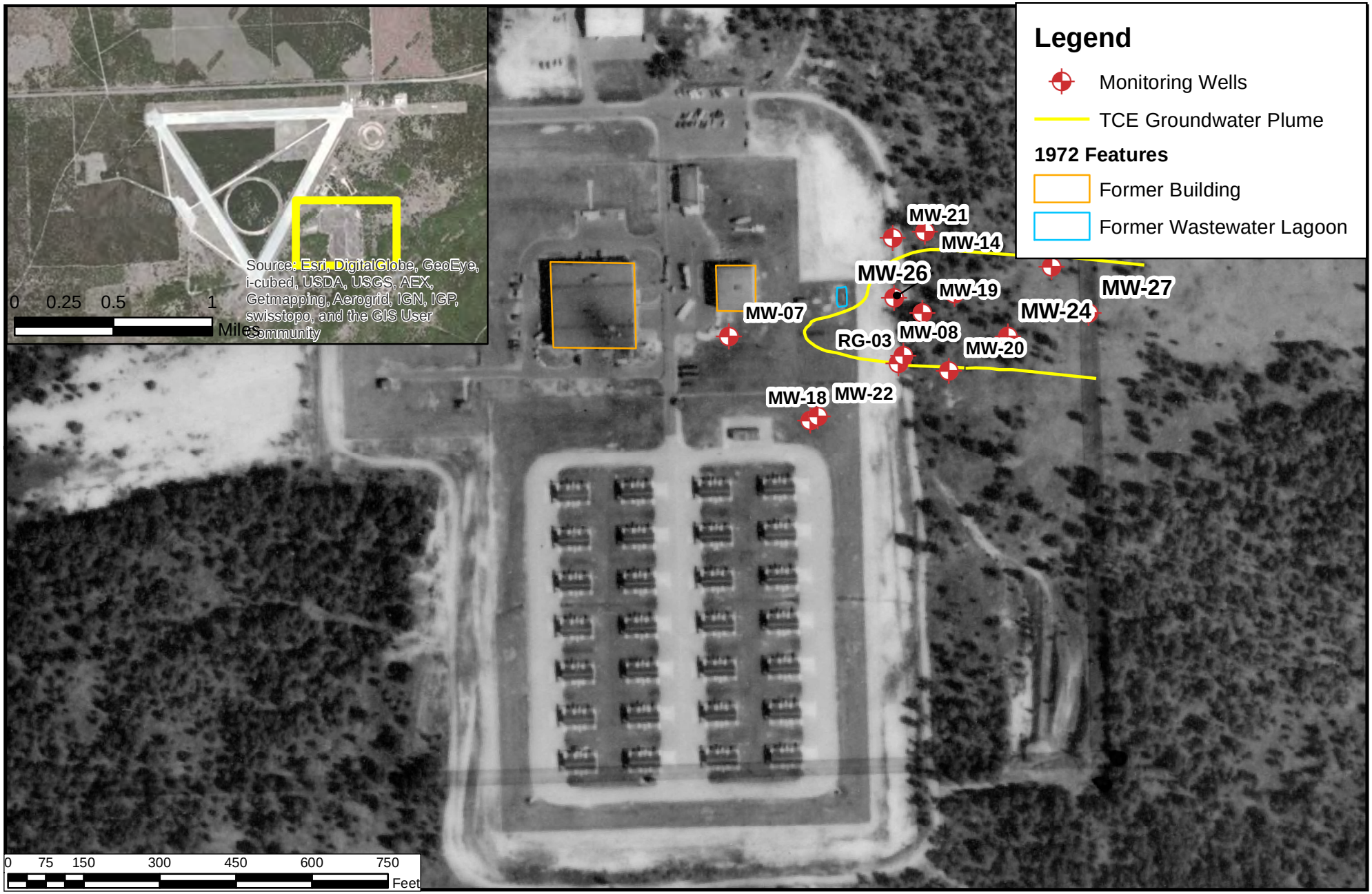
Figure 2.
Site features

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: January 2014



Base map source - Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Figure 3.
Former Missile Base Area
1972 aerial

U.S. Army Corps of Engineers
Louisville District

N

TCE Groundwater Plume, Former Raco Army Airfield and Missile Site
Chippewa County, Michigan

By: GEO Consultants, LLC
Date: April 2014

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

Table 1. Summary of Best Management Practices

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Planning	BMP A-1	Develop a culture of GSR within the project team and encourage GSR ideas from project staff, and review similar projects from other sites for possible transfer/adoption of GSR ides.	☒Applicable ☐Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	All Activities	Will utilize a GSR subject matter expert on the FS Alternatives.
Planning	BMP A-2	Incorporate a section of GSR in project meetings, Work Plans, and reports.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Documents	Work Plan to include appendix on GSR. Used double-sided printing for deliverables. Future reports will include a section on GSR.
Planning	BMP A-3	Identify and periodically update a list of key stakeholders and their concerns with respect to GSR considerations.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	All Activities	Identify and periodically update a list of key stakeholders and their concerns with respect to GSR considerations.
Planning	BMP A-4	Schedule activities for appropriate seasons and/or time of day to reduce delays caused by weather conditions and fuel needed for heating or cooling.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	All Field Work	All field work has been tentatively scheduled for Spring and Fall. Winter months restrict access to the site and would require additional fuel to keep vehicles and equipment running. Summer months, though they would allow for longer days, tend to have other environmental issues that would delay field work, such as black flies.
Planning	BMP A-5	Prepare, store, and distribute documents electronically.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Documents	Meeting agendas, meeting minutes, progress reports, and invoices are all submitted electronically. Submission of Comment Response Tables and Redline documents electronically. Documents are stored online at U.S. Army Corps of Engineers, Louisville District website to reduce the number of documents/copies included in the Library Administrative Record.
						Field Work	Field documents (boring logs, sampling data sheets) will be scanned after completion and submitted as 'electronic-only' appendices to the RI Report.
Planning	BMP A-6	Utilize teleconferences rather than meetings when feasible.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	All Activities	Teleconferences heavily utilized during discussions with regulators. Teleconferences utilized for monthly progress meetings.
Planning	BMP A-7	Incorporate green specifications into solicitations and contracts.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☒N/A or Hard to Estimate ☐To Be Determined	All Activities	Subcontractors/vendors encouraged to submit data electronically (laboratory data, reports, etc.)
Planning	BMP A-8	Integrate schedules to allow for resource sharing and fewer days of field mobilization.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	Field mobilizations optimized to reduce days in the field by planning to perform as many field tasks as possible during one mobilization (e.g., slug testing will be performed during the same field event as the groundwater sampling). In addition, near real-time, high resolution delineation technology (VAP) is being used to complete delineation in a single mobilization, eliminating the need for an iterative approach. Two drill rigs are being utilized to shorten field time.
Planning	BMP A-9	Tailor the remedy cleanup goals such that they are appropriate for anticipated end use of the property, rather than assuming a more conservative exposure scenario with more stringent cleanup goals.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Reports/Document	The more conservative residential scenario is unlikely given the site is located within a National Forest..

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Planning	BMP A-10	Conduct a thorough review of project documents and historical records to minimize required scopes of investigation.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☒Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Document	Previous documents reviewed during the proposal and technical project planning (TPP) meeting to analyze previous field efforts. Historical data were reviewed during the field work planning. From this review it was determined that the Western portion of the TCE plume was previously defined, on-site drinking water sources did not require sampling at this time, and no further soil sampling for chemical analysis is required.
Planning	BMP A-11	Use language in Work Plans, Proposed Plans, and Decision Documents that maximizes flexibility to allow GSR recommendations to be implemented.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Reports/Documents	Will be incorporated into future reports.
Characterization and/or Remedy Approach	BMP B-1	Develop and routinely update a conceptual site model (CSM) to use as a basis for making remedial process decisions.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Documents	A preliminary CSM has been created and included in the Work Plan, based on current and anticipated future use of the site, a residential scenario has not been included. The CSM will be revised as needed in future documents.
Characterization and/or Remedy Approach	BMP B-2	Perform regular optimization evaluations to improve efficiency of current or planned actions and/or develop alternative remedial approaches that might shorten remedy duration or otherwise improve the net environmental benefit of the remedy, including the use of any methodologies, such as TRIAD, systematic planning (TPP), value engineering studies, and remedial system evaluations, expected to optimize the planning and/or execution of the project.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Reports/Documents/ Remedial Alternatives	TPP conducted with regulators during Work Plan development. A dynamic work plan strategy consistent with the TRIAD approach is being applied to the positioning of new VAP boreholes. In accordance with the dynamic work strategy recommended by the TRIAD approach, the siting of VAP boreholes subsequent to the initial locations will be based on groundwater analysis for TCE and its chlorinated degradation products [cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-DCE, vinyl chloride] by an on-site mobile laboratory. Statistical software researched to determine if applicable to RI field work, currently none have been deemed appropriate. This will be revisited during the design of any potential remediation activities.
Characterization and/or Remedy Approach	BMP B-3	Use appropriate characterization or remedy approach based on site conditions.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	All Activities	Field efforts have been focused on the TCE plume and obtaining data to properly evaluate alternatives in the FS including: MNA parameters, microbial testing, and slug testing. Sonic drilling will be utilized to minimize water usage. Near real-time, high resolution delineation technology (VAP) and a mobile laboratory are being used to complete delineation in a single mobilization, eliminating the need for an iterative approach that would have required multiple mobilizations to the remote site location. A Membrane Interface Probe (MIP) equipped with a Flame Ionization or Photoionization Detector was evaluated, but the detection limits of this technology (1 mg/L) were higher than the target delineation concentration (5 µg/L). Passive monitoring of groundwater flow rates through the use of Passive Flux Meters™ was considered as a borehole dilution test method by utilizing the wait time between well development and sampling.
Characterization and/or Remedy Approach	BMP B-4	Establish decision points to trigger a change from one technology to another from one remedy alternative to another.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Reports/Documents/ Remedial Alternatives	The potential remediation activities (if required) will include decision points to switch from a passive monitoring method (considered most likely) to a more active remediation method.
Characterization and/or Remedy Approach	BMP B-5	Focus sampling efforts to meet objectives of the specific remedial phase.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Documents/ Field Work/ Remedial Alternatives	Sampling efforts are focused on plume delineation and collecting data to determine if MNA may be a feasible remedy. Reduction of sample locations and analysis to focus on the TCE plume delineation. Defining the source was eliminated from the scope based on previous investigation at likely locations and none were identified. If the plume is not expanding or impacting any receptors the source is irrelevant.

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Characterization and/or Remedy Approach	BMP B-6	Consider real-time measurements and dynamic Work Plans to reduce mobilizations and improve effectiveness of investigation efforts.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Documents/ Field Work/ Remedial Alternatives	Verification Sampling Event to determine if plume configuration has changed since previous sampling events prior to drill rig mobilization. Field plume delineation during a single field mobilization. On-site mobile laboratory during VAP boring activities to assist in field decisions regarding subsequent VAP borings and monitoring well placement. A Membrane Interface Probe (MIP) equipped with a Flame Ionization or Photoionization Detector was evaluated, but the detection limits of this technology (1 mg/L) were higher than the target delineation concentration (5 µg/L).
Characterization and/or Remedy Approach	BMP B-7	Consider the use of existing site structures/infrastructure or mobilization of temporary structures versus new construction.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Characterization and/or Remedy Approach	BMP B-8	Establish project-specific decision points to limit extent of remediation.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Reports/Documents/ Remedial Alternatives	The potential remediation activities (if required) will include decision points to alter the extent of the remediation based on changes in the TCE plume configuration (expanding, stable, contracting).
Characterization and/or Remedy Approach	BMP B-9	Consider leaving in place structures whose removal is not necessary (i.e., foundations, underground pillars, etc.).	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Energy/ Emissions - Transportation	BMP C-1	Reduce the number of trips for personnel.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work/ Remedial Alternatives	Passive monitoring of groundwater flow rates through the use of Passive Flux Meters™ was considered as a borehole dilution test to reduce field work time by utilizing an already scheduled trip to the field, as the in-ground time required for the method is the same as the wait time between well development and sampling. Slug testing scheduled to occur during the mobilization for the 1st round of groundwater sampling.
Energy/ Emissions - Transportation	BMP C-2	Reduce the number of trips and/or volume for transported materials, equipment, or waste.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work/ Remedial Alternatives	If practical, supplies shipped to local hotel, instead of shipped to Kentucky office and then transported or shipped to the site. All waste to be stored on-site until completion of field work and removed from site in a single mobilization. Low-flow sampling methodologies will be used to reduce the volume of aqueous waste. Sonic drilling will be utilized to minimize drilling fluids and soil waste.
Energy/ Emissions - Transportation	BMP C-3	Reduce trip lengths.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☒Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work/ Remedial Alternatives	Waste to be disposed at nearest appropriate facility. Waste storage containers to be purchased locally, if possible. Local subcontractors utilized where possible, currently includes: mobile laboratory, driller, surveyor. The use of two drilling rigs simultaneously will reduce the length of the VAP sampling and MW installation field mobilization.
Energy/ Emissions - Transportation	BMP C-4	Use alternate fuels or other options for transportation when possible.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field work/ Remedial Alternatives	The use of ethanol-blends and bio-diesel blends will be utilized where possible, if a local retailer can be located.

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Energy/ Emissions – Equipment Use	BMP D-1	Consider and implement approaches to minimize engine idle times.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field work/ Remedial Alternatives	Bladder pump control box can be powered by a deep-cell battery instead of an idling vehicle and will be utilized when practical. Field work scheduled during Spring and Fall to avoid requiring an idling vehicle for cooling/warmth. This will also reduce the warm-up time (idle time) of the drill rig. Power source for the mobile laboratory is available, removing the requirement of a generator.
Energy/ Emissions – Equipment Use	BMP D-2	Ensure peak operating efficiency of equipment to reduce energy use and emissions.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field work/ Remedial Alternatives	Proper equipment maintenance prior to mobilization to ensure equipment is in proper working order. Pre-planning day (length) of day for fuel savings.
Energy/ Emissions – Equipment Use	BMP D-3	Use alternate fuel options for equipment when possible.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field work/ Remedial Alternatives	The use of ethanol-blends and bio-diesel blends will be utilized where possible, if a local retailer can be located.
Energy/ Emissions – Equipment Use	BMP D-4	Select appropriate equipment and/or power source for the job.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field work Remedial Alternatives	Selection of sonic drilling rigs to complete drilling while minimizing water usage. Power source for the mobile laboratory is available, removing the requirement of a generator. This will be revisited during the design of any potential remediation activities.
Energy/ Emissions – Equipment Use	BMP D-5	Use variable frequency drives on motors (e.g., pumps, blowers), or replace oversized motors with property sized motors.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Energy/ Emissions – Equipment Use	BMP D-6	Identify options for generating renewable energy for direct use in the remedy and/or for alternate use at or near the project site.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Energy/ Emissions – Equipment Use	BMP D-7	Consider the purchase of renewable energy certificates to offset emissions from the remedial activities.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Energy/ Emissions – Equipment Use	BMP D-8	Design/modify housing required for above-ground treatment components for energy-efficiency.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Energy/ Emissions – Equipment Use	BMP D-9	For remedies that involve groundwater or air extraction, optimize extraction to reduce flow rates (potentially beneficial with respect to energy use, materials use, water resources, waste disposal, etc.).	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Energy/ Emissions – Equipment Use	BMP D-10	Consider pulsing for extraction and/or injection of water or air to maximize mass removal per unit of time or energy, by extracting higher concentrations.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Energy/ Emissions – Equipment Use	BMP D-11	Run electrical equipment during times of lower energy demand if possible (this does not reduce energy use but could use lower stress on the energy grid during periods of peak demand).	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Materials and Off-Site Services	BMP E-1	Use materials that are made from recycled materials.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Reports/Documents Field work Remedial Alternatives	Reports printed on 30% postconsumer fiber paper. Recycled products to be used during field work where feasible [personal protective equipment (PPE)]. This will be revisited during the design of any potential remediation activities.
Materials and Off-Site Services	BMP E-2	Optimize the amount of materials used.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☒Partially Implemented ☐Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Reports/Documents Remedial Alternatives	Double-sided printing used for reports/documents. This will be revisited during the design of any potential remediation activities.
Materials and Off-Site Services	BMP E-3	Utilize less refined materials when feasible.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Materials and Off-Site Services	BMP E-4	Identify opportunities for using by-products or 'waste' materials from local sources in place of refined chemicals or materials.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Materials and Off-Site Services	BMP E-5	Reduce demand on Publically Owned Treatment Works	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Water Resource Use	BMP F-1	Minimize water consumption.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work Remedial Alternatives	Sonic drillers will minimize water usage where practical. Dedicated tubing/bladder pumps in well will minimize decontamination water needed. This will be revisited during the design of any potential remediation activities.
Water Resource Use	BMP F-2	Preferentially use less refined water resources when feasible.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Water Resource Use	BMP F-3	Used extracted and treated water for beneficial purposes.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.
Water Resource Use	BMP F-4	Promote groundwater recharge.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Remedial Alternatives	This will be revisited during the design of any potential remediation activities.

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Water Resource Use	BMP F-5	Maintain water quality by preventing nutrient loading to surface water or groundwater.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work Remedial Alternatives	Spill containment and mitigation activities will be used in decontamination areas. However, if a spill were to occur, phosphate-free detergents and/or steam will be utilized for decontamination purposes and pose no risk to water quality in surface or ground water. This will be revisited during the design of any potential remediation activities.
Waste Generation, Disposal, and Recycling	BMP G-1	Minimize drill cuttings and all other investigative derived waste (including personal protective equipment).	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☒N/A or Hard to Estimate ☐To Be Determined	Field Work	Low-flow sampling methodologies will be utilized to minimize aqueous investigative-derived waste. Sonic drilling will be used to reduce the volume of drill cuttings. The first 50 feet of soil boring material from drilling activities will be segregated from other waste and will potentially be utilized for on-site disposal.
Waste Generation, Disposal, and Recycling	BMP G-2	Segregate excavated soil in pre-planned staged areas so that 'clean' material can be deposited on-site and/or reused rather than transported off-site for disposal.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work	The first 50 feet of soil boring material from drilling activities will be segregated and potentially utilized for on-site disposal.
Waste Generation, Disposal, and Recycling	BMP G-3	Consider on-site treatment and re-use of soil instead of off-site disposal.	☒Applicable ☒Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work	Plan to segregate the first 50 feet of soil boring material from drilling activities and analyze potential for on-site disposal or re-use options. This first 50 feet of material is not anticipated to exceed RCRA and Michigan Department of Environmental Quality waste definitions.
Waste Generation, Disposal, and Recycling	BMP G-4	Minimize the need to transport and dispose hazardous waste.	☒Applicable ☒Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work	The waste is anticipated to be F-listed based on how IDW from previous investigations was classified; this classification may be revised pending an ongoing historical archive search. If no records are found to warrant an F-listing then this classification will not be applied to IDW from future field activities. The first 50 feet of soil boring material is expected to be 'clean' and will be segregated and characterized separately.
Waste Generation, Disposal, and Recycling	BMP G-5	When possible avoid/minimize use of hazardous/toxic materials that may require special handling or disposal.	☒Applicable ☒Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	PPE will be used to protect personnel from exposure to the on-site chemicals, including, but not limited to sample bottle preservatives. Sample containers will be received from the laboratory pre-preserved minimizing the risk of exposure by removing the handling of bulk chemicals.
Waste Generation, Disposal, and Recycling	BMP G-6	Recycle or reuse materials rather than disposing of them.	☒Applicable ☐Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	Recycling will be utilized as much as practicable, if a nearby recycling facility can be located.
Land Use, Ecosystems, and Cultural Resources	BMP H-1	Minimize erosion and soil transport to surface water bodies.	☒Applicable ☐Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	Containment will be used in the field when erosion potentials are found.
Land Use, Ecosystems, and Cultural Resources	BMP H-2	Minimize disturbances to land.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	Traffic pathways into and within the area will be minimized. Utilize pads when appropriate to minimize sinking of heavy vehicles
Land Use, Ecosystems, and Cultural Resources	BMP H-3	Preserve/restore ecosystems to the extent possible.	☒Applicable ☐Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	Will be evaluated based on field conditions after field activities, and restored where required. Spill containment and mitigation activities. Tarp under drill rigs for potential spill containment.

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Land Use, Ecosystems, and Cultural Resources	BMP H-4	Minimize drawdown of the water table in sensitive areas such as wetlands or areas subject to subsidence.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work Remedial Alternatives	Low- flow sampling methods will minimize drawdown of the water table. This will be revisited during the design of any potential remediation activities.
Land Use, Ecosystems, and Cultural Resources	BMP H-5	Construct wells and other remedial process infrastructure (piping, buildings, etc.) to minimize restrictions to anticipated future use of the site.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work Remedial Alternatives	To the extent possible, minimize the footprint of the well and bollards and located reduce impact on traffic or mowing patterns. This will be revisited during the design of any potential remediation activities.
Land Use, Ecosystems, and Cultural Resources	BMP H-6	Preserve/restore cultural resources to the extent possible.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work	No cultural resources anticipated. Will be evaluated based on field conditions after field activities, and restored where required.
Land Use, Ecosystems, and Cultural Resources	BMP H-7	Document sensitive ecological and cultural resources prior to initiating actions that might diminish or destroy those resources.	☒Applicable ☒Evaluated ☐Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work Remedial Alternatives	No sensitive ecological or cultural resources are anticipated in the TCE groundwater plume area; however, an Ecological Site Reconnaissance is scheduled to confirm no sensitive ecological resources. This will be revisited during the design of any potential remediation activities.
Safety and Community	BMP I-1	Minimize and mitigate noise, light, and odor disturbance during all phases of the remedial process, to the extent practicable.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Field Work Remedial Alternatives	All drilling activities will take place during day light hours to minimize potential light disturbance. Two drilling rigs will be utilized simultaneously to minimize duration of noise disturbances. No odor disturbances are anticipated. This will be revisited during the design of any potential remediation activities.
Safety and Community	BMP I-2	Minimize dust during construction activities by spraying water or techniques such as laying biodegradable mats, tarps, or materials.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	/ Remedial Alternatives	During field work the applicability of dust minimization strategies will be evaluated. However, field work is not currently scheduled during dry periods and dust is not anticipated.
Safety and Community	BMP I-3	Select transportation routes for trucks and heavy equipment that minimize impacts to residential areas to maximize safety and minimize noise and other aesthetic impacts.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☒N/A or Hard to Estimate ☐To Be Determined	Not Applicable	No residential areas in the site vicinity.
Safety and Community	BMP I-4	Minimize drawdown of the water table in areas that could impact production rates at supply and/or irrigation wells.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work Remedial Alternatives	Low-flow sampling methods will minimize drawdown during sampling events. This will be revisited during the design of any potential remediation activities.
Safety and Community	BMP I-5	Minimize amount of time heavy machinery is needed to enhance safety.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work Remedial Alternatives	Two drill rigs will be used during drilling activities to minimize the length of field work. This will be revisited during the design of any potential remediation activities.
Safety and Community	BMP I-6	Minimize handling of dangerous chemicals by selecting alternate chemicals and/or engineering to minimize contact with chemicals.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work/ Remedial Alternatives	Fuel tanks will, to the maximum extent practicable, be filled at commercial gas stations and not on-site. PPE will be used to protect personnel from exposure to the on-site chemicals, including, but not limited to sample bottle preservatives.

Phase	BMP Number	BMP Description	Evaluation Status	Implementation Status	Value Evaluation	Project Task	Notes
Safety and Community	BMP I-7	Contribute to the local economy when possible.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work	Local vendors will be utilized as much as practicable (i.e., waste storage containers will be purchased locally if a vendor can be found). Currently, the planned land surveyor is a local subcontractor. The office location was a selection factor when choosing both a drilling contractor and a mobile laboratory.
Safety and Community	BMP I-8	Utilize on-site construction practices and PPE requirements for anticipated exposure scenarios rather than overly conservative level of protectiveness that is more resource intensive.	☒Applicable ☒Evaluated ☒Practical ☐N/A	☐Fully Implemented ☐Partially Implemented ☒Not Yet Implemented ☐N/A	☐Significant Cost Increase ☒Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☐To Be Determined	Field Work/ Remedial Alternatives	It is not anticipated that PPE requirements in excess of modified Level D will be required. See Site-Specific Safety and Health Plan for modified Level D requirements.
Site-Specific BMPs	BMP J-1	None identified at this time.	☐Applicable ☐Evaluated ☐Practical ☒N/A	☐Fully Implemented ☐Partially Implemented ☐Not Yet Implemented ☒N/A	☐Significant Cost Increase ☐Generally Cost Neutral ☐Significant Cost Savings ☐N/A or Hard to Estimate ☒To Be Determined	Not Applicable	None identified at this time.

Table 2. Summary of Best Management Practices Applicability and Implementation

	A. Planning	B. Characterization or Remedy of the Approach	C. Energy/ Emission – Transportation	D. Energy/ Emission – Equipment Use	E. Materials & Offsite Services	F. Water Resource Use	G. Waste Generation, Disposal, and Recycling	H. Land Use, Ecosystems, and Cultural Resources	I. Safety and Community	J. Other Site-Specific BMPs
Total BMPs	**11**	**9**	**4**	**11**	**5**	**5**	**6**	**7**	**8**	**0**
Applicable	11	7	4	4	2	2	6	7	7	0
Practicable	10	7	4	4	0	2	2	4	7	0
Implemented	**11**	**8**	**4**	**3**	**2**	**2**	**6**	**7**	**7**	**0**
Fully	1	0	0	0	0	0	0	0	0	0
Partially	8	5	0	1	0	0	0	0	0	0
Not Yet	2	2	4	3	2	2	6	7	7	0
Likely to results in significant cost savings	4	2	3	0	0	0	0	0	0	0

THIS PAGE INTENTIONALLY LAFT BLANK