EA Engineering, Science, and Technology, Inc., PBC

405 S. Highway 121, Suite C-100
Lewisville, TX 75067
Telephone: 972-315-3922
Fax: 972-315-5181
www.eaest.com

12 September 2016

Ms. Katrina Higgins-Coltrain
Task Order Monitor
U.S. Environmental Protection Agency (EPA) Region 6
1445 Ross Avenue
Dallas, TX 75202-2733

RE: Sampling and Analysis Plan (Revision 01)
Wilcox Oil Company Superfund Site
Remedial Investigation/Feasibility Study
Remedial Action Contract 2
Contract: EP-W-06-004
Task Order 0128-RICO-06GG

Dear Ms. Higgins-Coltrain:

This letter serves to notify EPA that EA Engineering, Science, and Technology, Inc., PBC (EA) has uploaded the Final Sampling and Analysis Plan (Revision 01) for the above-referenced Task Order to its SharePoint site. EA will email access instructions for the SharePoint site to EPA and ODEQ.

Please do not hesitate to contact me at (505) 224-9013 if you have any questions.

Sincerely,

Patrick Appel
Project Manager

cc: Michael Pheeny, EPA Contract Officer (letter only)
Rena McClurg, EPA Project Officer (letter only)
Todd Downham, ODEQ (email access via SharePoint)
Tim Startz, EA Program Manager (letter only)
File

Sampling and Analysis Plan

Remedial Investigation/Feasibility Study
Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma
EPA Identification No. OK0001010917

Response Action Contract 2 Full Service
Contract: EP-W-06-004
Task Order: 0128-RICO-06GG

Prepared for

U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue
Dallas, Texas 75202-2733

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
405 State Highway 121 (Bypass)
Building C, Suite 100
Lewisville, Texas 75067
(972) 315-3922

September 2016
Revision: 01
EA Project No. 14342.128

Sampling and Analysis Plan

Remedial Investigation/Feasibility Study
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12 September 2016

Patrick Appel — Date
EA Project Manager

12 September 2016

Frank Barranco, Jr., Ph.D., P.G., P.E. — Date
EA Program Quality Assurance Officer

Katrina Higgins-Coltrain — Date
U.S. Environmental Protection Agency Region 6 Task Order Monitor

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LIST OF ACRONYMS AND ABBREVIATIONS

95UCL	95% upper confidence limit of the mean
ACM	Asbestos-containing material(s)
AVS	Acid volatile sulfide
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COPC	Contaminant of potential concern
CRDL	Contract-required Detection Limit
CRQL	Contract-required Quantitation Limit
CSM	Conceptual Site Model
DESR	Data Evaluation Summary Report
DPT	Direct-push technology
DQA	Data quality assessment
DQO	Data quality objective
EA	EA Engineering, Science, and Technology, Inc., PBC
E&E	Ecology & Environment, Inc.
EDB	Ethylene dibromide
EDD	Electronic data deliverable
EDR	Environmental Data Resources Inc.
EPA	U.S. Environmental Protection Agency
ERT	Environmental Response Team
ESI	Expanded Site Inspection
FS	Feasibility Study
FSP	Field Sampling Plan
ft	Foot (feet)
GPS	Global Positioning System
HHRA	Human Health Risk Assessment
HRS	Hazard Ranking System
HSA	Hollow-stem auger
HSP	Health and Safety Plan
ICS	Incremental composite sampling
IDW	Investigation-derived waste

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

LCS	Laboratory control sample
LIF	Laser-induced fluorescence
LMS	Lockheed Martin SERAS
LNAPL	Light non-aqueous phase liquid
MCL	Maximum Contaminant Level
MD	Matrix duplicate
MDL	Method detection limit
mg/kg	Milligram(s) per kilogram
MS	Matrix spike
MSD	Matrix spike duplicate
NOAA	National Oceanic and Atmospheric Administration
NORM	Naturally-occurring radioactive materials
NWI	National Wetland Inventory
ODEQ	Oklahoma Department of Environmental Quality
OS	Original sample
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbon
PARCC	Precision, accuracy, representativeness, completeness, and comparability
PCB	Polychlorinated biphenyl
PCL	Protective Concentration Level
PPE	Probable point of entry
ppm	Part(s) per million
PSG	Passive soil gas
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RAC	Response Action Contract
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RL	Reporting limit
ROD	Record of Decision
ROST	Rapid Optical Scanning Tool
RPD	Relative percent difference
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SEM	Simultaneously extracted metals

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

SERAS	Scientific, Engineering, Response and Analytical Services
Site	Wilcox Oil Company Superfund Site
SLERA	Screening Level Ecological Risk Assessment
SOP	Standard operating procedure
SOW	Statement of Work
SQuIRT	Screening Quick Reference Tables
SVOC	Semivolatile organic compound
TAL	Target Analyte List
TCEQ	Texas Commission on Environmental Quality
TCLP	Toxicity characteristic leaching procedure
TDS	Total dissolved solids
TENORM	Technologically-enhanced naturally-occurring radioactive materials
TOM	Task Order Monitor
TPH	Total petroleum hydrocarbons
TRRP	Texas Risk Reduction Program
TSS	Total suspended solids
USGS	U.S. Geological Survey
VOC	Volatile organic compound
Wilcox Oil	Wilcox Oil Company Superfund Site
XRF	X-ray fluorescence

DISTRIBUTION LIST

U.S. Environmental Protection Agency (EPA)

Name: Michael Pheeny
Title: EPA Region 6 Contracting Officer (Letter Only)

Name: Rena McClurg
Title: EPA Region 6 Project Officer (Letter Only)

Name: Katrina Higgins-Coltrain
Title: EPA Region 6 Remedial Project Manager

Oklahoma Department of Environmental Quality (ODEQ)

Name: Todd Downham
Title: ODEQ Remedial Project Manager

EA Engineering, Science, and Technology, Inc., PBC (EA)

Name: Tim Startz
Title: EA Program Manager (Letter Only Via E-mail)

Name: Teresa McMillan
Title: EA Project Manager

Name: Luis Vega
Title: EA Alternate Project Manager

Name: File
Title: EA Document Control File

1. PROJECT DESCRIPTION AND MANAGEMENT

EA Engineering, Science, and Technology, Inc., PBC (EA) has been authorized by the U.S. Environmental Protection Agency (EPA), under Response Action Contract (RAC) No. EP-W-06-004, Task Order 0128-RICO-06GG, to conduct a Remedial Investigation (RI) at the Wilcox Oil Company Superfund Site (site or Wilcox Oil). EA has prepared this Sampling and Analysis Plan (SAP) in accordance with: (1) specifications provided in the EPA Statement of Work (SOW), dated 13 July 2015 (EPA 2015b); (2) the EPA-approved EA Work Plan, dated 31 August 2015 (EA 2015); and (3) feedback received during multiple technical exchange meetings between November 2015 and June 2016. The project activities will be conducted under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

This SAP specifically addresses the field program associated with Mobilization Event 1 (see Section 1.2.2.1). Data collected during Mobilization Event 1 will form the basis for subsequent data collection efforts (or mobilizations). EA will revise the SAP prior to any subsequent mobilizations.

This SAP is a combination Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). It details data collection methods, proposed sample locations and frequency, sampling equipment and procedures, and analytical methods required to collect sufficient data to perform a RI for the site. Combining the QAPP and FSP into the SAP allows for a streamlining of the planning process, while ensuring that the data collected are of sufficient quality for the intended use.

Upon implementation, this SAP should be used in conjunction with the site-specific Health and Safety Plan (HSP) (EA 2016), which specifies employee training, protective equipment, personal air monitoring procedures, medical surveillance requirements, standard operating procedures (SOPs), and contingency planning procedures.

This SAP was prepared in accordance with EA's Quality Management Plan (EA 2014) and meets requirements set forth in *EPA Requirements for Quality Assurance Project Plans (QA/R-5)* (EPA 2001a) and *Guidance for Quality Assurance Project Plans (QA/G-5)* (EPA 2002b).

This SAP details the project specific data quality objectives (DQOs) and describes procedures to ensure that the DQOs are met and that the quality of data (represented by precision, accuracy, completeness, comparability, representativeness, and sensitivity) is known and documented. The SAP presents the project description, project organization and responsibilities, and quality assurance (QA) objectives associated with the sampling and analytical services to be provided in support of the RI. Table 1 demonstrates how this SAP complies with elements of a QAPP currently required by EPA guidance (EPA 2001a, 2002b). DQOs were prepared in accordance with *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006a).

The overall QA objectives are as follows:

- Attain quality control (QC) requirements for analyses specified in this SAP

- Obtain data of known quality to support goals set forth for this project.

The EPA Region 6 Task Order Monitor (TOM), Ms. Katrina Higgins-Coltrain, is responsible for the project oversight. The Contracting Office for EPA Region 6 is Mr. Michael Pheeny. The Project Officer for EPA Region 6 is Ms. Rena McClurg. Upon direction, including an approved Work Plan, EA will perform RI tasks in accordance with this SAP. The EA Project Manager, Ms. Teresa McMillan and the Alternate Project Manager, Mr. Luis Vega, are responsible for implementing activities required by this Task Order. Figure 1 presents the proposed project organization for this Task Order.

1.1 SAP ORGANIZATION

This SAP is organized as follows:

- Section 1 includes the project description, document organization, problem definition and site background, a description of the project objectives and associated data quality objectives, the quality assurance objectives, and documentation that will be generated.
- Section 2 addresses data generation and acquisition, including sampling design and methodology for all media being investigated under the SAP, sample processing, handling and disposal of waste generated during the investigation and decontamination of equipment, analytical methods used, quality control, and data management.
- Section 3 incorporated details on assessment and oversight.
- Section 4 describes requirements for data validation and usability assessment.
- Section 5 contains the references cited in this SAP.

The following appendices support the implementation of the SAP:

- Appendix A Conceptual Site Model Technical Memorandum
- Appendix B Screening Criteria and CLP/Private Laboratory Reference Limits
- Appendix C Analytical Method Reference Sheets and Contract Required Quantitation Limits
- Appendix D Field Forms
- Appendix E Sanborn Maps and Historical Aerial Photographs
- Appendix F Vapor Intrusion Sampling Procedures
- Appendix G Standard Operating Procedures.

1.2 PROBLEM DEFINITION AND BACKGROUND

This section describes the following:

- Purpose of the investigation and sampling events

- Site background and description
- Previous site investigations.

1.2.1 Purpose of the Investigation and Sampling Events

The purpose of this investigation is to complete the characterization of Wilcox Oil by delineating and defining the contamination present at the site and determine if there is a risk to human health and the environment from contamination in soil, surface water, sediment, ground water, and through vapor intrusion. For this purpose, media samples will be collected for analysis so that they supplement existing data and support development of the RI. The data collected as part of the RI will support the selection of an approach for site remediation in the Feasibility Study (FS) and Record of Decision (ROD). The goal is to collect the minimum amount of data necessary to result in a well-supported FS and ROD.

1.2.2 Site Background

The Wilcox Oil site is an abandoned and demolished oil refinery and associated tank farm located north of Bristow, Creek County, Oklahoma (Figure 2) (EPA 2013a, 2015b). The approximate geographic coordinates for the site are 35°50'31" North latitude and 96°23'02" West longitude. The site spans approximately 140 to 150 acres.

The site consists of contaminated areas, including surface water bodies, due to releases from the former Lorraine and former Wilcox Refineries (Figure 3) (EPA 2013a, 2015b). Properties where refinery waste is present at the surface are fenced and secured to deter trespassing and potential contact with the waste. These refineries were located in the N ½ of the NW ¼ of S29 T16N R9E and the SW ¼ of the SW ¼ of S20 T16N R9E in Creek County, Oklahoma. Two refinery process facilities and storage tank areas once operated at the two facilities. Historical investigations indicate the presence of contamination from former activities.

A detailed title search in the Creek County Clerk office confirms that the property was used in oil refinery operations from 1915 until November 1963 (EPA 2013a, 2015b). A skimming and cracking plant was constructed in 1929. The main components of the plant consisted of a skimming plant, cracking unit, and re-distillation battery with a vapor recovery system and treatment equipment. The Wilcox Oil Company expanded when it acquired the Lorraine Refinery in 1937, which was located west of the railroad. Oil refining began in 1915 at the Lorraine Refinery. Wilcox sold the property to a private individual in 1963. Most of the equipment and storage tanks were auctioned or salvaged for scrap metal by the new property owners. Wilcox Oil Company no longer operates in Oklahoma. Based on information from the Oklahoma Secretary of States' office, the company merged with Tenneco Oil Company in 1967.

A modern skimming and cracking plant was constructed in 1929 (EPA 2013a, 2015b). The upgraded facility had an operating capacity of 4,000 barrels of crude oil per day. The main components of the system consisted of a skimming plant, cracking unit, and re-distillation battery with a vapor recovery system and continuous treating equipment. The crude oil was brought directly from the field, eliminating storage and handling facilities, but resulting in crude oil with high sediment and water.

Sanborn Fire Insurance Maps can be used to understand historical property usage (EPA 2013a). The Wilcox Oil and Gas Company and Lorraine Refining Company Sanborn Insurance Maps (provided as Appendix E to this SAP) indicate that the properties contained approximately 80 storage tanks of various sizes, a cooling pond, and approximately 10 buildings housing refinery operations. The maps also indicate that crude oil, fuel oil, gas oil, distillate, kerosene, naphtha, and benzene (petroleum ether) were all stored on the property.

After the refinery operations ceased and most of the tanks and buildings were demolished and sold for scrap, the property was sold to private interests (EPA 2013a, 2015b). Beginning in 1975 with the construction of the church, private residences were constructed on six parcels of land that were part of the former refinery operations, with the most recent being constructed in 2004. One former building associated with the refinery was repurposed as a residence. As a result, there are seven residences on the site located within former tank or refinery operation areas. Three of the residences that are located on the eastern portion of the site (East Tank Farm) are known to use water from domestic/private wells.

1.2.3 Site Description

The location of the releases from the two refineries is considered to be a single site composed of a commingled release from the combined refinery operations threatening the same targets (Lockheed Martin SERAS [LMS] 2016; EPA 2013a, 2015b). The release from the two refineries is comingled and/or the contamination is contiguous. The Wilcox Oil site is composed of a release from the combined facility operations.

The site includes remnants of former oil refining operations and tank farms (LMS 2016; EPA 2013a, 2015b). The facility can be divided into five (5) major former operational areas (Figures 3 and 4): the Wilcox and Lorraine Process Areas, the East and North Tank Farms, and the Loading Dock Area. An active railroad divides the two former process areas and product storage areas.

- Wilcox Process Area – The Wilcox Process Area is fenced and spans approximately 26 acres. Most of the equipment and storage tanks that remained onsite in 1963 were auctioned and salvaged for scrap iron by private land owners; any remaining structures are in ruins. Four aboveground storage tanks (12,500-gallon capacity each) remain standing, in addition to a number of discarded drums and pieces of scrap iron and piping. A former Lead Additive area is present that is barren. There are multiple areas of stressed vegetation, barren areas, and visible, black tarry waste of a hydrocarbon nature. A building in the northern part of the former refinery has been converted to a residence. This building is currently vacant, as is a residence located in the eastern portion of the process area; however, the occupancy status of the residences onsite may change at any time. An intermittent creek (West Tributary) flows southward across the eastern portion of the refinery process area through a small pond in the southeast corner of the Wilcox Process Area into Sand Creek. Hydrocarbon waste has also been observed in several drainage channels that empty into Sand Creek.

- Lorraine Process Area – The Lorraine Process Area spans approximately eight acres and covers the southwestern portion of the site, south of West 221st Street South (formerly Refinery Road) and west of the railroad tracks. No refinery structures remain in either the processing area or refined product storage area. The First Assembly of God Church (currently vacant), a playground, and a vacant residence (parsonage) are located in this area. Sand Creek borders the western boundary of the Lorraine Process Area. A drainage feature is located near the northwestern corner of the former process area that drains south into Sand Creek. There are multiple areas of stressed vegetation, barren soil, and visible, black tarry waste of a hydrocarbon nature. For the purposes of the RI, a portion of the North Tank Area has been re-designated as part of the Lorraine Process Area (Figure 4); the triangular-shaped section is south of Refinery Road and is located within the fenced compound that comprises the vacant First Assembly of God Church.

- East Tank Farm – The East Tank Farm spans approximately 80 acres and includes pits, ponds, and a number of circular berms that surrounded former tank locations. All of the former crude oil storage tanks have been removed; however, remnants of the former tank locations remain visible. It is not known if piping associated with the tanks remains in place underground or was removed. Many of the berms surrounding the pits, ponds, and former tanks have been breached or leveled. Of the three residential properties, two are occupied and are located on or directly next to former tank locations in the East Tank Farm. There are multiple areas of stressed vegetation, barren soil, and visible, black tarry waste of a hydrocarbon nature. The East Tributary is located along the eastern boundary of the East Tank Farm and perennially flows south through a series of ponds to Sand Creek. Magellan Midstream Partners, LP operates a pumping station in the north-central portion of the East Tank Farm Area, as well as an active pipeline that transects the East Tank Farm, Loading Dock, and North Tank Farm Areas from the southeast to the northwest. Magellan Midstream Partners, LP has been known to pump several different petroleum products through the active pipeline, including kerosene, gasoline, jet fuel, and diesel.

- North Tank Farm – The North Tank Farm is located north of Refinery Road and west of the railroad tracks and spans approximately 20 acres. The North Tank Farm included crude oil and fuel oil storage tanks associated with the Lorraine Refinery. All of the tanks and other structures have since been removed. An occupied residence is located in the center of the North Tank Farm. There are areas of stressed vegetation, and visible, black tarry waste of a hydrocarbon nature.

- Loading Dock Area – The triangular-shaped Loading Dock Area spans approximately seven acres and is located north of Refinery Road and east of the railroad tracks. The Loading Dock Area was used for loading and unloading product by rail. There are multiple areas of stressed vegetation, barren areas, and visible black tarry waste of a hydrocarbon nature.

Current access to the property is not controlled, although portions of the site are fenced (LMS 2016; EPA 2013a, 2015b). A vacant church and seven residences (four of which are occupied at

the time this SAP was written) are presently located on the facility. The seven residences are located on former crude oil storage tank or refinery operations areas. The two occupied residences located on the East Tank Farm are known to use water from domestic/private wells located onsite; the occupied residence in the North Tank Farm has a private well; however, the residence uses city water. The site is flanked by Route 66 to the west; a residential area and Turner Turnpike to the northwest and north; Sand Creek to the southwest; and residential, agricultural, and wooded areas to the east and south. The topography in the vicinity of the site slopes to the south. The drainage pattern of the property is primarily towards Sand Creek, which borders the western and southwestern boundaries of the property. An intermittent stream (West Tributary), a perennial stream (East Tributary), and several drainage channels transect the property east of the railroad (Wilcox Process Area and East Tank Farm), all of which flow into Sand Creek.

1.2.4 Historical Site Investigations

EPA and the Oklahoma Department of Environmental Quality (ODEQ) have conducted multiple investigations at the site beginning in 1994. The associated historical documents are as follows:

- Preliminary Assessment of the Wilcox Oil Company (Oklahoma Department of Environmental Quality [ODEQ] 1994)
- Expanded Site Inspection (ESI) Report – Wilcox Oil Company (Roy F. Weston 1997)
- Site Assessment Report for Wilcox Refinery (Ecology and Environment, Inc. [E&E] 1999)
- Preliminary Assessment of the Lorraine Refinery Site (ODEQ 2008)
- Site Inspection Report – Lorraine Refinery (ODEQ 2009)
- ESI Report – Lorraine Refinery (ODEQ 2010)
- ESI Report – Wilcox Refinery (ODEQ 2011a)
- Supplemental Sampling Report for Wilcox ESI (ODEQ 2011b).

Table 2 summarizes the most significant findings from these investigations.

On 24 May 2013, EPA proposed the site to the National Priorities List (NPL). On 12 December 2013, the site officially became a Federal Superfund site (EPA Identification No. OK0001010917), when it was added to the NPL.

During May/June 2015, EPA performed residential soil sampling. Areas in the proximity of 5 onsite and 4 offsite residences were sampled by collecting 5-point composites from each cell for grids comprised of 4 to 8 cells of varying size. Soil samples were collected from 0–2 inches below ground surface (bgs), 2–6 inches bgs, 0.5–1 foot (ft) bgs, and 1–2 ft bgs. Samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), pesticides, polychlorinated biphenyls (PCBs), and Target Analyte List (TAL) metals.

In October and December 2015, EPA expanded the site investigation under the Scientific, Engineering, Response and Analytical Services (SERAS) contract to include performing a geophysical survey, a Rapid Optical Scanning Tool (ROST) laser-induced fluorescence (LIF) survey, and a field-portable X-ray fluorescence (XRF) survey across portions of Wilcox and Lorraine Process Areas and the East Tank Farm. Samples of waste, soil, surface water, and infiltrated water were collected for laboratory analysis. This investigation is summarized in the following report, which was recently released:

- Trip Report (Draft): November 30 through December 16, 2015, Wilcox Oil Company Superfund Site (LMS 2016).

Data from these investigations will be used to design the RI approach; however, there are limitations with the data, as follows:

- Samples for all media were not analyzed for the full set of contaminants of potential concern (COPCs) at the site; the specific analytical suites are specified under the medium-specific discussion in this SAP.

- Detection limits for a number of historical analyses are too high in some cases to allow evaluation of data with respect to current risk-based screening levels; more recent analytical methods are able to yield lower detection limits.

- For metals and naturally-occurring radioactive materials (NORM)/technologically enhanced naturally-occurring radioactive materials (TENORM), detections are possible in all media sampled; analytical results indicate contamination likely occurred; however, no rigorous background or upstream concentrations have been derived and, for this reason, a definitive determination of presence and nature of contamination cannot be made.

- Field-portable XRF survey was performed in situ and no confirmation samples were submitted to the analytical laboratory for correlation with the field data; thus, a quantitative evaluation of the XRF data is not possible.

ROST LIF Survey (December 2015)

The ROST LIF study area covered a significant portion of the site and focused on areas where the contamination was most likely to have occurred (Lorraine Process Area, Wilcox Process Area, and East Tank Farm). The preliminary results of this survey are discussed in Section 1.2.5 for each source of contamination.

As summarized in the SERAS Trip Report (LMS 2016):

- "ROST utilizes LIF technology to introduce a laser into the subsurface. The laser excites hydrocarbon compounds, causing them to fluoresce. This fluorescence is then measured as a percent relative emittance (%RE). This %RE is based on a reference oil used to calibrate the ROST to '100%'. Different compounds and mixtures of compounds fluoresce differently. ROST uses four wavelengths of fluoresced light along with the

intensity to provide a signature waveform for each mixture of hydrocarbon compounds. This waveform can be used to identify similar compound mixtures or mixtures which fluoresce in similar ways. This process can be used to identify areas impacted by different contaminants or multiple contaminant streams."

- "ROST detects double-ring polycyclic aromatic hydrocarbon (PAH) compounds. These compounds are present in all refined fractions, e.g. gasoline, kerosene, fuel oils, and lubricating oils, which makes ROST particularly suitable for assessing these mixtures. Of notable exception, however, are single-ring aromatic compounds (e.g. benzene, toluene, ethylbenzene, and xylene, etc.), which most refineries separate into their pure forms. If there is a release of pure benzene or other single-ring compound, it would not be detected by ROST."

- "ROST results will vary depending on soil type. For example, contaminants in sands and gravels can fluoresce an order of magnitude higher than the same contaminant in silts and clays."

- "ROST detects product or non-aqueous phase liquids, not dissolved phase compounds."

Soil sampling performed in December 2015 in conjunction with the ROST LIF investigation included the following (LMS 2016):

- Twenty-three soil samples analyzed for SVOCs, VOCs, TAL metals, and total petroleum hydrocarbons (TPH)(reported as gasoline-, diesel-, and oil-range organic fractions); none of these samples were collected from the 0–2 ft bgs interval for residential exposure.

- One sand sample analyzed for SVOCs, VOCs, and TAL metals (surface sample)

- One pond discharge sample analyzed for SVOCs, VOCs, and total and dissolved metals

- Six samples coded as "ground water," but more representative of water infiltrated and ponded on top of the sandstone/clay layer, were analyzed for SVOCs, VOCs, and total and dissolved metals.

The samples collected in 2015 have not been analyzed for the full COPC suite for the site, and consequently, full characterization of the contamination at the locations sampled was not possible; moreover, heavier hydrocarbons, which are the more significant site COPCs, cannot be detected by this field screening technique. As a consequence, the ROST LIF survey output will be used as indicator data to guide the soil investigation in assessing potential source areas and delineate nature and extent of contamination at the site.

XRF Survey (December 2015)

Approximately 170 samples were analyzed for over 20 metal analytes via field-portable XRF; however, no split samples were sent to an analytical laboratory for confirmation analysis, so the XRF results are qualitative (LMS 2016).

As noted in the SERAS Trip Report (LMS 2016), "XRF technology is used to measure the concentrations of metals in soils either in-situ or in a laboratory setting. This technology uses an X-ray source to cause metals to fluoresce. This fluorescence is then detected by the XRF and resolved into concentrations of metals in the soil sample."

1.2.5 Sources of Potential Contamination

Primary sources of contamination are present at this site, ten of which were identified and evaluated in the Hazard Ranking System (HRS) Documentation Record for the site (EPA 2013a). In addition, industrial activities took place at various locations, but these locations are not identified as separate sources of contamination. This is due to the fact that significant demolition has taken place at the site and the specific locations could not be identified on a map.

Historical waste management practices are not known at this site. Historical Sanborn maps (Appendix E) were available for some areas of the site and were reviewed to identify the possible locations where contamination may have originated. Waste associated with crude oil refining may include the following: petroleum-related compounds, tank residues, crude oil, fuel oil, gas oil, petroleum distillate, kerosene, benzene, petroleum ether, brine, acid and caustic sludge, heavy metals, coke, sulfur compounds, solvents, and NORM/TENORM. Hexavalent chromium may be present where activities associated with cooling towers and cooling ponds took place. In addition, there is a possibility that PCBs and pesticides may have been used at the site, and as a consequence, they have been added to the list of COPCs. Multimedia samples will also be collected for analysis of dioxins and furans for completeness. In the case of hexavalent chromium, PCBs, pesticides, dioxin/furans, a smaller quantity of samples will be collected relative to the other COPCs, and limited to associated process areas where they are more likely to be detected. The sources of potential contamination are discussed in the following subsections.

1.2.5.1 Sources Associated with Refined Oil Operations – Lorraine Process Area

Based on available data, depth to bedrock/refusal varies widely across the Lorraine Process Area, between 3-5 ft bgs at the northwest corner to approximately 15 ft bgs for a significant portion of the process area.

The review of the 1923 Sanborn map (Appendix E) indicated the following potential source areas at the former Lorraine Refinery (LMS 2016):

- Several former aboveground storage tanks associated with refined petroleum products, including fuel oil, distillate, benzene, kerosene, and gasoline

- Former petroleum distillation process equipment that included stills, product rundown tanks, and agitator

- Former cooling tower and associated cooling pond (backfilled) that may be possible sources for hexavalent chromium.

Most tanks and stills were located on the northern portion of the property where the church, rectory, and parking lot are currently located. Storage tanks typically ranged in size from 100 to 2,000 gallons, with one 10,000-gallon fuel oil tank located on the southern portion of the property. Review of the available aerial photographs from 1941, 1956, and 1961 show no evidence of the former refinery. Review of the 1915, 1920, and 1923 Sanborn maps provide information regarding operations.

During the 2015 investigation, the ROST rig was only able to access the northern two-thirds of the process area (Figure 5). Based on the ROST-LIF data, there is widespread hydrocarbon contamination in the northern half of the Lorraine Process Area. The associated sample data indicated a wide variety of petroleum hydrocarbon mixtures: (1) a lighter hydrocarbon fraction with some heavy constituents, consistent with a fuel oil or mixed hydrocarbon product; (2) mid-range to heavy organic constituents consistent with weathered crude oil and mixed hydrocarbon material; and (3) hydrocarbon compounds consistent with a refined product in the diesel range with possible mixing with other products/hydrocarbons.

XRF analysis of soil detected percent levels of lead within 1 foot of the surface at the northwest corner of the process area and in the vicinity of the former cooling tower and cooling pond.

A drainage pathway was evident that follows the location of the original county road shown on the 1923 Sanborn and the 1941 and 1956 aerial photographs (Figure 3; Appendix E).

A former cooling pond is located on the southwestern end of the former Lorraine Process Area (Figure 3) that was buried/backfilled. According to the 1923 Sanborn Map (Appendix E), the cooling pond measured approximately 90 ft by 100 ft (9,000 square ft) and was associated with a two nearby cooling tower, petroleum distillation equipment, and storage tanks.

During the December 2015 investigation (LMS 2016), a ROST LIF survey was performed in the area where the former cooling towers were located indicating that a possible release had occurred; however, the area where the former cooling pond was located was not investigated. A soil sample collected by direct-push was collocated with ROST LIF location LOR-25A at a depth of 12–14 ft bgs to correlate with percent fluorescence signature at this ROST LIF location. The soil sample was analyzed for TAL metals, SVOCs, and VOCs, but not for hexavalent chromium. Acenaphthylene, chloroethane, and fluorene were the only organic compounds detected, with concentrations estimated below analytical reporting limits; several metals were also detected or estimated. For metals, a comparison to background values would still need to be performed in order to confirm a release has occurred. Due to the depth (>10 ft bgs) from where it was collected, this soil sample would not be used to assess human health risk; however, the results can be used for evaluation of migration to ground water.

Additional COPCs other than those for which historical samples were analyzed apply to this source area and, for this reason, the historical data will only be used as a guideline for this RI. The COPCs for this process area include VOCs, PAHs, SVOCs, TAL metals (of note, the TAL metals list includes mercury), and cyanide. Soil samples collected in the vicinity of the former cooling tower/pond would also be analyzed for hexavalent chromium. LNAPL reportedly within the onsite water supply well will also be sampled and submitted for waste characterization analysis.

1.2.5.2 Sources Associated with Refined Oil Operations – Wilcox Process Area

Based on a review of Sanborn maps and historical aerial photographs (Figure 3; Appendix E), the following potential source areas were identified in the Wilcox Process Area:

- Several former aboveground storage tanks associated with refined petroleum products, including fuel oil, distillate, gasoline, naphtha, and kerosene
- Former petroleum distillation process areas that included distillation towers, stills, product rundown tanks, and steam plant
- Ethyl Blending Area
- Lead Additive Area that included acid tanks, agitators, and treaters
- Former Cooling Water/Makeup Water Pond, which may or may not be associated with one or more former cooling towers (possible source for hexavalent chromium)
- Two Produced Water Evaporation Ponds.

Conservatively, the COPCs for these source areas are the extended COPC suite: VOCs, PAHs, SVOCs, TAL metals, and cyanide. Due to the likelihood that they are likely to be associated with former refinery process area operations, additional COPCs include hexavalent chromium, PCBs, pesticides, dioxin/furans, and NORM/TENORM.

Historical data available for these source areas and their immediate vicinity are presented below and shown in Figure 3.

<u>Former Locations of Tank 18 and Tank19</u>

- Tanks 18 and 19 were located within the same bermed area.
- 1999: One boring (SB19) was installed southeast of this source area; two soil samples were collected from 1–2 ft bgs and 7–8 ft bgs. All samples were analyzed for benzene, toluene, ethylbenzene, and xylene (BTEX), PAHs, TPHs, metals, and pH. The surface soil sample contained several PAHs, TPH, and estimated concentrations of ethylbenzene, xylenes, and toluene. In the deeper sample, only one PAH was detected at an estimated concentration; however, the detection limits for PAHs were relatively elevated. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).

- 2015: One location by ROST LIF; no contamination was noted in this boring, but data are insufficient for a conclusive determination (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Locations of Tank 20 and Tank 21

- Tank 20 and Tank 21 were located within the same bermed area.
- 2015: ROST LIF data indicate contamination is present, but data are insufficient to delineate contamination (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Locations of Tanks 22 through 29

- Tanks 22 through 29 were located within the same bermed area.
- 2011: A soil sample (SS-3) collected during the ESI (ODEQ 2011a) that may have been located within this source area; several PAHs were detected.
- 2015: ROST LIF data indicate contamination is present, but data are insufficient to delineate contamination. One direct-push soil sample was collected from the south side of this source area between 7 to 10 ft bgs and analyzed for VOCs, SVOCs, and metals. Metals, VOCs (BTEX, chloroform, cyclohexane, 1,2-dichloropropane, isopropylbenzene, and methylcyclohexane), several PAHs, and dibenzofuran were detected in this sample (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Locations of Tank 30 and Tank 31

- 2011: A soil sample (SS-4) collected during the ESI (ODEQ 2011a) may be located within this source area; several PAHs were detected.
- ROST LIF data indicate contamination is present, but data are insufficient to delineate contamination (LMS 2016).

Former Locations of Tank 32 and Tank 33

- In the 1961 Sanborn map (EDR 2012) and older aerial photography, 10 smaller tanks were identified between these two tank locations.
- The presence or absence of contamination at this source area has not been confirmed.

Former Location of Tank 34

- 1999: One soil boring (SB14) was installed in the vicinity of this source area to the north-northeast; soil samples were collected form 1–2 ft bgs and 5–6 ft bgs. Soil samples were analyzed for BTEX, PAHs, TPH, metals, and pH. Both soil samples exhibited estimated detections of several PAHs and TPH. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in

this area (E&E 1999).

- 2015: This location was investigated by ROST LIF, which confirmed the presence of contamination; however, the extent of contamination has not been fully delineated with this technology. One direct-push soil sample was collected from this source area from 6-8 ft bgs and analyzed for VOCs, SVOCs, and metals. Metals, VOC (BTEX, chloroform, cyclohexane, isopropylbenzene, and methylcyclohexane) and several PAHs were detected in this sample (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Location of Tank 35

- 2015: This location was investigated by ROST LIF and the presence of contamination is confirmed to the southeast; however, the extent of contamination has not been delineated with this technology (LMS 2016).
- The nature and extent of contamination in this source area is not defined.

Former Location of Tank 36

- 2015: This location was not investigated by ROST LIF.
- The presence or absence of contamination in this source area has not been confirmed.

Former Location of Tank 37

- 2015: This location was investigated by ROST LIF and no evidence of contamination has been confirmed (LMS 2016).

Lead Additive Area (Doctor Process Area)

- This location was initially suspected to be a fuel additives area (e.g., tetraethyl lead); however, further investigation indicates that area was more likely where the doctor process occurred to sweeten refined petroleum products (remove odorous mercaptans and other sulfur compounds).
- 2011: Analysis of surface soil samples detected lead concentrations ranging from 43,600 to 50,000 mg/kg (ODEQ 2011a).
- 2015: Field XRF investigation detected percent levels of lead in soil that attenuated with depth. Analysis of soil boring samples detected high levels of phenolic compounds. Analysis of water collected from piezometers detected concentrations of total and dissolved lead as high as 151,000 and 3,860 µg/L, respectively (LMS 2016).

1.2.5.3 Sources Associated with Crude Oil Operations – East Tank Farm and Wilcox Process Area

Several sources were identified as associated with crude oil storage based on Sanborn maps (Appendix E). These sources are the locations of former crude oil storage tanks where spills may have occurred. In many cases, the tank berms used to contain crude oil spills are still evident, as well as is waste consisting of an asphaltic or tar-like hydrocarbon material. Most of

the crude oil storage tanks were located within the East Tank Farm; however, two tanks (Tanks 11 and 12) were located on the eastern portion of the Wilcox Process Area (Figure 3). The area of each tank berm area was estimated based upon the Sanborn maps and historical aerial photographs (Appendix E).

The COPCs for these source areas are VOCs, PAHs, SVOCs, TAL metals, and cyanide.

Historical data available for these source areas and their immediate vicinity are presented below and are shown in Figure 3.

Former Location of Tank 2

- This is the current location of Pond 4, which will also be investigated to assess impacts to surface water and sediment.
- The presence or absence of contamination at this source area has not been confirmed.

Former Location of Tank 3

- 1999: One boring was installed within the area of the source (SB05); three samples were collected from 1–2 ft bgs, 4–5 ft bgs, and 14–15 ft bgs. Five (5) additional borings (SB41 through SB45) were installed east, southeast, and south of the source area, and samples were collected from depths varying from 2–3 ft bgs to 6–7 ft bgs. All samples were analyzed for BTEX, PAHs, TPH, metals, and pH. Petroleum-odor was noted in SB05 and a hydrocarbon sheen was observed on the infiltration water that accumulated in the bottom of this boring. In all 3 soil samples collected from SB05, benzene, ethylbenzene, xylenes, several PAHs, and TPH were detected. Although no organics were detected in the samples collected from borings SB41 through SB45, the detection limits for PAHs were elevated and the heavier TPH fractions were not reported. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).
- 2010: A sample called “waste” was collected from the center of the tank location; only metals were detected. The sample was also analyzed for VOCs and SVOCs (ODEQ 2010).
- 2015: ROST LIF data indicate the presence of contamination in the center of this source; however, the presence of contamination is not delineated with this technology to the north, northeast, and east (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Location of Tank 5

- Early 2000s: The property owner confirmed that he dug the two existing onsite ponds.
- 2015: During the June 2015 residential soil sampling event, an oily sludge was observed at 1 and 1.5 ft bgs in the vicinity of former Tank 5. ROST LIF data indicate the presence of contamination at this location to the east; however, the presence of contamination is not delineated with this technology to the north, south, and west (LMS

2016).

- The nature and extent of contamination at this source area is not defined.

Former Location of Tank 6

- 2010: A sample called "waste" was collected from the center of the tank location for analysis of metals, VOCs, and SVOCs; only metals were detected (source) (ODEQ 2010).
- 2015: ROST LIF data do not indicate the presence of contamination at this location (LMS 2016).
- The presence or absence of contamination at this source area is not confirmed.

Former Location of Tank 7

- 2015: ROST LIF data do not indicate the presence of contamination at this location (LMS 2016).
- The presence or absence of contamination at this source area is not confirmed.

Former Location of Tank 8

- 1999: One soil boring (SBX) was installed to the northwest of the source area; however, no samples are reported to have been analyzed per Table 4.1 of the report (E&E 1999).
- 2010: A sample called "waste" was collected from the center of the former tank location. Metals and several PAHs were detected, although VOCs were not (ODEQ 2010).
- 2015: ROST LIF data do not indicate the presence of contamination at this location but the survey was limited (LMS 2016).
- The presence or absence of contamination at this source area is not confirmed.

Former Location of Tank 9

- 1999: One boring was installed to the southwest of the source area berm (SB06), with a soil sample collected from 1–2 ft bgs and analyzed for BTEX, PAHs, TPH, metals, and pH. Several PAHs were detected in the surface soil sample from SB06. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).
- 2010: A sample called "waste" was collected from the center of the former Tank 9 location. Metals and several PAHs were detected, although VOCs were not (ODEQ 2010).
- 2015: ROST LIF data do not indicate the presence of contamination at this source area; however, no ROST LIF points were installed to the west of the source area, where soil boring SB06 appears to have been installed in 1999 (LMS 2016).

- The nature and extent of contamination at this source area is not defined.

Tank Farm Area 10

- Currently, this area is partially covered with a sludge-like material.
- 1999: Waste was disposed of at this location; this area is described as a pit in the 1999 report (E&E), and the existence of a tank has never been confirmed. Two borings were installed: SB07 southwest of the berm, with a soil sample and a field duplicate collected from 4–5 ft bgs; and SB09 south of the source, with a sample collected from 1–2 ft bgs. The samples were analyzed for BTEX, PAHs, TPH, metals, and pH. Select PAHs were detected in both samples. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area.
- 2015: Due to the presence of waste sludge material at this source, the investigation by ROST LIF was limited in nature. Although the presence of contamination was confirmed at this location, delineation was not completed. From the aerial photographs, it appears this area was intended for use as a tank pad; however, it was apparently repurposed, as a separation pond or waste storage area (LMS 2016).
- The nature and extent of contamination at this source area is not defined, and characterization of the waste sludge is also necessary.

Former Location of Tank 11

- 1999: One boring (SB11) was installed within the area of the source within the berm, with a soil sample collected from 2–3 ft bgs. The sample was analyzed for BTEX, PAHs, TPH, metals, and pH. In all these soil samples, several PAHs were detected. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).
- 2015: ROST LIF investigation was focused in the center of the source area and to the south; the data indicate the presence of contamination in the center of this source. However, the presence of contamination is not delineated using ROST LIF to the northeast, east, and south. ROST LIF was not used in the location of the former 1999 boring location for SB11. Two direct-push soil samples were collected from this source area between 5 and 10 ft bgs and were analyzed for VOCs, SVOCs, and metals. Metals, three VOCs (cyclohexane, isopropylbenzene, and methylcyclohexane) and several PAHs were detected in these samples (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Location of Tank 12

- 1999: One boring (SB12) was installed in the southern portion of this source area within the berm; two soil samples were collected from 1–2 ft bgs and 8–9 ft bgs. The samples were analyzed for BTEX, PAHs, TPH, metals, and pH. No organic compounds were detected in this sample; however, the detection limits for PAHs were elevated and the heavier TPH fractions were not reported for this sample. The detections of metals have

not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).

- 2015: ROST LIF data indicates the presence of contamination at this location; however, the source area was not delineated using ROST LIF technology. Three direct-push soil samples were collected from this source area from between 7 and 10 ft bgs and analyzed for VOCs, SVOCs, and metals. Metals, two VOCs (cyclohexane and isopropylbenzene), and several PAHs were detected in two of the samples, while only phthalates were detected in the third sample (LMS 2016).
- The nature and extent of contamination at this source area is not defined.

Former Location of Tank 13

- 2015: ROST LIF data do not indicate the presence of contamination at this location (LMS 2016).
- The presence or absence of contamination at this source area is not confirmed.

Former Location of Tanks 14 through 17

- These four aboveground storage tanks appear to have been located within the same bermed area.
- This source area was not investigated in the past.

1.2.5.4 Sources Associated with Crude Oil and Refinery Operations – North Tank Farm and Loading Dock Area

Based on a review of Sanborn maps (Appendix E), several former aboveground tanks were identified as sources associated with crude oil and fuel oil storage. No information is available regarding the raw materials or products managed at the Loading Dock Area. Past investigations did not include any sampling activities in either of these areas. Conservatively, the COPCs for these source areas are the extended COPC suite: VOCs, PAHs, SVOCs, TPH, TAL metals, and cyanide.

1.2.5.5 Sources Not Anticipated to be Associated with Refining Activities – East Tank Farm

Review of historical aerial photographs indicates that two locations on the extreme eastern boundary of the East Tank Farm may have been cleared for additional crude oil storage tanks; however, no historical data indicate that tanks were constructed or industrial activities took place in this area.
Due the low likelihood that these areas may have been used for industrial operations, the COPCs for these source areas are limited to VOCs, PAHs, SVOCs, TPH, TAL metals, and cyanide.

Results of historical investigations at these source areas are summarized below.

Unconfirmed Location of Tank 1

- 1999: No samples were collected from within the estimated footprint of this unconfirmed source area. However, three soil borings (SB36, SB37, and SB38) were installed in the vicinity of this potential source area, which is a cleared location where Tank 1 may or may not have been located. Samples collected from the subsurface (6–7 ft bgs) from SB36 and SB37, and from the surface (0–1 ft bgs) at SB38 were analyzed for BTEX, PAHs, TPH, metals, and pH. No detections of organic compounds were noted, but the detection limits for PAHs were relatively elevated and the heavier TPH fractions were not reported. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).
- 2015: This area was not investigated in 2015.

Unconfirmed Location of Tank 4

- 1999: No samples were collected from within the estimated footprint of this unconfirmed source area. However, two soil borings (SB39 and SB40) were installed in the vicinity of this potential source area, which is a cleared location where Tank 4 may or may not have been located. Samples collected from the subsurface (3-4 ft bgs) from each of these borings were analyzed for BTEX, PAHs, TPH, metals, and pH. No detections of organic compounds were noted, but the detection limits for PAHs were relatively elevated and the heavier fractions of TPHs were not reported. The detections of metals have not been evaluated, as a background concentration is not available to determine if a release has occurred in this area (E&E 1999).
- 2015: This area was not investigated in 2015.

1.2.5.6 Waste Sources

Several waste piles or areas of exposed waste material have been observed onsite. Waste piles located in the following areas will be investigated to include assessing subsurface soil for contaminant leaching:

- Waste observed within the former location of crude oil storage tank in North Tank Farm
- Waste observed along the railroad tracks in the Loading Dock Area
- Waste pit (Former Pond 1) located in the East Tank Farm
- Waste observed within the former location of Tank 10 in the East Tank Farm
- Waste observed in drainage pathways leading from process areas to Sand Creek.

The COPCs for waste are: VOCs, ethylene dibromide (EDB), PAHs, SVOCs, TPH, TAL metals, and cyanide. Due to the likelihood that these waste piles or areas may be associated with former refinery process area operations, additional COPCs include PCBs, pesticides, dioxins/furans, and NORM/TENORM.

Previous work conducted within specific waste source areas that will be characterized are summarized below.

Former Location of Pond 2

- 1999: Three soil borings were installed in the vicinity of this source: SB08 with a sample collected from 1–2 ft bgs, SB35 with a sample collected from 0 to 3 ft bgs, and SB46 with a sample collected from 6–12 ft bgs. Samples were analyzed for BTEX, PAHs, TPH, and metals. Only metals and an estimated, biased high concentration for pyrene in SB35 were detected in these samples (E&E 1999).
- 2015: One soil sample (P-03-SAND) was collected from the southwest side of this area from the surface (0 ft bgs) and was analyzed for VOCs, SVOCs, and metals. Only metals were detected in this sample (LMS 2016).

Former Location of Pond 1

- 1996: Two waste samples were collected from tar-like seeps on the surface of the former pond; VOCs and SVOCs were detected in samples, with some PAHs at concentrations above current EPA residential risk-based screening levels (Weston 1997).
- 1999: Three soil borings were installed in the vicinity of this source: SB02 with a sample collected from 1–2 ft bgs, SB03 with a sample collected from 1.5 to 2 ft bgs, and SB04 with a sample collected from 4–5 ft bgs. Samples were analyzed for BTEX, PAHs, TPH, and metals. Only metals were detected in these samples (E&E 1999).
- 2015: Test pits were excavated around the perimeter of the former pond. One soil sample (P-04-01) was collected from within the source area from 3.5 to 4.5 ft bgs and analyzed for VOCs, SVOCs, and metals. Metals, several PAHs, and dibenzofuran were detected in this sample (LMS 2016).

Additional waste samples were collected from the East Tank Area in 2010 (ODEQ 2010); there is insufficient information to determine if these samples were of contaminated soil or actual waste material, as no description of the sample matrix is available. The samples were analyzed for VOCs, SVOCs, and metals, and several PAHs were detected in two of the samples.

1.2.5.7 Sources Not Differentiated

Conservatively, the COPCs for these source areas are the extended COPC suite: VOCs, EDB, PAHs, SVOCs, TAL metals, and cyanide. Due to the likelihood that these source areas may be associated with former refinery process area operations, additional COPCs include PCBs, pesticides, dioxins/furans, and NORM/TENORM.

In addition to the waste areas identified above, there are other historical sources of contamination located within Wilcox and Lorraine Process Areas, as well as in the East Tank Farm. However, due to the significant demolition that took place at the site over the years, as well as changing of tank placement and storage area configurations in the East Tank Farm, specific locations could not be identified. Other areas that may have been impacted by site COPCs include the drainage pathways leading from source areas to the surface water bodies. The most prominent of these drainage pathways lead from the Wilcox Process Area and East

Tank Farm southward to Sand Creek. These remaining areas will be characterized in a different manner than the distinct source areas. Throughout the investigation, the field crew will make observations regarding the presence of underground features, such as buried piping that was not identified during the 2015 geophysical survey.

Additional analytical data for soil samples collected from the Wilcox Process Area are summarized below:

- 1999: BTEX, PAHs, and TPH were detected in soil samples collected from numerous locations, many of which were generally shallow (within the 0-3 ft bgs interval) (E&E 1999).

- 2015: In addition to the samples discussed above, nine soil samples were collected from this area at depths spanning 5 to 15 ft bgs; samples were analyzed for VOCs, SVOCs, and metals. VOCs (benzene, isopropylbenzene, and xylenes) and phenol (an SVOC) were detected in two of these samples (WIL-AA-10 and WIL-AA-11) that were collected from the vicinity of the lead mixing area. In the remainder of the samples, metals, VOCs (acetone, BTEX, 2-butanone, cyclohaxane, 1,2-dichloropropane, isopropylbenzene, methylcyclohexane, and methylene chloride), several PAHs, and several SVOCs (1,1'-biphenyl, 1,4-dioxane, bis[2-ethylhexyl]phthalate) were detected (LMS 2016).

Additional analytical data for soil samples collected from the Lorraine Process Area in 2015 are summarized below:

- In addition to the samples discussed above, four soil samples were collected from this area at depths spanning 6 to 14 ft bgs. Metals, VOCs (cyclohexane, isopropylbenzene, and methylcyclohexane), several PAHs, and dibenzofuran were detected in these samples (LMS 2016).

1.3 DESCRIPTION OF PROJECT OBJECTIVES AND TASKS

This section describes the project objectives and tasks for this SAP.

1.3.1 Project Objectives

The primary objectives of the RI are to characterize source material; determine the nature and extent of contamination; evaluate fate and transport of contamination and the migration pathways; conduct human health and ecological risk screenings; and, if risk screenings indicate exceedances of the conservative screening levels or background/reference values, perform human health and ecological risk assessments to determine if a risk is present from former site operations. Ultimately, the goal is to gather sufficient information so that the EPA, in case of a risk remaining at the site, can select a remedy that eliminates, reduces, or controls risks to human health and the environment. The following components are considered key to conducting a RI for the site:

- Data collection for media characterization for definition of nature and extent of contamination; collection of other supporting data

- Risk screening, and if necessary, performance of risk assessments for human health and the environment

  — Human Health Risk Assessment (HHRA) to characterize and quantify the current and potential human health risks that would prevail if no remedial action were taken.

  — Screening Level Ecological Risk Assessment (SLERA) to characterize and quantify the current and potential ecological risks.

- Production of a RI Report that accurately establishes site characteristics, including identification of source materials as applicable, definition of the nature and extent of contamination, and evaluation of migration pathways. The RI provides information to assess risks to human health and the environment, and to support the development, evaluation, and selection of appropriate response alternatives.

- Project Close-out includes the activities necessary to close out the Task Order in accordance with contract requirements.

1.3.2 Project Tasks

The following RI components will be completed upon EPA direction:

- Project planning and support
- Field investigation/data acquisition
- Sample analysis
- Analytical support and data validation
- Data evaluation
- Risk assessment
- RI Report preparation
- Task order closeout.

Based on the preliminary review of the data, it is proposed that the RI be performed in several mobilizations, such that the need for data collection for mobilization 2 and 3, if necessary, is based on the results of the previous mobilization. The staging of the investigation is presented below.

1.3.2.1 Mobilization Event 1

Mobilization Event 1 will include the following field activities:

1. Assist the EPA Environmental Response Team (ERT) with passive soil gas (PSG) investigation of Lorraine Process Area, Wilcox Process Area, and East Tank Farm; PSG samples will be analyzed for the mass content of BTEX, naphthalene, and 2-

methylnaphthalene to provide information regarding the presence of volatile components in soil gas.

2. Clear buried and overhead utility locations.

3. Set up onsite facilities.

4. Clear vegetation on two properties: Wilcox Processing Area (former Wilcox Refinery) and former Lorraine Refinery (southern portion). Other areas will be cleared as needed for access during site reconnaissance and waste delineation, including the North Tank Farm and Loading Dock Area.
5. Perform a site reconnaissance with the following goals:
   a) Assess if there is evidence that the two bermed areas (unconfirmed Tanks 1 and 4) in the eastern portion of the East Tank Farm areas have been used for industrial activities.
   b) Assist ODEQ in using a thermal infrared imaging camera to determine the location of the seeps and locations where runoff from the site drains into Sand Creek, including the East Tributary (probable point of entry [PPE]); also, reconnoiter the PPE of the West Tributary into Sand Creek. This information will be used to determine the potential locations for surface water/sediment sampling in order to optimize the sampling strategy and eliminate duplication of effort.
   c) Perform wetlands survey to confirm presence of a sensitive environment.
   d) Supervise subcontractor performance of a suspected asbestos-containing material (ACM) survey and collect samples for testing, if applicable.
   e) Perform field screening activities using field instruments and detectors to identify the possible presence and degree of NORM/TENORM in coal tar-coated piping, sludge ponds, and separation ponds. Note that further assessment for the presence of NORM/TENORM in soil, surface water, sediment, and ground water exposure media will be performed only if the field screening performed during the reconnaissance indicated NORM/TENORM is present. If confirmed, a subset of the multimedia samples collected during Mobilization 1 will be also analyzed for NORM/TENORM.
   f) Coordinate with Oklahoma Department of Transportation (ODOT) to (1) visually assess the Sand Creek bridge that was constructed using onsite borrow material; and possibly select locations for sampling using a hand auger or similar coring device.
   g) Reconnoiter the large field across Refinery Road from the East Tank Farm (just north of Former Tank 5), which is currently proposed for soil background sampling. Assess if this area has evidence of anthropogenic activities and confirm location is adequate for background sampling; if not, select another location.
   h) Confirm how many residences have private water supply wells and obtain consent to sample their wells in coordination with ODEQ.
   i) Locate the three inactive private wells (church well located at the Lorraine Process Area and two wells located on the East Tank Farm), and determine if pumps are

present; if possible, gauge the wells using a water level indicator and/or interface probe.

j) Identify additional waste piles and areas of exposed waste material. Delineate the waste piles using Global Positioning System (GPS) and visually assess how many types of waste may be present in each pile.

k) Identify sandstone outcrops in the North Tank Farm area to determine overburden depths.

6. Perform soil investigation:

a) Install soil borings to horizontally and vertically delineate the contamination is soil; ROST LIF fluorescence signature outputs from the Lorraine Process Area, Wilcox Process Area, and East Tank Farm (Tanks 3 and 5 only) will be utilized as a starting point for the delineation. Surface and subsurface soil samples will be collected from the borings at select intervals for analysis for VOCs, SVOCs (including SIM for PAHs), TAL metals, cyanide, and hexavalent chromium (at locations in the vicinity of the former cooling towers and associated cooling ponds).

b) Install soil borings and collect surface and subsurface soil samples in areas where a ROST LIF survey has left data gaps or was not performed and/or in areas where source areas may have been located at the Lorraine Process Area (former cooling towers/pond and Tank 38 location) and Wilcox Process Area (distillation process areas and former cooling towers/pond). Soil samples will be analyzed for VOCs, SVOCs (including SIM for PAHs), TAL metals, cyanide, and hexavalent chromium (vicinity of former cooling towers and associated cooling ponds).

c) Install soil borings and collect surface and subsurface soil samples between suspected source areas and Sand Creek to evaluate surface/subsurface migration to surface water. If infiltrated water is identified in soil borings, install piezometers to evaluate potential seepage to Sand Creek. Piezometer water levels will be monitored and water samples will be collected for analysis for VOCs, SVOCs (including SIM for PAHs), TAL metals, cyanide, and hexavalent chromium. The soil samples will be analyzed for the same COPC suite.

d) Aliquots for analysis for PCBs, dioxins/furans, and pesticides in soil will be collected from shallow horizons at 10 sample locations in the Wilcox Process Area.

e) Based on reconnaissance information, install soil borings and collect surface and subsurface soil samples to assess Former Tanks 1 and 4 (located on the east side of East Tributary) for analysis for VOCs, SVOCs (including SIM for PAHs), and TAL metals.

f) Assist EPA Headquarters representatives with XRF delineation of Lead Additive Area (Wilcox Process Area).

g) Perform a soil background assessment for PAHs and metals (0 – 0.5 ft bgs) using incremental composite sampling (ICS) methodology. The background soil assessment will also include NORM/TENORM, if it is determined to be present

during the initial reconnaissance survey.

h) Soil investigation may be refined based on findings of EPA ERT's PSG investigation.

7. Initial ground water assessment:

   a) Investigate and sample inactive private water supply wells, including the LNAPL-impacted well located in Lorraine Process Area. Investigation of each well may include (1) evacuating the well adequately to remove, sample, and characterize LNAPL (if present); (2) gauge the well using an interface probe to determine presence and thickness of LNAPL (if present); (3) log the well to determine well construction, lithology, and flow using video camera, temperature and fluid conductivity probe, and/or geophysical logging tool; and (4) and collect a representative ground water sample (if possible) for analysis for VOCs, EDB, SVOCs (including SIM for PAHs), TAL metals, cyanide, and hexavalent chromium.

   b) Coordinate with ODEQ to resample the 10 on- and offsite residential wells that were sampled in 2015/2016; if additional wells are identified during site reconnaissance, include them in the sampling effort and analyze the ground water samples for VOCs, EDB, SVOCs (including SIM for PAHs), TAL metals, cyanide, and hexavalent chromium.

   c) Sample two wells located in East Tank Farm that are currently not in use for VOCs, SVOCs (including SIM for PAHs), TAL metals, and cyanide. These inactive wells may also be logged as described for the Lorraine well pending availability of funding and schedule).

      Sample residential well located at residence on North Tank Farm for VOCs, SVOCs (including SIM for PAHs), TAL metals, cyanide, and hexavalent chromium.

8. Survey and catalog relevant site features and sampling locations using GPS.

9. Perform soil gas and vapor intrusion sampling at the two vacant residences and the vacant church located on the Lorraine and Wilcox Process Areas and analyze samples for VOCs and naphthalene (pending funding availability and schedule); this investigation may be refined based on findings of EPA ERT's PSG investigation.

10. Perform surface water and sediment investigation (pending funding availability and schedule):

    a) Collect surface water and sediment samples to assess conditions along Sand Creek, West and East Tributaries, ponds located along the streams, isolated ponds, and the Sand Creek bridge (in coordination with ODOT, as appropriate).

    b) Collect surface water and sediment samples to determine upstream conditions for Sand Creek and the tributaries and background conditions for the isolated ponds.

    c) Surface water samples will be analyzed for VOCs, SVOCs (including SIM for PAHs), total and dissolved TAL metals, cyanide, and hexavalent chromium (10 percent), as well as surface water quality parameters.

d) Sediment samples will be analyzed for VOCs, SVOCs (including SIM for PAHs), TAL metals, cyanide, and AVS/SEM.

1.3.2.2 Mobilization Event 2

Mobilization Event 2 may include the following field activities contingent on findings of Mobilization 1 investigation (will require SAP revision):

1. Additional clearing of vegetation on the North Tank Farm and Loading Dock Area, as necessary.

2. Expand the PSG investigation based on findings of EPA ERT's initial PSG investigation.

3. Based on Mobilization 1 findings, refine COPC list and define appropriate decision units in Lorraine Process Area, Wilcox Process Area, and East Tank Farm for surface soil investigation (0 – 2 ft bgs) using ICS methodology. ICS soil data will be used to characterize source areas and assess residential human health risk.

4. Based on Mobilization 1 soil investigation, reconnaissance, and waste area delineation, refine the COPC list and investigate the North Tank Farm and Loading Dock Area soils using ICS methodology.

5. Perform initial surface water and sediment investigation if not completed under Mobilization 1. If initial investigation completed during Mobilization 1, then use data to refine the COPC list and expand sampling downstream, as appropriate, so that surface water and sediment impact can be delineated.

6. Characterize surface soil in drainage pathways leading from source areas to Sand Creek using ICS methodology. Samples from these drainage pathways were called sediment in past investigations; however, they are representative of the soil exposure medium as the ground is only wet following precipitation events.

7. Based on information obtained from the ground water investigation performed during Mobilization Event 1, determine the locations for new monitoring well locations. Install and develop the new monitoring wells, and collect ground water samples. Survey the wells and gather additional information for the characterization of the hydrologic regime so the potential for seasonal fluctuations is assessed.

8. Plug and abandon the private water supply well located on the Lorraine Process Area.

9. Perform soil gas and vapor intrusion sampling at two vacant residences and the vacant church located on the Lorraine and Wilcox Process Areas and analyze samples for VOCs and naphthalene if not completed under Mobilization 1; this investigation may be refined based on findings of EPA ERT's PSG investigation. If initial investigation is completed during Mobilization 1, then, based on the results of initial soil gas and vapor intrusion sampling, perform a second round of vapor intrusion sampling at residences and buildings associated with the church to evaluate seasonal variation (if warranted), and

expand the soil gas and vapor intrusion investigation to occupied residences located on the East Tank Farm and North Tank Farm.

10. Perform characterization (sampling) of waste areas by collecting surficial samples for the complete suite of site COPCs.

11. If suspected ACM is confirmed to be present through sampling performed by a subcontractor during Mobilization Event 1, follow up on ACM removal.

1.3.2.3 Mobilization Event 3

Mobilization Event 3, if deemed necessary, will include the following field activities:

1. Field activities will entail further delineation of impact to ground water and additional gauging of existing and installed wells to assess seasonal variations. The SAP will require revision to address the sampling and analytical approach for Mobilization 3.

2. Based on the results of the first or second soil gas and vapor intrusion investigation, perform additional vapor intrusion sampling to evaluate seasonal variation.

3. Collection of samples for ecological assessment (fish tissue, plant tissue, and/or sediment for toxicity testing, if warranted); locations will be selected based on soil/sediment/ surface water analytical results obtained during prior mobilizations.

1.4 DATA QUALITY OBJECTIVES

The following sections present the DQOs for this project. The SOW issued by the EPA (2015b), the EPA-approved Work Plan (EA 2015), and the preliminary Conceptual Site Model (CSM) (Appendix A) form the basis for the DQO assessment. This DQO assessment follows EPA's 7-step DQO process (Table 3), which is outlined in *Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)* (EPA 2006a) and *Systematic Planning: A Case Study for Hazardous Waste Site Investigations (QA/CS-1)* (EPA 2006b).

Additional information is referenced, as appropriate, in the following sections:

- Section 1.3.1 Purpose and Goal
- Section 1.3.2 Step 1 – State the Problem
- Section 1.3.3 Step 2 – Identify the Goal of the Study
- Section 1.3.4 Step 3 – Identify Information Inputs
- Section 1.3.5 Step 4 – Define the Boundaries of the Study
- Section 1.3.6 Step 5 – Develop the Analytical Approach
- Section 1.3.7 Step 6 – Specify the Performance or Acceptance Criteria
- Section 1.3.8 Step 7 – Develop the Plan for Obtaining Data.

1.4.1 Purpose and Goal

The purpose of defining the DQOs is to support decision-making by applying a systematic planning and statistical hypothesis-testing methodology to decide between alternatives. The goal is to develop an analytical approach and data collection strategy that is effective and efficient.

1.4.2 Step 1 – State the Problem

The first step in systematic planning process, and therefore the DQO process, is to define the problem that has initiated the study. As environmental problems are often complex combinations of technical, economic, social, and political issues, it is critical to the success of the process to separate each problem, define it completely, and express it in an uncomplicated format.

The activities in DQO Step 1 are as follows:

- Give a concise description of the problem
- Identify a leader and members of the planning team
- Develop a CSM of the environmental hazard to be investigated
- Determine resources (i.e., budget, personnel, and schedule).

1.4.2.1 Problem Description

Industrial/manufacturing processes at the Site have resulted in a release of contaminants to media creating primary sources of contamination. Contamination is present at five separate areas at the site that has migrated from the known sources of contamination to the environment. These areas are the Wilcox Process Area, Lorraine Process Area, East Tank Farm, North Tank Farm, and Loading Dock Area. Contamination has been documented at the site through sampling and analysis of soil, surface water, sediment, and waste (Sections 1.2.4 and 1.2.5). However, the nature and extent of media impacted by site COPCs, possible migration of impacted media, and risks associated with impacted media are unknown. The transport mechanisms, exposure media, and receptors are detailed according to the CSMs for human health and the environment as presented in Appendix A to this plan.

The current land use across the site is residential; however, the possibility exists that the process areas may be zoned as commercial/industrial in the future. Short term exposure of construction workers and trespassers to contaminated soil is also considered, as is infrequent recreational use of the area. Data will also be collected to assess a risk to ecological receptors.

The current COPCs at the site are as follows:

- VOCs
- EDB
- PAHs
- SVOCs
- TAL metals

- Cyanide.

Due to the likelihood that they may have been impacted by former refinery process area operations, a select number of shallow surface soil samples (0.0–0.5 ft bgs) from the process areas will also undergo the following analyses:

- Hexavalent chromium
- PCBs
- Pesticides
- Dioxins/furans
- NORM/TENORM (if necessary, based on survey results).

Additional analyses will be performed on samples collected from the site for the RI; they are discussed in detail in Section 2.2.

As noted in Section 1.2.2, Project Tasks, a staged approach is taken for the characterization of the site. Specific items will be investigated during Mobilization 1 that will provide data to inform the next steps (subsequent mobilizations) in the RI. The problems or data gaps that will be addressed during either Mobilization 1 and/or Mobilization 2 are summarized below.

Soil Exposure Medium

- Semi-quantitatively assess presence of volatile COPCs in subsurface (Mobilization 1).
- Use existing ROST LIF and XRF data to direct the assessment of potential source areas in the Lorraine Process Area, Wilcox Process Area, and East Tank Farm and delineate nature and extent of contamination (Mobilization 1).
- Assess potential source areas that were not investigated using ROST LIF (Lorraine and Wilcox Process Areas) (Mobilization 1)
- Assess if contamination is present at former locations for Tanks 1 and 4, located east of the East Tributary (Mobilization 1).
- Establish background values for PAHs, metals, and NORM/TENORM, as applicable (Mobilization 1).
- Use ICS methodology to characterize contamination in surface soil (0 – 2 ft bgs) across the Lorraine Process Area, Wilcox Process Area, and East Tank Farm to evaluate human health and ecological risk in exposure units defined using Mobilization 1 data (Mobilization 2).
- Confirm presence of contamination in soil below waste piles across the site (Mobilization 2).
- Characterize the most likely areas to be contaminated at the North Tank Farm (Mobilization 2).
- Assess soil in drainage pathways that channel surface runoff from sources of contamination to the tributaries (Mobilization 2).

Surface and Sediment Exposure Media

- Identify seeps and discharges from the site into Sand Creek (Mobilization 1).
- Assess if contamination from source areas is migrating to Sand Creek (Mobilization 1).
- Evaluate impacts to surface water and sediment along Sand Creek, intermittent tributary, perennial tributary, and ponds (Mobilization 1 and/or 2).
- Evaluate upstream surface water and sediment quality and background pond sediment and surface water quality (Mobilization 1 and/or 2).

Ground Water Exposure Medium

- Investigate the interaction of the contaminated infiltrated water (if present) on top of the sandstone or clay layer and the underlying regional aquifer (Mobilization 1 and/or 2).
- Determine nature and extent of contamination in ground water (Mobilization 1 and 2).
- Investigate the interaction between surface water and ground water (Mobilization 1 and 2).

Air Exposure via Vapor Intrusion Medium

- Semi-quantitatively assess presence of volatile COPCs in subsurface (Mobilization 1).
- Determine if vapor intrusion is a concern on several properties at the site (Mobilization 1 and/or 2).

Waste Material

- Identify and visually delineate waste piles and areas of exposed waste material across the site (Mobilization 1).
- Characterize waste piles and areas of exposed waste material across the site and assess impacts to soil immediately below the waste piles (Mobilization 2).

Surveys to Determine Presence of Other Contaminants or Other Media Requiring Characterization

- Evaluate whether NORM/TENORM are present at the site (Mobilization 1).
- Evaluate whether asbestos is present at the site (Mobilization 1).
- Confirm the presence of wetlands that are referenced in the HRS Documentation Record (EPA 2013a) (Mobilization 1).

1.4.2.2 Planning Team Members and Stakeholders

A proven, effective approach to formulating a problem and establishing a plan for obtaining information that is necessary to resolve the problem is to involve a team of experts and stakeholders that represent a diverse, multidisciplinary background. Such a team provides the ability to develop a concise description of complex problems, and multifaceted experience and

awareness of potential data uses. Planning team members (including the leader) and stakeholders are presented below.

Planning Team Members

- Katrina Higgins-Coltrain, EPA Region 6 TOM
- Philip Turner, EPA Region 6 Risk Assessor
- Thomas Kady, EPA Environmental Response Team
- Barry Forsythe, U.S. Fish and Wildlife Service
- Todd Downham, ODEQ
- Teresa McMillan, EA.

Stakeholders

- EPA Region 6 Superfund Division Management
- EPA Headquarters
- U.S. Fish and Wildlife Service
- ODEQ
- Interested tribal nations (Cherokee Nation, Muskogee [Creek] Nation, Sac and Fox Nation)
- City of Bristow, Oklahoma
- Other interested parties, such as residents living at the site.

If additional planning team members and/or stakeholders are identified as the RI progresses, they will be incorporated into the decision-making process as appropriate.

1.4.2.3 Conceptual Site Model

It is critical to carefully develop an accurate CSM of the environmental problem, as this model will serve as the basis for subsequent inputs and decisions. Details on the CSM for the site and diagrams for the human health and ecological receptors are included in Appendix A to this SAP.

As described in Table 2 and Sections 1.2.4 and 1.2.5, the presence of organic contaminants—PAHs in particular—are confirmed to be present in waste materials, soil, and sediment samples associated with the site. Metals were detected in samples collected from all media, but because metals are naturally occurring, a more rigorous study would be necessary to determine if elevated concentrations (above background) are due to site activities or from contamination migrating to the site from other refineries in the area.

Data to be collected during the RI effort will be used to supplement existing data and resolve data gaps relating to nature and extent of contamination in all media, including presence of contaminants in air within select buildings, potential ground water plumes, and hot spot delineation. The following potential migration pathways of impacted media have been identified and will have to be evaluated: (1) infiltration to subsurface soil, (2) transport of contamination to surface water and sediment via infiltrated contaminated water, (3) transport of contamination

downstream via surface water and sediment; (4) leaching to ground water, (5) interaction of surface water and ground water, and (6) ground water transport. Data will be screened against conservative screening levels and, if potential unacceptable risks to human health or ecological receptors are identified as a result of exposure to COPCs in site-related media, a human health and/or ecological risk assessment will be performed.

Additional details pertaining to the CSM are provided in the attached CSM Technical Memorandum (Appendix A) and are not repeated here for brevity.

1.4.2.4 Determine Resources

Resources should be identified by the planning team so that constraints (e.g., budget, time, etc.) associated with collecting/evaluating data can be anticipated during the project life cycle. To assist in this evaluation, the DQO process (e.g., developing performance or acceptance criteria) and the SAP (i.e., for collecting and analyzing samples, and interpreting and assessing the collected data) have been completed.

EA personnel, team subcontractor personnel, and/or non-team subcontractor personnel with appropriate oversight will perform data collection tasks with the following possible exceptions:

- EPA ERT contractor has been tasked with implementing the PSG investigation prior to EA's Mobilization 1 activities, with support from EA as necessary.
- U.S. Geological Survey may be tasked with performing geophysical and camera logging of site water supply wells, with support from EA as necessary.
- EPA Headquarters has been tasked with implementing the investigation of the Lead Additive Area, with support from EA as necessary.
- ODEQ has been tasked with using their thermal infrared imaging camera to identify possible seeps along Sand Creek, with support from EA as necessary.

EA will utilize the services of the EPA's Region 6 Houston Laboratory or the EPA Contract Laboratory Program (CLP), where feasible. When samples cannot be analyzed by either the EPA Region 6 Laboratory or the CLP, due to method requirements, schedule requirements, or elevated analyte concentrations, a non-CLP commercial laboratory will be subcontracted by EA to support the analyses. Data generated by the EPA Region 6 Laboratory or CLP will be validated by EPA or EPA contractors. Data generated by the EA-subcontracted laboratory will be validated by EA personnel or subcontracted personnel.

The EPA will perform a review of each required deliverable and provide comments, as necessary. EPA will also solicit comments from other planning team members or stakeholders, as appropriate.

1.4.3 Step 2 – Identify the Goal of the Study

Step 2 of the DQO process involves identifying the key questions that the study attempts to address, along with alternative actions or outcomes that may result based on the answers to these key questions. These two items are combined to develop decision statements, which are critical for defining decision performance criteria later in Step 6 of the DQO process.

The activities in DQO Step 2 are as follows:

- Identify principal study questions (PSQs)
- Consider alternative actions that can occur upon answering the questions
- Develop decision statement(s) and organize multiple decisions.

1.4.3.1 Principal Study Questions

The PSQs define the questions to be answered by the HHRA, SLERA, and RI following completion of the field program (Mobilizations 1 through 3). The PSQs are as follows:

- Are waste piles Resource Conservation and Recovery Act (RCRA) hazardous or non-hazardous and have contaminants leached from the waste into the underlying soil layer?
- What is the nature of contamination in soil within specific source areas and what is the extent of contamination?
- What is the nature of contamination in surface water and sediment and what is the extent?
- What is the extent and volume of contaminated media in the Lead Additive Area?
- Is there a ground water aquifer at the site, and if present what is the classification and what is the nature and extent of contamination?
- Is there LNAPL present and what is the extent and volume?
- Is the refusal layer continuous across the site and does it provide a barrier to downward contaminant migration?
- Is vapor intrusion an issue at select properties?
- What are the migration pathways for transport of these contaminants in different media?
- Are asbestos and/or NORM/TENORM present at the site?
- Are wetlands present at the site?
- Is there a risk to human health or the environment from contamination at the site?

1.4.3.2 Alternative Actions

The alternative actions provide PSQ alternatives in the FS, as follows. Potential alternative actions, which will be evaluated in the FS, include, but are not limited to, the following:

- Remove or remediate the source areas.

- Restrict access to limit exposure.
- Mitigate migration pathways.
- Address other migration/exposure pathways impacting receptors by employing engineering or institutional controls.

1.4.3.3 Decision Statement

For decision-making problems, the PSQs and alternative actions are combined to develop decision statements, which are critical for defining decision performance criteria in DQO Step 6. This RI field program is planned to be implemented in up to three mobilizations, where data from Mobilization 1 will be utilized to plan specific activities in the subsequent Mobilization 2 and Mobilization 3, if necessary. The decision statements for the RI field program (Mobilizations 1 through 3) are as follows:

- Delineate and characterize waste piles and underlying soil.
- Determine if ROST LIF data are adequate to characterize the nature and extent of contamination in surface and subsurface soil and use that information to continue delineation of contamination and soil sampling.
- Characterize and delineate soil contamination at specific source areas.
- Characterize and delineate contamination in surface water and sediment.
- Characterize and delineate contamination to determine how and what future actions (e.g., investigation, delineation, characterization) are necessary to characterize the ground water; otherwise, consider no further action.
- Characterize and delineate contamination in ground water to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment); otherwise, consider no further action.
- Confirm the presence or absence of ground water contamination discharge to the surface water to determine how and what future actions (e.g., investigation, delineation, characterization) are necessary to characterize this interaction; otherwise, consider no further action.
- Characterize and delineate ground water discharge to surface water to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment); otherwise, consider no further action.
- Confirm the presence or absence of LNAPL to determine whether future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment) are necessary; otherwise, consider no further action.

- Characterize and delineate the LNAPL to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation or in-place containment); otherwise, consider no further action.
- Confirm the presence or absence of a continuous refusal layer at depth to determine whether future actions (e.g., investigation, delineation, and characterization) are necessary; otherwise, consider no further action.
- Characterize and delineate the refusal layer to determine whether it provides a barrier to downward contaminant migration and whether future actions (e.g., investigation, delineation, and characterization) are necessary; otherwise, consider no further action.
- Characterize and delineate the Lead Additive Area to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment); otherwise, consider no further action.
- Determine if vapors have impacted onsite vacant residences on Wilcox and Lorraine Process Areas and the vacant church.
- Determine if asbestos and/or NORM/TENORM are present at the site.
- Determine if wetlands are present at the site.
- Determine if there are risks to human health and/or the environment.

These statements will not be satisfied until all the RI data are available for evaluation.

1.4.4 Step 3 – Identify Information Inputs

Step 3 of the DQO process determines the types and sources of information needed to resolve: (1) the decision statement or produce the desired estimates; (2) whether new data collection is necessary; (3) the information basis the planning team will need for establishing appropriate analysis approaches and performance or acceptance criteria; and (4) whether appropriate sampling and analysis methodology exists to properly measure environmental characteristics for addressing the problem.

The activities in DQO Step 3 are as follows:

- Identify types and sources of information needed to resolve decisions or generate estimates.
- Identify the basis of information that will guide or support choices to be made in later steps of the DQO process.
- Select appropriate sampling and analysis methods for generating the information.

1.4.4.1 Necessary Information and Sources

A variety of sources and types of information form the basis for resolving the decision statements. The following information and sources are necessary to resolve this step of the DQO process.

The decision statements are supported by the information and sources summarized below.

Determine Source of Contamination

- Additional data for all media will be collected as necessary to augment the historical dataset and resolve data gaps; the data will also be adequate to perform risk screening, and if necessary, risk assessment.
- Following review of Mobilization 1 data, collect additional geologic and hydrogeologic information (e.g., borehole geophysics, soil borings, new monitoring wells, pump testing, clay permeability testing, etc.) during Mobilization 2 to evaluate subsurface impacts and potential migration.
- For soil samples, data will be collected to determine background levels for metals and NORM/TENORM for comparison to sample concentrations. For surface water and sediment, data will be collected to define upstream conditions, such that contamination entering the flowing water bodies upstream from the site can be distinguished from site contamination. For ponds not connected to permanent or temporary streams, background concentrations for metals and NORM/TENORM will also be utilized to distinguish from contamination originating onsite.

Determine the Nature and Extent of Contamination

- Soil characterization will be required in areas where ROST LIF survey was performed and in areas not covered by the survey; soil samples will be collected from soil borings and will be analyzed for VOCs, SVOCs (including PAHs), TAL metals, and cyanide. Samples for a smaller set of COPCs (hexavalent chromium, PCBs, pesticides, and dioxin/furans) will be collected from suspect source areas in the Wilcox Process Area, as well as the Lorraine Process Area in the case of hexavalent chromium.
- Surface water and sediment characterization will be required; samples will be analyzed for VOCs, SVOCs (including PAHs), total and dissolved TAL metals, cyanide, and total and dissolved hexavalent chromium; if the extent of contamination is not defined under the initial sampling program, further sampling may be necessary to complete the delineation.
- Initial characterization of ground water will be performed by sampling existing private supply wells. It could not be verified at the time this SAP was written, but the wells are assumed to be extracting water from the regional aquifer; the ground water samples will be analyzed for VOCs, SVOCs (including PAHs), TAL metals, cyanide, and hexavalent chromium. Moreover, information will be collected to ascertain if the water historically called "ground water"—which is believed to be infiltrated water ponding on top of the sandstone/clay layer—is actually water with beneficial uses, and if so, whether it qualifies

as a ground water exposure medium and/or is connected with the regional aquifer or surface water. A determination of the depth to the water in the regional aquifer and the potentiometric surface map and ground water gradient will not be accomplished until monitoring wells are installed in this aquifer. Delineation of a ground water impact, if one exists, will be accomplished during a subsequent mobilization.

- Sampling for vapor intrusion will be performed in two residences and the church to assess if there is a threat to human receptors.
- Geologic and hydrogeologic information will be collected to evaluate subsurface impacts and potential migration.
- Sampling for biota, should it prove necessary, will be performed to evaluate impacts to ecological receptors.

Determine the Migration Pathways for Contamination

- An evaluation of the migration pathways will be performed for surface runoff outside of source areas
- Surface water transport will be conducted to aid in understanding the transport of contamination via surface water flow and sediment from source areas to the adjacent waterways
- An evaluation of leaching of source material to ground water will be conducted to aid in the understanding of contaminant transport
- An evaluation of ground water migration will be conducted to aid in the understanding of contaminant transport.

Determine if Exposure to COPCs Pose a Potential Unacceptable Risk to Human Health and Ecological Receptors (Appendix B)

- Analytical results for soil, sediment, surface water, vapor intrusion, and ground water samples will be first compared to the screening levels for human health and environmental protection agreed upon during the scoping effort; these values are provided in Appendix B and consist of the following:

  — Soil screening levels:
    - 0.0 - 2.0 ft bgs
      - EPA Regional Screening Levels (RSLs) for human health exposure for residential scenario (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015) (EPA 2016b).
    - 0.0 – 10.0 ft bgs
      - EPA RSLs for human health exposure for industrial/construction scenario (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015) (EPA 2016b)

  - 0.0 – 0.5 ft bgs: Ecological soil screening levels, ECOTOXicology database (ECOTOX) (http://www.epa.gov/ecotox/ecossl) (EPA 2016a).

— Ground water screening levels:

  - Federal Maximum Contaminant Levels (MCLs) (https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants) (EPA 2009b)
  - EPA tap water RSLs (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015) (EPA 2016b)
  - Oklahoma Water Resources Board (OWRB) Interim Water Quality Standards (WQSs) (https://www.owrb.ok.gov/quality/standards/standards.php) (OWRB 2013)

— Surface water:

  - EPA National Water Quality Criteria (https://www.epa.gov/wqc/aquatic-life-ambient-water-quality-criteria) (EPA 1985)
  - OWRB Interim WQSs (https://www.owrb.ok.gov/quality/standards/standards.php) (OWRB 2013).

— Sediment screening levels:

  - Benthic protection based on the National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuIRT) values listed in (NOAA 2008) (consensus-based unless not available).
  - For comparative purposes only, utilize the Texas Commission on Environmental Quality (TCEQ) Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs) (TCEQ 2014) (https://www.tceq.texas.gov/remediation/trrp/trrppcls.html).

— Air/soil gas screening levels:

  - EPA RSLs for human health exposure in residential and industrial/construction scenarios (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015) (EPA 2016b)
  - EPA *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Source to Indoor Air* (EPA 2015a).

— Removal management levels (RMLs):

  - EPA RMLs for use to support the decision to undertake removal action (https://www.epa.gov/risk/regional-removal-management-levels-chemicals-rmls) (EPA 2016c)

- For metals and NORM/TENORM, concentrations in all media will also be compared to the following values:

— Background values for soil
— Upgradient concentrations for ground water
— Upstream concentrations for sediment and surface water.

- If the concentrations exceed the screening levels, a risk assessment will be performed.

Determine Characteristics of Site Waste and Whether It Leached Contaminants to Underlying Soil.

- The waste will be characterized as hazardous or non-hazardous based on the standards in the RCRA, 40 Code of Federal Regulations (CFR) Part 261 (Appendix B).
- Concentrations of soil samples collected from underneath the waste piles will be compared to the standards specified above.

1.4.4.2 Basis of Information

The basis of information will guide or support choices to be made in later steps of the DQO process.

The basis of information is supported by the following:

Determine Source of Contamination

- Biased or judgmental sample locations will be based on evaluation of historical data, photographs, or visual cues.
- Geologic and hydrogeologic information (e.g., soil borings, new monitoring wells, ground water and surface water elevation, etc.) will be collected to evaluate impacts to ground water and the interconnectivity between surface water and ground water.

Determine the Nature and Extent of Contamination

- Biased or judgmental sample locations will be based on evaluation of historical data, photographs, or visual cues.
- Geologic and hydrogeologic information (e.g., soil borings, new monitoring wells, ground water and surface water elevation, etc.) will be collected to evaluate impacts to ground water and the interconnectivity between surface water and ground water.

Determine the Migration Pathways for these Contaminants

- The Interim Final *Guidance for Conducting Remedial Investigations and Feasibility Studies Under Comprehensive Environmental Response, Compensation, and Liability Act* (EPA 1988) describes the process for evaluating migration pathways.

Determine if COPC Exposure Poses a Potential Unacceptable Risk to Human Health and Ecological Receptors

- A HHRA will be conducted in accordance with the EPA's guidance which includes, but is not limited to, the following:
  - *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (EPA 1989)
  - *RAGS for Superfund Volume I: Human Health Evaluation Manual. Supplemental Guidance: Standard Default Exposure Factors* (EPA 1991)
  - *RAGS, Volume I: Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments* (EPA 2001b)
  - *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (EPA 2002c)
  - *RAGS, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (EPA 2004)
  - *RAGS, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)* (EPA 2009a).
- A SLERA will be conducted in accordance with the EPA's guidance which includes, but is not limited to, the following:
  - *Ecological RAGS: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (EPA 1997)
  - *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (EPA 1999b).

To determine the nature and extent of contamination at the site, a field investigation has been proposed to collect multimedia data and resolve data gaps to support the risk assessments and ultimately the FS and ROD for the site. Details pertaining to this effort are presented in Section 2.0 and will not be repeated here for brevity.

Determine the Ultimate Disposition of Site Waste and Whether Further Action is Warranted to Address Underlying Contaminated Soil

- The requirements of RCRA, 40 CFR Part 261, will be followed.
- Soil will be addressed as described above.

1.4.4.3 Sampling and Analysis Methods

An extensive field investigation has been proposed to collect multimedia data. Analyses to be performed on site samples are presented in Appendix B. Details pertaining to this effort are presented in Section 2.0 and will not be repeated here for brevity.

1.4.5 Step 4 – Define the Boundaries of the Study

In Step 4 of the DQO process, the target population of interest and spatial/temporal features pertinent for decision-making should be identified. The activities in DQO Step 4 are as follows:

- Define the target population of interest.
- Specify temporal or spatial boundaries and other practical constraints associated with sample/data collection.

1.4.5.1 Target Population

The target population consists of soil, surface water, sediment, ground water, air, and biota. The following descriptions of the target population are segregated by media below.

Generally soil is not considered mobile because ground cover or vegetation often precludes migration. Mobility of soil due to storm water or particulate migration can lead to a slight temporal aspect to characterization. However, for the purpose of this investigation, soil is not considered to be mobile enough to have a significant temporal aspect. The distribution of soil is from the ground surface to: the bottom of impacted soil, until the water table is encountered, or refusal, whichever is first.

Surface water is mobile with a high temporal aspect in Sand Creek and in East and West Tributaries. Surface water in the ponds located along the temporary creeks is not mobile except under flood conditions and likely has a low temporal aspect. Surface water in the isolated ponds is not mobile and has a low temporal aspect.

Sediment is considered potentially mobile during storm or other high flow events. The fine grain materials are potentially subject to migration and may be transported some distance from the source. Therefore, a minor temporal aspect to the concentration of sediments in a particular location may occur over time. The distribution of sediments is thought to be from several inches to several ft thick in most areas. Typically, sediments contained within the banks of waterways often have higher deposition rates near bends or where surface water flow is reduced.

Limited information is available for ground water. Typically, ground water is found at depths of 30 feet bgs at the Lorraine Process Area to 110 ft bgs in topographically high areas. The ground water gradient at the site is not known, but ground water is assumed to be moving toward Sand Creek.

Soil vapors may have impacted vacant residences located within the process areas and the vacant church at a level that poses a human health risk. A vapor intrusion investigation will be implemented to determine if indoor air has impacted any habitations.

The presence and extent of the waste materials and asbestos present at the site will be defined during the site reconnaissance.

Regarding biota, the media to be sampled have not been decided upon at this time. Generally speaking, plants, soil invertebrates, aquatic organisms in ponds, and benthic organisms are not mobile. Aquatic organisms (unless they are in isolated ponds), mammals, reptiles, and amphibians are considered to have limited mobility. Birds and mammals have high mobility.

1.4.5.2 Spatial Boundaries

Exposure areas are considered to be the site and potentially the sediment and surface water in Sand Creek, its tributaries, and one pond along the East Tributary downstream from the site. This investigation will further evaluate the exposure area and additional areas identified during this investigation, as appropriate. The exposure area may be further subdivided based on the presence of contaminants, potential reuse, available receptors, etc.

1.4.6 Step 5 – Develop the Analytical Approach

Step 5 of the DQO process involves developing an analytical approach that will guide how to analyze the study results and draw conclusions from the data. It is the intention of this step to integrate the outputs from the previous four steps with the parameters developed in this step.

The activities in DQO Step 5 are as follows:

- Specify the appropriate population parameters for making decisions.
- Choose a workable action level and generate an "If … then … else" decision rule which involves it.

1.4.6.1 Population Parameters

The population parameter is defined as the value used in the decision statement to evaluate a decision point. The population parameter will be used as an exposure point concentration in the HHRA and SLERA. A population parameter will be determined for each chemical detected in each exposure area (if unique areas are identified), for each sample group (e.g., surface soil from 0 to 2 ft bgs). Maximum exposure unit concentrations will be used first to determine if a chemical should be kept as a site COPC. If COPCs are identified, the 95% upper confidence limit of the mean (95UCL) will be calculated using ProUCL Version 5.0.0 (EPA 2013c, 2013d) and used in the risk assessments.

For COPCs with detection limits above screening levels, if one-half the lowest Contract-required Quantitation Limit (CRQL) or method reporting limit (RL) for a chemical is greater than its respective screening level, then it will be evaluated in the uncertainty section of the risk assessment (see Section 1.4.3).

In the case of non-detect results, one-half the CRQL or RL will be represented.

1.4.6.2 Action Level Decision Rule

The action levels for the site will likely be either: (1) risk-based screening criteria developed during the HHRA and/or SLERA or (2) federally-mandated ground water criteria such as MCLs.

The risk-based screening criteria for COPCs, as well as background values for soil, upgradient values for ground water, and upstream values for surface water and sediments will be used to evaluate whether the analytical data will have appropriate sensitivity for the risk assessment. Although it is understood that the type of data used to develop the screening criteria may differ from that which will be used in the site-specific risk assessments, these criteria should present conservative values suitable for the initial screening.

Mineral or chemical interference may lead to elevated sample quantitation limits which are greater than their respective risk-based screening levels. If these analytes are not detected in an exposure area and sample quantitation limits are greater than risk-based values, then they may be a source of potential risk underestimation or additional sampling may be conducted to mitigate the uncertainty.

The decision rules for the site are as follows:

- If contamination in soil at a specific source area is above screening levels, perform a risk assessment to determine if the contamination poses an unacceptable risk. If it does pose a risk, determine the most appropriate actions to be taken for risk mitigation during the FS.

- If contamination in surface water and sediment is above screening levels, perform a risk assessment to determine if the contamination poses an unacceptable risk. If it does pose a risk, determine the most appropriate actions to be taken for risk mitigation during the FS.

- If ground water is contaminated above screening levels, perform a risk assessment to determine if the contamination poses an unacceptable risk. If it does pose a risk, determine the most appropriate actions to be taken for risk mitigation during the FS.

- If vapors are present in shallow soil as indicated by PSG mass in the samplers or if vapors have impacted the residences or the church at a level that poses a human health risk, determine the source of the vapors and implement means of mitigating the intrusion in the future. During the FS, determine the most appropriate actions to be taken for risk mitigation.

- If waste is RCRA hazardous, arrange for disposal at a hazardous waste disposal facility. If it is not RCRA hazardous, arrange for disposal at a non-hazardous waste disposal facility; in the case where no contamination is present in the waste and there is no evidence of leaching to soil, consider leaving the waste onsite. If contamination is present below the waste piles, perform nature and extent characterization following waste removal.

- If the asbestos survey and testing indicates ACM is present at the site, arrange for a specialized contractor to perform a removal of the material.

- If the NORM/TENORM survey indicates these materials are present at the site and pose an unacceptable risk, extend the COPC suite to other media for the site characterization. During the FS, determine the most appropriate actions to be taken for risk mitigation.

- If the wetlands survey confirms that wetlands are present at the site, expand the scope of surface water and sediment sampling to include wetlands characterization. If during risk screening and subsequent risk assessment, it is determined that there is a risk to human health or the environment, determine the most appropriate actions to be taken for risk mitigation during the FS.

Note that some of these decision rules will not be satisfied until data collection is completed during the last mobilization that takes place at the site.

1.4.7 Step 6 – Specify the Performance or Acceptance Criteria

Step 6 of the DQO process specifies the tolerable limits on decision errors. Data are subject to various types of errors (e.g., how samples were collected, how measurements were made, etc.). As a result, estimates or conclusions that are made from the collected data may deviate from what is actually true within the population. Therefore, there is a chance that an erroneous conclusion could be made or that the uncertainty in the estimates will exceed what is acceptable.

The performance or acceptance criteria for collected data will be derived to minimize the possibility of either making erroneous conclusions or failing to keep uncertainty in estimates to within acceptable levels. Performance criteria and QA practices will guide the design of new data collection efforts. Acceptance criteria will guide the design of procedures to acquire and evaluate existing data.

The activities in DQO Step 6 are as follows:

- Recognizing the total study error and devising mitigation techniques to limit error.

- Specify the decision rule as a statistical hypothesis test, examine consequences of making incorrect decisions from the test, and place acceptable limits on the likelihood of making decision errors.

1.4.7.1 Total Study Error

Even though unbiased data collection methods may be used, the resulting data will still be subject to random and systematic errors at different stages of the collection process (e.g., from field sample collection to sample analysis). The combination of these errors is called the “total study error” (or “total variability”) associated with the collected data. There can be many contributors to total study error, but there are typically two main components, sampling error and measurement error.

Sampling Error

Sampling error, sometimes called statistical sampling error, is influenced by the inherent variability of the population over space and time, the sample collection design, and the number of samples collected. It is usually impractical to measure the entire population space, and limited sampling may miss some features of the natural variation of the measurement of interest. Sampling design error occurs when the data collection design does not capture the complete variability within the population space, to the extent appropriate for making conclusions. Sampling error can lead to random error (i.e., random variability or imprecision) and systematic error (bias) in estimates of population parameters. In general, sampling error is larger than measurement error and consequently needs a larger proportion of resources to control.

Measurement Error

Sometimes called physical sampling error, measurement error is influenced by imperfections in the measurement and analysis protocols. Random and systematic measurement errors are introduced in the measurement process during physical sample collection, sample handling, sample preparation, sample analysis, data reduction, transmission, and storage.

The potential for measurement error will be mitigated by using accurate measurement techniques. Sampling techniques were selected to limit the measurement error, including the following:

- Sample collection procedures, sample processing, and field sample analysis protocols are standardized and documented in SOPs to ensure that the methodology remains consistent and limits the potential for measurement error.
- Field teams will be trained and will perform specific tasks (e.g., sample collection or processing) throughout the field sampling effort to limit the potential for measurement error.
- Potential for measurement error in the sample analysis will be limited by the analysis of QC samples (e.g., duplicates).
- Data management procedures and sample tracking software (i.e., Scribe) will limit the potential for data reduction, transmission, and storage errors.

1.4.7.2 Statistical Hypothesis Testing and Decision Errors

Decision-making problems are often transformed into one or more statistical hypothesis tests that are applied to the collected data. Data analysts make assumptions on the underlying distribution of the parameters addressed by these hypothesis tests, in order to identify appropriate statistical procedures for performing the chosen statistical tests.

Due to the inherent uncertainty associated with the collected data, the results of statistical hypothesis tests cannot establish with certainty whether a given situation is true. There will be some likelihood that the outcome of the test will lead to an erroneous conclusion (i.e., a decision error).

When a decision needs to be made, there are typically two possible outcomes: either a given situation is true, or it is not. Although it is impossible to know whether an outcome is really true, data are collected and statistical hypothesis testing is performed to make an informed decision. In formulating the statistical hypothesis test, one of the two outcomes is labeled the "baseline condition" and is assumed to represent the *de facto*, true condition going into the test, and the other situation is labeled the "alternative condition." The baseline condition is retained until the information (data) from the sample indicates that it is highly unlikely to be true.

The statistical theory behind hypothesis testing allows for defining the probability of making decision errors. However, by specifying the hypothesis testing procedures during the design phase of the project, the performance or acceptance criteria can be specified.

There are four possible outcomes of a statistical hypothesis test. Two of the four outcomes may lead to no decision error; there is no decision error when the results of the test lead to correctly adopting the true condition, whether it is the baseline or the alternative condition. The remaining two outcomes represent the two possible decision errors. The first is a false rejection decision error, which occurs when the data leads to decision that the baseline condition is false when, in reality, it is true. The second is a false acceptance decision error, which occurs when the data are insufficient to change the belief that the baseline condition is true when, in reality, it is false.

In the statistical language of hypothesis testing, the baseline condition is called the "null hypothesis" (H_o) and the alternative condition is called the "alternative hypothesis" (H_a). A false rejection decision error, or a Type I error, occurs when you reject the null hypothesis when it is actually true. The probability of this error occurring is called alpha (α) and is called the hypothesis test's level of significance. A false acceptance decision error, or a Type II error, occurs when you fail to reject the null hypothesis when it is actually false. The probability that this error will occur is called beta (β). Frequently, a false rejection decision error is the more severe decision error, and therefore, criteria placed on an acceptable value of alpha (α) are typically more stringent than for beta (β). Statisticians call the probability of rejecting the null hypothesis when it is actually false the statistical power of the hypothesis test. Statistical power is a measure of how likely the collected data will allow you to make the correct conclusion that the alternative condition is true rather than the default baseline condition and is a key concept in determining DQOs for decision-making problems. Note that statistical power represents the probability of "true rejection" (i.e., the opposite of false acceptance) and, therefore, is equal to $1-\beta$.

Decision errors can never be totally eliminated when performing a statistical hypothesis test. However, the primary aim of this step is to arrive at the upper limits on the probabilities of each of these two types of decision errors that the planning team finds acceptable.

1.4.8 Step 7 – Develop the Plan for Obtaining Data

In the Steps 1 through 6 of the DQO process, performance or acceptance criteria were developed. The goal of Step 7 is to develop a resource-effective sampling design for collecting and measuring environmental samples, or for generating other types of information needed to address

the PSQs. In addition, this sampling design will lead to data that will achieve the performance and acceptance criteria. The sampling design is detailed in Section 2.

The most important activity in DQO Step 7 is to use the information from Steps 1 through 6 of the DQO process to identify a sampling and analysis design that will answer the PSQs and achieve the performance or acceptance criteria.

The soil, sediment, surface water, and ground water sampling approach incorporates biased or judgmental samples. Samples will be biased toward impacted areas, based on using historical site evidence (e.g., photographic documentation, historical sampling results, etc.) and information obtained during site visit. This does introduce bias and potential sampling error; however, the bias is likely to increase the sample concentration, which will likely result in a more protective remedial decision. Sampling error that is considered more protective of human health or the environment is acceptable for this evaluation.

New data will be combined with the historical dataset to evaluate the nature and extent of contamination in the RI. Data collected during previous site investigations will be considered further during the risk assessment. Only historical data suitable for risk assessment will be combined with the new data to evaluate potential risks for ecological and human health receptors.

1.5 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

A well-defined QA/QC process is integral to the generation of analytical data of known and documented quality. The QC process includes those activities required during data collection to produce data of sufficient quality to support the decisions that will be made based on the data (e.g., decisions to be made prior to, during, and after site removal or remedial actions) (EPA 2006a). After environmental data are collected, QA activities focus on evaluating the quality of the data in order to determine the data usability with respect to support for remedial or enforcement decisions. Table 4 presents the acceptance criteria for definitive onsite and offsite laboratory data for chemical analyses of investigation samples only.

1.5.1 Data Categories

In order to produce data suitable for decision-making, an appropriate analytical technique must be selected. The EPA Superfund program has developed two descriptive categories of analytical techniques: (1) field-based techniques and (2) fixed-laboratory techniques. The type of data generated depends on the qualitative and quantitative DQOs developed for a project. Regardless of whether the data were analyzed utilizing field or laboratory techniques, the data must be of adequate quality for the decision-making process for which the data were collected. For this project, data from both types of techniques will be collected. Section 2 discusses the methods that will be used to analyze the samples. Both field-based and definitive analytical data will be used to support decisions made for this project.

Rigorous analytical methods (e.g., EPA CLP methods or third-party laboratory, if short analytical turnaround time is necessary) are used to generate analyte-specific, definitive data. The definitive quality of the data are assured by: (1) using SOPs and QC processes during data

collection; (2) documented control and traceability of reference standards, calibrations, and instrument performance; and (3) acceptable performance of field and laboratory QC procedures within the defined limits established for these procedures.

The majority of the fixed-laboratory analysis for samples collected during the RI sampling event will be conducted by the EPA Region 6 Laboratory and/or an EPA-designated CLP laboratory. Quick Reference Fact Sheets for relevant analytical methods are included in Appendix C. The EA subcontracted commercial laboratory will provide analytical support for analyses that the EPA Region 6 Laboratory and CLP laboratories cannot analyze due to method requirements (e.g., hexavalent chromium), due to schedule requirements, or due to elevated concentrations of contaminants. In addition, a third-party analytical laboratory will be employed to generate data within a short turnaround time. The analytical methods employed will be either EPA-issued or EPA-approved.

1.5.2 Measurement Quality Objectives

The analytical results will be evaluated in accordance with precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters to document the quality of the data and to ensure that the data are of sufficient quality to meet the project objectives. Of these PARCC parameters, precision and accuracy will be evaluated quantitatively by using results of field and laboratory QC check samples.

The sections below describe each of the PARCC parameters and how they will be assessed within this project.

1.5.2.1 Precision

Precision is the degree of mutual agreement between individual measurements of the same property under similar conditions. Usually, combined field and laboratory precision is evaluated by collecting and analyzing field duplicates and then calculating the variance between the samples, typically as a relative percent difference (RPD).

RPD is calculated as follows:

$$\text{RPD} = \frac{|A - B|}{(A + B)/2} \times 100\%$$

where: A = original sample concentration
B = duplicate sample concentration

Field sampling precision is evaluated by analyzing field duplicate samples. For every 10 samples collected, one duplicate sample will be collected.

Laboratory analytical precision is evaluated by analyzing laboratory duplicates (also called matrix duplicates [MDs]) or matrix spikes (MSs) and matrix spike duplicates (MSDs). For this project, MS/MSD and original sample [OS]/MD samples will be generated for analytes. The

results of the analysis of each MS/MSD or OS/MD pair will be used to calculate the RPD as a measure of lab precision. In addition, laboratory control samples (LCS) and LCS duplicates are also used for laboratory precision.

1.5.2.2 Accuracy

A program of sample spiking will be conducted to evaluate laboratory accuracy. This program includes analysis of the MS and MSD samples, LCSs or blank spikes, surrogate standards, and method blanks. MS and MSD samples will be prepared and analyzed at a frequency of 5 percent for project samples. LCSs or blank spikes will also be analyzed at a frequency of 5 percent or one per batch. Surrogate standards, where applicable, are added to every sample analyzed for organic constituents. The results of the spiked samples are used to calculate the percent recovery for evaluating accuracy.

$$\text{Percent Recovery} = \frac{S - C}{T} \times 100\%$$

where: S = measured spike sample concentration
C = sample concentration
T = true or actual concentration of the spike

The objective for accuracy of field measurements is to achieve and maintain factory specifications for the field equipment.

1.5.2.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a population, variations in a parameter at a sampling point, or an environmental condition that they are intended to represent. For this project, representative data will be obtained through careful selection of sampling locations and analytical parameters. Representative data will also be obtained through proper collection and handling of samples to avoid interference and minimize contamination.

Representativeness of data will also be ensured through the consistent application of established field and laboratory procedures. Field blanks (if appropriate) and laboratory blank samples will be evaluated for the presence of contaminants to aid in evaluating the representativeness of sample results. Data determined to be non-representative, by comparison with existing data, will be used only if accompanied by appropriate qualifiers and limits of uncertainty.

1.5.2.4 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this SAP, and when the QC criteria that affect data usability are not grossly exceeded. When data validation is completed, the percent completeness value will be calculated by dividing the number of useable sample results by the total number of sample results planned for this investigation.

Completeness will also be evaluated as part of the data quality assessment (DQA) process (EPA 2006c, 2006d). This evaluation will help determine whether limitations are associated with the decisions to be made based on the data collected.

1.5.2.5 Comparability

Comparability expresses the confidence with which one data set can be compared with another. Comparability of data will be achieved by consistently following standard field and laboratory procedures and by using standard measurement units in reporting analytical data. Standard EPA analytical methods and QC will be used to support the comparability of analytical results with those obtained in previous testing. Calibrations will be performed in accordance with EPA or manufacturer's specifications and will be checked with the frequency specified in the EPA CLP SOW(s) or applicable methods.

1.5.3 Detection and Quantitation Limits

The analytical parameters and their quantitation limits for use on this project are determined under the EPA CLP SOW(s) or applicable method. The Contract-required Detection Limit (CRDL), for CLP methods, or Method Detection Limit (MDL), for non-CLP methods, is the minimum concentration of an analyte that can be reliably distinguished from background noise for a specific analytical method. The quantitation limit represents the lowest concentration of an analyte that can be accurately and reproducibly quantified in a sample matrix. The CRQL, for CLP methods, or RL for non-CLP methods, is the contractually specified maximum quantitation limit for specific analytical methods and sample matrices, such as soil or water, and are typically several times the CRDL or MDL, to allow for matrix effects. Quantitation limits for non-CLP methods are typically referred to as the method RL.

For this project, analytical methods have been selected so that the CRQL or RL for each target analyte is below the applicable screening criteria, wherever practical. Samples results will be reported as estimated values if concentrations are less than the CRQL/RL but greater than CRDL/MDL. The CRDL or MDL for each analyte will be listed as the detection limit in the laboratory's electronic data deliverable (EDD).

Laboratory analysis methods were selected to obtain the lowest CRQLs and RLs. Data collected during the RI will undergo an evaluation of the CRQLs and RLs in conjunction with screening criteria to ensure that the data are adequate.

- If one-half the lowest CRQL or RL for a chemical is greater than its respective screening level, then it will be evaluated in the uncertainty section of the risk assessment.

- If a chemical is reported in a field sample and in a method blank or field blank, it will be considered as a positive identification if the field sample concentration is present at a concentration greater than 10 times the maximum blank concentration for common laboratory contaminants or 5 times the maximum blank concentration for other analytes. Common laboratory contaminants include acetone, methylene chloride, methyl ethyl ketone, phthalate esters, and toluene.

- Data with "estimated" qualifiers (e.g., J-qualifier) will be considered detected concentrations.

1.6 SPECIAL TRAINING AND CERTIFICATION

This section outlines the training and certification required to complete the activities described in this SAP. The following sections describe the requirements for the EA team and subcontractor personnel working onsite.

1.6.1 Health and Safety Training

EA field team personnel who work at hazardous waste project sites are required to meet the Occupational Safety and Health Administration (OSHA) training requirements defined in 29 CFR 1910.120(e). These requirements include: (1) 40 hours of formal offsite instruction; (2) a minimum of 3 days of actual onsite field experience under the supervision of a trained and experienced field supervisor; and (3) 8 hours of annual refresher training. Field personnel who directly supervise employees engaged in hazardous waste operations also receive at least 8 additional hours of specialized supervisor training.

Copies of the field team's health and safety training records, including course completion certifications for the initial health and safety training, refresher training, and specialized supervisor training are maintained in project files.

Additional health and safety details can be found in EA's site-specific HSP (EA 2016).

1.6.2 Subcontractor Health and Safety Training

Subcontractors who work onsite will certify that their employees have been trained for work on hazardous waste project sites. Training will meet OSHA requirements defined in 29 CFR 1910.120(e). In addition, the asbestos and NORM/TENORM surveys will be performed by specialized contractors that will hold the training and certification necessary to do that work. Subcontractors will attend a safety briefing and complete the Safety Meeting Sign-Off Sheet before they conduct onsite work (EA 2016). This briefing is conducted by the EA Site Health and Safety Officer or other qualified person. Alternatively, the subcontractors may elect to conduct their own safety briefings; EA personnel may audit these briefings.

Before work begins at the project site, subcontractors will submit copies of the training certification for each employee assigned to the project. Copies of the subcontractor's health and safety training records will be maintained in project files.

1.7 DOCUMENTS AND RECORDS

The following sections discuss the requirements for documenting field activities and for preparing laboratory data packages. This section also describes reports that will be generated as a result of this project.

1.7.1 Field Documentation

Field personnel will use permanently bound field logbooks with sequentially numbered pages to record and document field activities and will follow EA SOP 016 (Appendix G) for completing field logbooks. The logbook will list the contract name and number, the site name, and names of subcontractors, service client, and EA Project Manager. At a minimum, the following information will be recorded in the field logbook:

- Name and affiliation of onsite personnel or visitors
- Weather conditions during the field activity
- Other non-weather-related conditions at the time of sampling
- Summary of daily activities and significant events
- Notes of conversations with coordinating officials
- References to other field logbooks or forms that contain specific information
- Discussions of problems encountered and their resolution
- Discussions of deviations from the SAP or other governing documents
- Description of photographs taken
- Specific volumes of materials used to plug holes, wells, etc.
- GPS data.

1.7.2 Laboratory Documentation

This section describes the data reporting requirements for EA field personnel and laboratories (e.g., EPA CLP laboratories, EPA Region 6 Laboratory, or subcontracted commercial laboratories) that submit field and laboratory measurement data under the EPA Region 6 RAC II program.

EA will require fixed offsite, subcontracted private commercial laboratories to prepare and submit data packages in accordance with the EPA CLP protocols (EPA 2014d, 2015c, 2015d) for hardcopy and EDD format of data. Data packages will include applicable documentation for independent validation of data and verification of the DQOs. The following documentation will be required for full data validation, if applicable:

- Case narratives, which will describe QC non-conformances that are encountered during the analysis of samples in addition to corrective actions that are taken:
  - Statement of samples received
  - Description of deviations from the specified analytical method
  - Explanations of data qualifiers that are applied to the data
  - Other significant problems that were encountered.

- Tables that cross-reference field and laboratory sample numbers.

- Chain-of-custody forms, which pertain to each sample delivery group or sample batch that is analyzed.

- Laboratory reports, which must show traceability to the sample analyzed and must contain specified information:
  - Project identification
  - Field sample number
  - Laboratory sample number
  - Sample matrix description
  - Dates and times of sample collection, receipt at the laboratory, preparation, and analysis
  - Description of analytical method and reference citation
  - Results of individual parameters, with concentration units, including second column results, second detector results, and other confirmatory results, where appropriate
  - Quantitation limits achieved
  - Dilution or concentration factors.

- Data summary forms and QC summary forms showing analytical results, if applicable:
  - Samples
  - Surrogates
  - Blanks
  - Field QC samples
  - LCS
  - Initial and continuing calibrations
  - Other QC samples.

- Laboratory control charts:
  - Raw data
  - Instrument printouts
  - Laboratory bench sheets for preparation of samples.

- MDL study results.

EA's Project Manager, in cooperation with the EA QA Officer, will define site-specific requirements for data reporting. Requests for analytical services define these requirements, the turnaround time for receipt of the data deliverables specified, and requirements for retaining samples and laboratory records. Laboratory QA Managers are responsible for ensuring that laboratory data reporting requirements in this SAP are met.

1.7.3 EPA Level IV Type Data Package

The laboratory will prepare EPA Level IV type data packages in accordance with the instructions provided in the EPA CLP SOWs (EPA 2014d, 2015c, 2015d). Commercial laboratories conducting non-CLP analyses will be required to prepare Level IV type data packages. The data packages will contain the information from the summary data package and associated raw data and are due to EA within 35 days after the last sample in the sample delivery group is received.

Unless otherwise requested, the laboratory will deliver one copy of the Level IV type data package.

1.7.4 Reports Generated

Following the completion of the RI field program and receipt of validated data, the following reports associated with the site RI will be completed:

- Data Evaluation Summary Report (DESR)
- RI Report, including SLERA and HHRA Reports.

The DESR, prepared upon receipt of all RI analytical data, will (1) compile, tabulate, and summarize the analytical data; (2) discuss the usability of the data, including data validation summaries; and (3) discuss any discrepancies or data quality issues.

The RI Report will provide information to assess risks to human health and the environment, and to support the development, evaluation, and selection of appropriate response alternatives. The RI Report will be written in accordance with EPA's *Guidance for Conducting Remedial Investigations/Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act* (EPA 1988) and *Guidance for Data Usability in Risk Assessment* (EPA 1992a and 1992b).

Typical components of the RI Report include, but are not limited to, the following:

- Site Background
  - Site description
  - Site history
  - Previous investigations summary
- Investigation
  - CSM
  - Field investigation and technical approach
  - Chemical analyses and analytical methods
  - Field methodologies (e.g., soil gas sampling and sub-slab sampling)
  - Deviations from the SAP with explanation on impact to DQOs
- Site Characteristics
  - Geology
  - Hydrogeology
  - Demographics and land use
- Nature and Extent of Contamination
  - Contaminant sources
  - Summary of analytical results

  - Contaminant distribution and trends

- Fate and Transport
  - Contaminant characteristics
  - Degradation pathways
  - Transport processes
  - Contaminant migration trends

- Summary of the HHRA and SLERA.

- Summary and Conclusions.

2. DATA GENERATION AND ACQUISITION

This section describes the requirements for the following:

- Sampling process design
- Consent for property access
- Sampling methodology
- Sample processing
- Decontamination
- Management of investigation-derived waste (IDW)
- Sample designation
- Sample container, volume, preservation, and holding time requirements
- Sample handling and custody
- Analytical method requirements
- QC requirements
- Instrument calibration and frequency
- Requirements for inspection and acceptance of supplies and consumables
- Data acquisition requirements
- Data management.

2.1 SAMPLING PROCESS DESIGN

For the activities associated with this SAP, main elements of the sampling design include the numbers and types of samples to be collected, sampling locations, sampling frequencies, and sample matrices as appropriate to fill data gaps, define potential plumes and hot spots, and collect data as necessary to support ongoing evaluations of risk at the Site.

As stated in the DQOs (Section 1.4), the following PSQs were formulated for the RI field program (Mobilizations 1 through 3):

- Are waste piles Resource Conservation and Recovery Act (RCRA) hazardous or non-hazardous and have contaminants leached from the waste into the underlying soil layer?
- What is the nature of contamination in soil within specific source areas and what is the extent of contamination?
- What is the nature of contamination in surface water and sediment and what is the extent?
- What is the extent and volume of contaminated media in the Lead Additive Area?
- Is there a ground water aquifer at the site, and if present what is the classification and what is the nature and extent of contamination?
- Is there LNAPL present and what is the extent and volume?
- Is the refusal layer continuous across the site and does it provide a barrier to downward contaminant migration?

- Is vapor intrusion an issue at select properties?
- What are the migration pathways for transport of these contaminants in different media?
- Are asbestos and/or NORM/TENORM present at the site?
- Are wetlands present at the site?
- Is there a risk to human health or the environment from contamination at the site?

The primary objective of the sampling design is to collect data of sufficient quantity and quality to resolve the PSQs and support risk assessment and remedy evaluation. The purpose of the RI is to determine the nature and extent of contamination and to gather sufficient information so that the EPA can select a remedy that eliminates, reduces, or controls risks to human health or the environment. This can be accomplished by answering the PSQs as follows:

- Delineate and characterize waste piles and underlying soil.
- Determine if ROST LIF data are adequate to characterize the nature and extent of contamination in surface and subsurface soil and use that information to continue delineation of contamination and soil sampling.
- Characterize and delineate soil contamination at specific source areas.
- Characterize and delineate contamination in surface water and sediment.
- Characterize and delineate contamination to determine how and what future actions (e.g., investigation, delineation, characterization) are necessary to characterize the ground water; otherwise, consider no further action.
- Characterize and delineate contamination in ground water to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment); otherwise, consider no further action.
- Confirm the presence or absence of ground water contamination discharge to the surface water to determine how and what future actions (e.g., investigation, delineation, characterization) are necessary to characterize this interaction; otherwise, consider no further action.
- Characterize and delineate ground water discharge to surface water to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment); otherwise, consider no further action.
- Confirm the presence or absence of LNAPL to determine whether future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment) are necessary; otherwise, consider no further action.

- Characterize and delineate the LNAPL to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation or in-place containment); otherwise, consider no further action.
- Confirm the presence or absence of a continuous refusal layer at depth to determine whether future actions (e.g., investigation, delineation, and characterization) are necessary; otherwise, consider no further action.
- Characterize and delineate the refusal layer to determine whether it provides a barrier to downward contaminant migration and whether future actions (e.g., investigation, delineation, and characterization) are necessary; otherwise, consider no further action.
- Characterize and delineate the Lead Additive Area to determine whether COPCs present unacceptable human health/ecological risk requiring the evaluation of options and technologies to support future actions (e.g., removal, remediation, exposure restriction, migration mitigation, or in-place containment); otherwise, consider no further action.
- Determine if vapors have impacted onsite vacant residences and the vacant church within process areas.
- Determine if asbestos and/or NORM/TENORM are present at the site.
- Determine if wetlands are present at the site.
- Determine if there are risks to human health and/or the environment.

The goal is to collect the appropriate amount of data necessary to result in a well-supported FS and ROD. To achieve this goal, site media will be sampled during the RI.

2.2 ANALYSES

Multimedia samples will be collected for laboratory analysis using a host of field methods. Table 5 lists the SOPs that will be implemented during the field program at the direction of EPA. Tables 6 through 9 summarize the type and quantities of soil, surface water, sediment, ground water, and air samples that are planned for collection during the RI field program. Due to a number of uncertainties at this point in the RI, contingency samples are also specified for the sampling of various media. Rationale for analyses is discussed below.

As discussed in Section 1.4.2, the list of COPCs at the site will be initially applied conservatively to all media across the investigation, as relatively extensive rework of the site ground surface has taken place in several locations, thus removing historical site features. For these reasons, the full set of COPCs cannot be refined until source characterization has been completed. The exception to this approach is analysis for NORM/TENORM. Media samples will not be analyzed for these compounds until Mobilization 2, when this analysis will be added appropriately to samples for various media to be collected in the areas where the survey indicates the presence of these materials.

Table 10 summarizes the proposed analytical suites for each media and/or sample type during Mobilization 1.

Soil, sediment, ground water, and surface water samples will undergo the following analyses:

- VOCs
- EDB (only in water samples, if not included at an appropriately low detection limit in the VOC analysis)
- SVOCs (including PAHs)
- TAL metals (surface water samples will be analyzed for both total and dissolved TAL metals)
- Cyanide.

A subset of soil, sediment, ground water, and surface water samples associated with the former cooling tower/cooling pond areas will be analyzed for hexavalent chromium.

A subset of shallow surface soil samples (0.0–0.5 ft bgs) associated with the Wilcox Process Area will undergo the following analyses:

- PCBs
- Pesticides
- Dioxins/furans.

PSG, indoor air, and active soil gas samples will undergo the following analyses:

- BTEX
- Naphthalene

In addition, PSG samples will also be analyzed for 2-Methylnaphthalene.

Suspected ACM will be analyzed for the presence of asbestos.

The following additional testing will be performed:

- Ground water (all field parameters)
  - Temperature
  - pH
  - Conductivity
  - Oxidation-reduction potential (ORP)
  - Dissolved oxygen (DO)
  - Turbidity.

- Surface water
  - Dissolved metals
  - Hardness
  - Total dissolved solids (TDS)
  - Total suspended sediment
  - Alkalinity
  - Total organic carbon
  - Field parameters, including temperature, pH, conductivity, ORP, and DO.

- Sediment samples
  - Acid volatile sulfide (AVS)
  - Simultaneous extracted metals (SEM)
  - Grain size (20 percent of samples)
  - Total organic carbon
  - pH

IDW samples will undergo the following waste disposal characterization analyses:

- Toxicity Characteristic Leaching Procedure (TCLP) VOCs
- TCLP SVOCs
- TCLP metals
- TPH
- Reactivity, corrosivity, and ignitability.

2.3 SAMPLING METHODOLOGY (MOBILIZATION 1)

This section describes the procedures for sample collection during Mobilization 1. Table 5 lists the SOPs that will be implemented during the field program at the direction of EPA. The SOPs are provided in Appendix G.

Sample collection and handling procedures will follow CLP protocols in accordance with EPA's *Contract Laboratory Program Guidance for Field Samplers* (EPA 2014c).

During sample collection, preparation, and field analysis, chain of custody will be maintained and documented as required in Section 2.9. Sample locations will be delineated using GPS, be documented photographically, and sketched in the field logbook; an accompanying photograph log will be completed in the field logbook (Section 1.6.1).

2.3.1 Utilities, Access Agreements, and Permits

Prior to performing intrusive Mobilization 1 field activities, Oklahoma One Call will be contacted to locate all public underground utilities and a private utility locate company will be contracted to locate utilities on private property.

EPA will obtain consent for property access agreements from the private property owners that have been identified for investigation under the RI/FS. For properties where the property owner

cannot be identified and/or the property owner is not responsive, other properties may be identified for characterization, as appropriate.

The driller will be responsible for completing all permits associated with installation and plugging of monitoring wells and/or boreholes with the Oklahoma Water Resource Board.

2.3.2 Site Preparation

EA will mobilize to the site and set up temporary field offices within the church parking area (within the boundary of the Lorraine Process Area) to establish a command post for the field phase of the investigation.

While setting up the command post, clearing and chipping will be conducted in the Wilcox Process Area and the southern portion of the Lorraine Process Area. Shrubs and trees (less than 6 inches in diameter) will be cleared and chipped in place. It is estimated that up to 20 acres of land will require clearing. Other areas will be cleared, as needed, for access during site reconnaissance and waste delineation, including the North Tank Farm and Loading Dock Area.

2.3.3 Site Reconnaissance and Surveys

Prior to performing intrusive activities, a site reconnaissance will be conducted in preparation for the sampling program. Several surveys—including an ACM survey, wetlands survey, and NORM/TENORM survey—will also be conducted at this time, as well as the passive soil gas investigation by EPA ERT.

2.3.3.1 Site Reconnaissance

The following site reconnaissance activities will be conducted concurrent with site preparation activities:

- Assess former locations of unconfirmed Tanks 1 and 4 – Based on aerial photography, two areas to the east of the East Tributary have been cleared of vegetation. There is no evidence that these areas have ever been used for industrial operations. The two areas will be visited during the site reconnaissance and any indication of presence of discolored soil, distressed vegetation, and/or the presence of any equipment will be recorded and locations delineated with GPS. Also, access for sampling will be assessed and clearing of an access route will take place, if needed.

- Locate Seeps – Assist ODEQ in using a thermal infrared imaging camera to determine the location of the seeps and locations where runoff from the site drains into Sand Creek and the East and West Tributaries (PPEs), and delineate using GPS. This information will be used to determine the potential locations for surface water/sediment sampling in order to optimize the sampling strategy and eliminate duplication of effort.

- Assess Bridge Area – Coordinate with ODOT to (1) visually assess the Sand Creek bridge that was constructed using onsite borrow material; and (2) select possible locations for sediment sampling (no actual sample collection is planned during the site reconnaissance). Potential sample areas will be delineated using GPS.

- Assess Background Area – Reconnoiter the large field across Refinery Road from the East Tank Farm (just north of former Tank 5 location), which is currently proposed for soil background sampling, and assess if this area has evidence of anthropogenic activities; if so, confirm location is adequate for background sampling; if not, select another location.

- Residential Well Assessment – Determine how many residences have private water wells and determine if access has been granted; if not, obtain consent to sample their wells in coordination with ODEQ. Determine if the residents have any information on how the wells were constructed (depth of well, borehole log, screen interval, etc.); research if there is a state or local repository for drilling information.

- Private Wells Not In Use – There are three inactive wells (not in use): the church well located at the Lorraine Process Area, and two wells located on the East Tank Farm. Locate, determine if pumps are present, and, if possible, gauge the wells using a water level indicator and/or interface probe.

- Additional Waste Piles – Identify additional waste piles and areas of exposed waste material. Delineate the waste piles using GPS and visually assess how many types of waste may be present in each pile.

- Map Outcrops – An overburden thickness isopach map has been created during previous investigations; however, the Northern Tank Farm area was not included. Sandstone outcrops will be mapped in the Northern Tank Farm area to aid in determining overburden thickness in this area.

2.3.3.2 Site Surveys

In conjunction with site reconnaissance activities, wetlands, ACM, and NORM/TENORM surveys will be conducted.

Wetlands Survey

The HRS Documentation Record (EPA 2013a) notes the presence of wetlands associated with the site. The presence of the wetlands will be first confirmed per the protocol described below. If wetlands are identified, then this sensitive environment will be included in the CSM and additional characterization and sampling may be required.

The wetlands survey will be performed during the site reconnaissance. The following protocol will be applied:

1. Obtain and review available Natural Resource Conservation Service soil surveys, infrared and true color aerial imagery, National Wetland Inventory (NWI) data. Based on this data, preliminarily identify locations with hydric soil and potential hydric soil, areas identified as wetlands by NWI, and possible wetland signatures on infrared imagery.

2. Ground-truth wetland extents in accordance with the U.S. Army Corps of Engineers (USACE) *Wetland Delineation Manual* (1987) and *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region (Version 2.0)* (2010). Wetlands will be delineated based on the following three criteria:

    a. Indicators of hydrology
    b. Dominant hydrophytic vegetation in the appropriate stratum
    c. The presence of hydric soil.

    Delineation will be performed by walking along the wetland-upland interface and continually identifying the interface where these three criteria are met and not met. At each point where the line changes direction, the interface will be marked with colored surveyor flagging tape and pin flags, as appropriate. Additionally, flags and tape will also be set in a way as to capture the wetland areas, as well as so that each flagged location is visible from the next flag on each line in both directions. A Wetland Determination Data Form (Great Plains Region) will be populated at each location where the vegetative community or soil type changes along the wetland delineation. Each flag will be marked with a discrete identification number. Vegetative community boundaries will be identified, sketched, and recorded. Wetland community boundaries that border each other will be approximated and not delineated.

A GPS unit will be used to record the flagged locations. The GPS unit will be capable of locating each flagged location with sub-meter accuracy.

ACM Survey

An asbestos survey will be performed by a certified contractor during the site reconnaissance. During the asbestos survey, the contractor will identify potential asbestos locations and these locations will be sampled. If collected, the samples will be analyzed via Phase Contrast Microscopy and Polarized Light Microscopy.

NORM/TENORM Survey

Field screening activities for identification of NORM/TENORM will consist of using field instruments and detectors to identify the possible presence and degree of NORM/TENORM in remaining production equipment or tanks, pits, ponds, or temporary water storage areas. A walkover survey with gamma-detecting instruments will be performed around the site with an objective of surveying areas that may have been impacted by crude oil operations and water/wastewater storage. An area at or near the site thought to be non-impacted will be surveyed for use as a reference background area. Direct-read alpha/beta radiological instruments will be used throughout the field operations of the project for scanning and surveying of personnel, equipment, and materials to quantify the total surface radioactivity levels. If elevated alpha/beta readings are observed, smear samples will be collected and counted to quantify the

removable radioactivity levels. Measurement results (total and removable) will be compared to the Acceptable Surface Contamination Levels presented in Oklahoma General Radiation Control Regulations (Oklahoma Administrative Code 2014 and Association of State and Territorial Solid Waste Management Officials 2014) or concentration-based standards for soil and water. No NORM/TENORM-specific regulations exist in Oklahoma; therefore, NORM/TENORM are subject to the general radiation control regulations stated above.

Table 11 lists the proposed instruments, detectors, and equipment (or their equivalent) to be used onsite during field screening for NORM/TENORM.

If the field screening indicates that NORM/TENORM are present, then a subset of the waste, shallow surface soil, surface water, and sediment samples will be analyzed for NORM/TENORM.

2.3.3.3 Passive Soil Gas Survey

EPA ERT has been tasked with conducting passive soil gas (PSG) survey in an effort to delineate the vadose zone source area in accordance with SOPs 003, and 027A (Appendix G). PSG samplers will be deployed at depths ranging between 12 and 30 inches bgs, as specified by the soil gas vendor selected. The soil gas samplers will be judgmentally deployed based on a 50-ft-square grid system depending on location onsite. Figures 5, 6, and 7 present the proposed deployment layout. Sample borings will be advanced with a hammer drill equipped with a 0.75-inch diameter bit. The boring will be advanced to the desired depth and the PSG sampler will be lowered into the hole attached to a retrieval wire. A pin flag will also be placed at each location (if possible), and the boring covered. After a minimum of seven days, the soil gas samplers will be located using the pin flag and the sample will be retrieved by pulling the retrieval wire; the samplers will be placed into the sample container provided by the contracted soil gas vendor. The soil gas sampler locations will be surveyed using a hand-held GPS unit. GPS data attributes for each PSG sample position will be logged and include:

- Latitude and longitude
- Collector name
- Collection method
- Datum
- Maximum Positional Dilution of Precision
- Date and time.

PSG samplers will be submitted to the subcontracted vendor for analysis for BTEX, naphthalene, and 2-methylnaphthalene using SW-846 Method 8260C Modified (or equivalent method).

2.3.4 Soil Exposure Media Investigation

Soil sampling during Mobilization 1 will be performed to (1) horizontally and vertically delineate outer boundary of contaminated areas as defined during the December 2015 ROST LIF investigation; (2) collect samples for analysis of the full COPC suite in areas where a ROST LIF survey has left data gaps or was not performed or in areas where source areas may have been

located at the Lorraine and Wilcox Process Areas; (3) collect soil samples between suspected source areas and Sand Creek to evaluate subsurface migration to surface water; and (4) perform an initial assessment of former locations of Tanks 1 and 4 (located on the east side of East Tributary. Each of these goals of the soil investigation is discussed in the sections below. Additional detail on the sampling program is provided in Table 6 and the sample locations are shown on Figures 8 through 10.

In general terms, the usability of the soil samples is as follows, depending on the depth of collection:

- 0.0–0.5 ft bgs – human health and ecological risk assessment
- 0.0–2.0 ft bgs – residential scenario
- 0.0–10.0 ft bgs – construction, trespasser, and future residential scenarios
- >10.0 ft bgs – delineation/nature & extent of contamination and migration to ground water.

For clarity and to avoid repetition, the soil sampling techniques are only presented in Table 6. All soil samples will be described, screened, and homogenized (aliquots for non-volatile analysis only) as described in the following sections.

Following completion of sampling activities, soil borings will be abandoned in accordance with SOP 028 (Appendix G).

2.3.4.1 Soil Sample Collection Methods

Several methods of obtaining soil samples from the surface and subsurface are discussed below.

Hollow-stem Auger (HSA) Drilling and Sample Collection

Drilling using a HSA rig is proposed due to the advantage it affords in collection of sample material from the horizon where refusal has been encountered during previous investigations where cone penetrometer testing and direct-push technology (DPT) were attempted at the site. Drilling will be performed by a licensed driller. Borings will be sampled continuously using split spoons or continuous sampling device that is decontaminated between uses.

DPT and Sample Collection

A track-mounted DPT rig will be used in areas where access is difficult. This DPT rig will also be used for expediency in areas where sampling is to be performed at shallower depths and a characterization of the refusal horizon is not critical. DPT will be performed by a licensed driller. Continuous soil cores will be collected using clear polyvinyl chloride or acetate sleeves.

Sample Collection Using Hand-operated (Manual) Equipment

Hand-operated or manual soil sampling equipment will be implemented in areas where access to the track-mounted DPT rig is not possible, such as at former locations of Tanks 1 and 4. EA

personnel will collect soil samples with a hand-held slide hammer, or other similar hand-held sampling device.

2.3.4.2 Lithological Logging and Field Screening

A field geologist will log the material types within each core to assist in the understanding of site geology and for the nature and extent evaluation. Soil borings will be logged on standard boring log forms (Appendix D) using the Unified Soil Classification System methodology. During logging the field team will also screen the samples using a photoionization detector, make olfactory and visual observations, and record this data on the boring log form.

2.3.4.3 Sample Material Homogenization

Regardless of the method of collection, the soil sample material will be collected across the entire sampling interval specified in the SAP. Following collection of the aliquot for VOC analysis, the remaining sample material will be homogenized for collection of the remaining sample aliquots. The aliquot for VOC analysis will be collected from the sample material or core with as little disturbance as possible, and will be from a depth no shallower than 2 inches bgs. VOC sample aliquots will be collected directly from the sample material or soil core using the EasyDraw® syringe and PowerStop® handle or other single-use samplers in accordance with EPA SW-846 Method 5035/5035A. Each sample aliquot will then be extruded into a closed-system pre-weighed 40-milliliter amber glass vial with magnetic stir bar.

2.3.4.4 Delineation of the ROST LIF Boundaries and Delineation of Nature and Extent

Existing data for soil was reviewed prior to initiating data collection for the RI; however, none of the former samples were analyzed for the entire suite of COPCs and, in some cases, analytical methods used for PAH analysis either did not have low enough detection limits (such is the case with some of the 1999 samples) or samples were analyzed for PAHs at elevated detection limits due to matrix interference (high concentration samples). As such, a comparison to screening levels could not be completed. The ROST LIF data and the historical sample analysis results were used to guide the initiation of the sampling at each source area to optimize the characterization process. The following data will be collected during the RI to provide input into the decision process:

1. Sample locations and depths will be selected for collection from representative intervals determined based on the results of the ROST LIF screening data, in order to characterize and delineate the outer boundary of source areas identified by the ROST LIF data.

2. The total depth of the boring will be the depth of refusal or encountering bedrock or ground water. Soil borings will be installed using either a DPT or HSA rig at the locations indicated on Figures 8, 9, and 10.

3. Samples will be collected from the following depths:

   a. 0.0–0.5 ft bgs

   b. 0.5–2.0 ft bgs

c. 2.0–6.0 ft bgs

d. 6.0–10.0 ft bgs

e. Total depth of the boring (the sample will span 2 ft measured up from the bottom of the boring above refusal).

4. Soil samples will be analyzed by a fixed laboratory for the suite of analytes presented in Table 6.

Due to the fact that many of the site COPCs cannot be detected with the ROST LIF technology, the main goal of this comparison is to determine if the ROST LIF data can be used as an indicator for the preponderant paths of migration for contaminants in the areas screened in 2015, thus providing useful information in the placement of the new soil borings for collection of soil samples; however, no actual correlations will be drawn between the chemical and ROST LIF data, because it has been observed that the compounds that are detected by the ROST LIF technology do not seem to have migrated in a uniform manner through the subsurface. The focus will be placed on locations that show no detections with the ROST LIF technology, as they will be critical in the delineation of the lateral and vertical extent of the contamination. In some places, contamination is more prevalent in the shallow horizons, while in other cases, it has moved through the entire column of unconsolidated soil and is present on the surface where the DPT technique reached refusal. It is also upon this refusal surface that infiltrated water has been ponding. The infiltrated water is transient in nature and is the result of precipitation events at the site; it is not, however, considered to be ground water exposure medium, as it has no beneficial uses (cannot yield sufficient water for any prolonged use) and as such, concentrations in this water cannot be compared to human health-based standards. This water will be considered a transport medium for the contamination away from the point of infiltration.

If the usability of the ROST LIF data is confirmed as an indicator as described above, additional soil borings will be installed to collect data for both delineation of nature and extent of contamination and risk assessment. These data will collected as described above. Points where lead concentrations were indicated to be potentially high based on XRF screening results were also added to this sampling program.

After the delineation of contamination is performed as described above around the source areas during Mobilization 1, the data will be evaluated for any remaining data gaps. Based on Mobilization 1 data, additional soil sampling may be performed for risk evaluation under the residential scenario using ICS methodology during Mobilization 2, for which DQOs will be formulated.

2.3.4.5 Characterization of the Former Cooling Tower/Pond Areas

The former cooling towers and cooling ponds are associated with historical refining activities at Lorraine and Wilcox Process Areas (Figure 3). Borings will be installed for the characterization of these source areas as shown on Figures 8 and 9. Hexavalent chromium is an additional COPC for these sources area and it has been added to the analytical suite for these samples. The sampling program is presented in Table 6.

2.3.4.6 Initial Assessment at Former Locations for Tanks 1 and 4

Surface soil sampling is proposed at these two former tank locations if, during the reconnaissance, evidence is found that industrial activities have taken place. Judgmental sampling will first address any locations identified during reconnaissance that have the potential to be contaminated, or if present, around remaining equipment. If no evidence of anthropogenic activities besides clearing is observed, sampling will consist of collecting soil samples from 0.0–0.5 ft bgs and 0.5–2.0 ft bgs from five locations within each source area. Proposed sample locations are presented on Figure 10 and are shown on Table 6.

2.3.4.7 Soil Sampling for Delineation of Lead Impact

EPA Headquarters has been tasked with XRF delineation of the Lead Additive Area using ICS methodology, and as such, they will generate a task-specific SAP separate from this submittal. EA will assist EPA Headquarters representatives during their investigation, as necessary.

2.3.4.8 Soil Background Sampling

For use in the evaluation of the soil sample analytical results, the following steps will be taken to determine background concentrations for metals (TAL metals and hexavalent chromium), PAHs, and dioxins/furans in accordance with ICS methodology, as defined in ITRC's Incremental Sampling Methodology (EPA 2013b; ITRC 2012) and EA SOP 057 (Appendix G); NORM/TENORM may also be included if the initial survey supports its presence onsite:

1. Select a location where, based on historical photographs and potential for contaminant migration, anthropogenic activities are not expected to have impacted the surface or subsurface soil; the currently targeted location is the large field just north of the former location of Tank 5 (East Tank Farm) (Figure 10).
2. Place a grid 150 ft by 150 ft in size (assumes a residential exposure area [decision unit] of 0.5 acre) and split into cells 25 ft by 25 ft in size (36 cells total).
3. At each of the 36 sample increment locations (each designated by a pin flag) within the DU, collect a soil increment from 0.0–0.5 ft bgs. Surface vegetation, including grass and roots, will be removed at each sample increment location with a dedicated trowel, as appropriate. Place each of 36 increments into a dedicated and labeled resealable bag; this is the main background sample.
4. To collect the QC samples (duplicate and triplicate), repeat this process a second time for the ICS duplicate using a different starting point and direction. Place each of 36

increments into a dedicated and labeled resealable bag (designated "-D" for duplicate).

5. Repeat this process a third time (and final) for the ICS triplicate using a yet different starting point and direction. Place each of 36 increments into a dedicated and labeled resealable bag (designated '-T" for the triplicate).
6. The background sample and its replicate samples will be submitted intact to the laboratory for appropriate preparation (drying, sieving, grinding, homogenization, and subsampling) and subsequent analysis for TAL metals, hexavalent chromium, PAHs (PAHs to be used as an indicator of anthropogenic activity), dioxins/furans; the samples will also be analyzed for NORM/TENORM, if any are detected during the reconnaissance survey.

The background evaluation will be performed once the analytical results are received per the most recent EPA guidance:

- *ProUCL Version 5.0.00, Technical Guide* (EPA 2013c)
- *ProUCL Version 5.0.00, User Guide* (EPA 2013d)
- *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 2002a).

2.3.5 Surface Water and Sediment Sampling

Surface water and sediment sampling activities may take place during Mobilization 1 pending funding availability and schedule; otherwise, this activity will occur during Mobilization 2.

Surface water and sediment will be collocated, with the exception of the samples to be collected at the bridge downstream from the site. As shown in the CSM diagram (Appendix A), contamination can be exchanged between these two media and transport of contamination to sediment and surface water along the streams in the area of influence of the site can also originate from upstream sources of contamination. Moreover, migration of sediment, especially during times of high water, can be significant along the stream.

To clarify the terminology used in this SAP, the locations where the intermittent West Tributary and perennial East Tributary enter Sand Creek will be called "confluences" and the points where drainages (features that do not contain water for any significant length of time) enter Sand Creek will be called PPEs.

2.3.5.1 Surface Water Sampling Methodology

Surface water samples will be collected directly into the sample containers in accordance with EA SOP 021 (Appendix G). An alternative sampling method involves pumping water from the sample location through dedicated Teflon™-lined polyethylene tubing using a peristaltic pump; the intake of the sample tubing will be placed 6 inches below the surface of the water. Surface water samples collected for dissolved metals will be field-filtered using 0.45-micron disposable filters. Field parameters collected during surface water sample collection may include surface

water flow rate, water temperature, pH, conductivity, TDS, oxidation-reduction potential, and turbidity. Field data sheets are included in Appendix D. Coordinates for the sample locations will be obtained after sampling using a handheld GPS device. Sample locations may be adjusted based on existing field conditions.

2.3.5.2 Sediment Sampling Methodology

Sediment samples will be collected using sediment core samplers or laboratory-grade disposable scoops, in accordance with SOP 007 (Appendix G). AVS-SEM sediment sample containers will be completely filled to minimize head space. Field data sheets are included in Appendix D. Coordinates for the sample locations will be obtained after sampling using a handheld GPS device. Sample locations may be adjusted based on existing field conditions.

2.3.5.3 Surface Water and Sediment Sampling Program

Surface water and sediment samples will be collected from locations in flowing water bodies (Sand Creek and tributaries) and ponds. Due to the timeframe of operation for the Wilcox Oil Refinery, it is assumed that contaminant transport is fully developed. As such, media that are not presently contaminated are not anticipated to become so (i.e., no additional active primary releases, and steady-state to waning secondary releases). Consequently, if contaminant concentrations are below respective surface water or sediment criteria at a point of discharge, then the investigation at that location will be considered complete as the nature and extent of contamination is defined.

The sampling program proposed for surface water and sediment samples is presented below. Sample locations are provided on Figure 11 and details on the sampling program in Table 7. Additional surface water and sediment samples will be collected from seeps, the location in Sand Creek just below the seep, as well as from sand bar locations immediately downstream from the seeps; however, the seep locations could not be identified on Figure 11 at this time.

Samples will be collected from each location using the following methodology and in accordance with the U.S. Geological Survey's (USGS) *National Field Manual for the Collection of Water-Quality Data* (USGS 2014):

1. Collocated surface water/sediment pairs will be collected from each location, unless otherwise specified above.

2. All sediment samples will be collected from 0.0–0.5 ft bgs.

3. All surface water samples will be collected from 0.0–0.5 ft or shallower below the water surface; due to the flow in the creek and tributaries, the mixing of the water column deems this sampling depth representative.

4. All surface water and sediment samples will be collected from each location at the same time while moving upstream from the confluences as follows: from Sand Creek and East Tributary starting from Confluence 1 and from the West Tributary starting from Confluence 2. This manner of sampling will ensure that the water and sediment at the

upstream sampling locations are not disturbed due to ongoing sample collection occurring downstream.

5. Locations of the drainages from former potential sources of contamination will be verified during the initial mobilization. Surface soil and sediment samples will be collected from the points of confluence of the streams with these drainage pathways. Soil samples collected from drainage pathways are discussed under the soil DQOs.

6. Locations of seeps will be identified during the reconnaissance, based on the conditions at the time of sampling.

Sample locations are specified as described below. The prescribed sample locations based on drainages and seeps will be considered first, before the criterion of 200 ft spacing between sample locations is applied. Sampling will be performed using the following methodology:

1. Along each stream/tributary, the locations will be selected no closer than 200 ft by walking upstream from a former sample location, and where deposition and accumulation of contaminants may take place. Sand Creek, East Tributary, and West Tributary are meandering streams; therefore, deposition and contaminant accumulation is anticipated within the point bar portion of the stream bed. For this reason, the sand bars are the locations where samples are proposed to be collected. To optimize sample collection, locations will also coincide, if possible, with places where drainage of surface runoff may be discharging contamination from site sources (PPEs) or confluences discussed below.

2. By the bridge at 8th Street, crossing Sand Creek:

   a. Location of surface water samples will include one (1) upstream and one (1) downstream from the bridge; if present, the sample locations will be from areas where a "black oily substance" may be visible.

   b. For sediment samples, five (5) locations are estimated, to be determined in the field during the site reconnaissance and based upon information from stakeholders regarding former observations of a "black oily substance" presence in the area.

   c. Sediment samples will be collected from 0.0–0.5 ft bgs and an additional sediment sample will be collected from 0.5–1.0 ft bgs.

3. At seep locations along Sand Creek, a sample of the seepage will be collected, if present. If a seep is identified by seeing a wet area on the sandstone above the water level, then a sample of surface water and sediment (if sediment is present) will be collected below the wet spot; in addition, a surface water/sediment pair will be collected from the nearest downstream location where a sand bar is present.

4. Soil will be collected at PPEs along Sand Creek where runoff drains from the site. Please note that soil samples will be collected along the drainage pathways leading from the former potential source of contamination to the surface water to characterize the soil along this path; details on the soil samples are accounted for under the surface soil investigation.

5. Samples will be collected at locations where reference values for surface water and sediment can be obtained. These reference values will characterize upstream conditions of the flowing bodies of water, because water flowing in Sand Creek, East Tributary, and West Tributary may be influenced by contamination originating upstream of the site. Each water body will require its own upstream water quality data that will only be applicable to that particular stream. Reference values will be obtained as follows:
    a. For Sand Creek, from three (3) locations upstream of the site, one locations being at the bridge underneath the highway; (Upstream Condition 1a, 1b, and 1c)
    b. One location for the West Tributary that crosses the site (Upstream Condition 3)
    c. One location for the East Tributary, at discharge point from Pond P9 (Upstream Condition 2); Pond P9 is upstream of the site, but may be impacted by non-site-related contamination originating upstream from the site, so it cannot serve as reference for natural conditions and will not be characterized under this RI.
6. Pond locations are shown on Figure 11. Ponds P2 through P6 are independent ponds that rely on rain and runoff whereas ponds P1 and P7 are connected with stream flow. Ponds P1, P2, P3, P4, and P6 are isolated and associated with areas that were used in the past by the refinery as either separation ponds or tank storage areas. Pond P5 is a new pond excavated by the property owner, and it is located downgradient of a former crude oil storage tank location. Pond P8 is not associated with site activities, it appears to rely on rain and runoff, and it is considered to be representative of background conditions for the isolated ponds. The pond sampling program is as follows:
7. Collect surface water/sediment sample pairs from four (4) locations each from Ponds P2 through P6.
8. Collect surface water/sediment sample pairs from five (5) locations in Pond P1: inflow, outflow, 1 center, and 2 sides of the pond.
9. Collect surface water/sediment sample pairs from seven (7) locations for Pond P7: intake, outflow, 1 center, and 4 sides.
10. To obtain reference/background conditions for ponds, six (6) sampling locations are proposed from Pond P8, located east of the site; because of its location on the other side of the East Tributary, this pond is not considered to have been impacted by site activities.

It is anticipated that, depending on the time of year, some ponds/intermittent streams, such as the West Tributary, may not contain surface water. If completely dry, only the sediment samples will be collected as per the strategy outlined above. If the bodies of water are dry, the sediment samples collected will also be evaluated for exposure as the surface soil exposure medium. If there is water ponding in the intermittent streams, collocated ponded water and sediment will be collected from available locations, but at a frequency of not more than 1 sample every 200 ft.

In order to be able to assess the appropriate exposure routes and receptors for each surface water body, sampling personnel will make a sufficiently detailed description of the vegetation surrounding the site, and will note if there are any animals present or any traces of animal life. Based on these observations and information collected from the residents on how the surface

water bodies are used (fishing, swimming, etc.), risk screening (and if screening criteria are exceeded, risk assessment) of a threat to the appropriate human and ecological receptors will be evaluated. The results for surface water and sediment samples will be also used to determine where biota samples will be collected during a subsequent mobilization (most likely, from the most contaminated locations).

If the wetlands survey indicates wetlands are present within the area of influence of the site, then additional surface water and sediment samples will be collected during a subsequent mobilization. Also, if the extent of contamination is not defined downstream, a plan for collecting additional samples will be developed and implemented during a subsequent mobilization.

2.3.6 Initial Assessment of Ground Water

Residential wells on and in the vicinity of the site have been sampled in the past; however, the analytical suite for which the samples were analyzed is not the complete COPC suite for the site. Moreover, PAHs and EDB were analyzed using analytical methods with detection limits above current risk-based screening levels and, as such, the results available to date may not be representative of ground water quality. As of the startup of the RI, little information is available for ground water beneath the site. Samples of infiltrated water have been collected over the time, but they are not representative of the quality of ground water in the regional aquifer. Although LNAPL is reported to be present in the church well located in Lorraine Process Area, there is a strong possibility that LNAPL is present in that well due to infiltration of contaminated water along the well casing or well annulus. Moreover, the hydrogeologic regime and the direction of ground water flow are unknown. Ground water monitoring wells will be installed utilizing conductive casing construction (to prevent downward migration of contaminants to lower water-bearing zones) during a subsequent mobilization. During drilling of these wells, the lithology will be characterized and other geotechnical data will be collected to fully assess the subsurface.

2.3.6.1 Geophysical Logging of Water Supply Wells

Existing public water supply wells to be sampled during Mobilization 1 will be geophysically logged, pending owner access and EPA technical direction. The information obtained through geophysical logging will assist with the understanding of the transport mechanism and provide some clarity on the potential presence of LNAPL in the church well from horizons above the regional aquifer.

EA will subcontract with a well pump service to pull and reset pumps in existing wells. The existing wells will be logged using gamma and resistivity logging instruments. Depending on availability, EPA will coordinate with the USGS to perform geophysical logging activities. As a contingency measure, EA will be use a subcontract with a geophysical logging firm to support the investigation in the case where the USGS is unavailable. EA will manage this effort in accordance with SOP 044 (Appendix G). EA will provide the necessary equipment and personnel to perform decontamination of these tools between well locations, and will also be responsible for the collection, characterization, and disposal of associated IDW in accordance with local, State, and Federal regulations.

2.3.6.2 Sampling of Residential Wells

Residential wells that are currently in use will be utilized to evaluate COPC concentrations in ground water at the site. The following wells are proposed for sampling as shown on (Figure 12):

- Three wells located on the East Tank Farm (GW-1, GW-3, and GW-4); GW-2 is reportedly plugged, which will be confirmed during reconnaissance activities.
- Three wells located north of the East Tank Farm (GW-5, GW-6, and GW-7)
- Two wells located south of the East Tank Farm (GW-8 and GW-9)

The following four additional wells that are not currently in use will also be sampled (Figure 12):

- One well located on the North Tank Farm (GW-11)
- One water supply well for the church and the vacant residence (parsonage) located at the former Lorraine Process Area (GW-10)
- Two wells located on the East Tank Farm (1 abandoned well located east of Tank 9, GW-15, and 1 well located west of Tank 6, GW-14).

The following two additional wells (operational status to be determined) will also be sampled (Figure 12):

- One well located north of the North Tank Farm (GW-12)
- One well located within the Wilcox Process Area (GW-13).

EA will coordinate with EPA prior to site mobilization to identify which locations are to be sampled and to ensure that the necessary access agreements are in place. Table 8 specifies the sample and analytical quantities and Table 12 specifies the required sample volume, container type, preservation technique, and holding times for the analytes.

Grab samples will be collected from all wells but different sampling methods will be utilized. Tap samples will be collected from the residential wells that are in use and are equipped with an operational pump. With the exception of the church well, which is known to contain LNAPL, wells will be purged by either letting the tap run or by other means and physical parameters monitored and logged using a calibrated water quality meter in accordance with EA SOP 014 (Appendix G). The parameters measured will be used to determine if the sample stream has been stabilized and it is representative of the water in the aquifer. The parameters that will be measured for stabilization are pH, temperature, and conductivity (EA SOPs 008, 009, and 012). If a pump is operational, these parameters will be measured during the 15 minutes prior to sampling or until the readings have stabilized (conductivity within ± 10%, pH within ± 0.5 pH units, and temperature within ±1 ^{o}C). Other parameters may be monitored during purging, including oxidation-reduction potential and turbidity, but will not be used as stabilizing criteria. If the wells are not sampled from the tap, parameters will be measured periodically during the

purging. Field parameters will be recorded on field forms provided in Appendix D. Sampling methods and equipment were selected to meet project objectives.

The four wells that are no longer in use will be sampled using the following methodology:

1. At the Lorraine Process Area, the well associated with the church and the vacant residence (parsonage) will be assessed and sampled as follows:
   a. The depth to LNAPL and the depth to water will be gauged with an interface probe.
   b. A bailer will be lowered into the well to obtain a sample of the LNAPL.
   c. A grab sample will be obtained of the ground water.

2. At the North Tank Farm, if the pump is still in the well, the pump will be energized and a tap sample will be collected as stated above. If the pump is not operational, a grab sample will be obtained from the water above the pump. If the pump is set higher in the well casing and a grab sample cannot be obtained, then the pump will be removed and a grab sample obtained.

3. The two wells located on the East Tank Farm will be purged and sampled using low-flow sampling methodology (EA SOP 048, Appendix G), if possible. If the wells cannot be sampled via low-flow methodology, then a grab sample will be collected with a disposable bailer after at least 3 volumes of water were purged and parameters stabilized.

The wells that will be sampled are shown on Figure 12 and the details for sampling and sample analysis are provided in Table 8.

2.3.6.3 Piezometer Installation and Sampling

Up to 10 piezometers will be installed where water may be seeping into Sand Creek from the Wilcox and Lorraine Process Areas and into the East Tributary from the former Tank 3 area located on the East Tank Farm. The location of the piezometers will be determined based on the information gathered through the infrared camera survey conducted during site reconnaissance. Once the seep locations are identified, the piezometers will be installed using a track-mounted DPT rig. The pre-packed piezometers will be constructed of 1-inch-diameter Schedule 40 polyvinyl chloride (PVC) well casing and screen with a filter pack attached. The piezometers will be installed in accordance with EA SOP 032 (Appendix G). Once the piezometers are installed they will be developed and then sampled using low-flow sampling methodology in accordance with EA SOP 048 (Appendix G). Water samples will be analyzed by a fixed laboratory for the suite of analytes presented in Table 8.

2.3.7 Vapor Intrusion Characterization

Two vacant residences within the Wilcox and Lorraine Process Areas and the church that will be sampled during the initial mobilization are shown on Figure 13 and the details for sampling and sample analysis are provided in Table 9.

2.3.7.1 Vapor Intrusion Sampling Methodology

EA will investigate the vapor intrusion pathway by conducting sub-slab soil gas and indoor air sampling at the church and the parsonage at the Lorraine Process Area and the residence located in the Wilcox Process Area, as summarized in Table 9. Sub-slab soil gas and indoor air samples will be analyzed for the VOCs and naphthalene. Although the methodology exists for analyzing PAHs in air, the reporting limits are above the screening level requirements. As a result, the samples will only be analyzed for VOCs and the naphthalene concentration will be used to determine if further PAH analysis will be warranted. If concentrations of mercury and/or cyanide in soil samples exceed project screening levels, then these COPCs will be included during a subsequent sampling event.

Based on the results of the vapor intrusion assessment, a soil gas survey may be performed during a subsequent mobilization at the residential properties located on the North Tank Farm and East Tank Farm.

2.3.7.2 Vapor Intrusion Sampling Program

Sub-slab soil gas and indoor air samples will be collected from occupied areas of the subject residence or building in accordance with the vapor intrusion sampling procedures and applicable site-specific SOP (Appendix F). Sub-slab soil gas samples will be used to evaluate the potential concentration of vadose zone source material and the attenuation of vapors from source material into indoor air. Indoor air samples will also be used to evaluate the attenuation of vapors from source material to indoor air, as well as provide an exposure point concentration for the building occupants.

2.3.8 Waste Delineation

During Mobilization 1, the waste areas will be delineated using a hand-held GPS unit to determine the lateral extent of area where waste disposal is visible. EA will also determine if more than one type of waste is present at each location. The waste piles will be sampled during Mobilization 2.

2.3.9 GPS Survey

During Mobilization 1 of the RI field program, EA staff will survey the following using GPS equipment:

- Sample locations for all media
- Seeps along Sand Creek
- Waste areas
- Wetlands extent
- Any other relevant site features.

The survey will be performed using hand-held Real-Time Kinetic GPS equipment. If more precise elevation or boundary surveys will be required, they will be performed by a State of

Oklahoma-Registered Professional Licensed Surveyor during a subsequent mobilization. After field activities are complete, the survey data will be used to generate accurate maps illustrating the information collected.

The following GPS data attributes for each location will be logged:

- Latitude and longitude
- Elevation
- Survey method
- Datum
- Maximum Positional Dilution of Precision
- GPS date and time
- Total positions collected at each well location.

2.4 SAMPLE PROCESSING

Samples for fixed laboratory analysis will be processed and packaged in accordance with the *Contract Laboratory Program Guidance for Field Samplers* (EPA 2014c) and/or SOP 004 (Appendix G), as applicable.

2.5 DECONTAMINATION

Re-usable field equipment utilized during the RI will be decontaminated prior to and after use in accordance with EA SOP 005 (Appendix G). Decontamination of field equipment will occur in buckets, plastic containers, or other similar containers with sealing lids, and the resulting fluid will be transferred to properly labeled IDW containment vessels (e.g., 55-gallon drums) staged in a designated staging area (Support Zone) on the Lorraine Process Area property. The decontamination fluids will be properly sampled and disposed of following local, State, and Federal guidelines (see Section 2.6).

2.6 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Decontamination water, purge water, drill cuttings, and unused portions of soil samples will be drummed, sealed, labeled, and stored at the designated staging area (Support Zone) until profiled for acceptance at an approved disposal facility (EA SOP 042, Appendix G). IDW samples will be submitted to the EA-subcontracted laboratory for profiling.

For IDW, Landfill Disposal Restrictions will dictate sample quantities and analyses, which may include, but not be limited to, the following:

- VOCs, SVOCs, and TAL metals by TCLP
- TPH
- Corrosivity
- Reactivity
- Corrosivity

- Ignitability.

2.7 SAMPLE DESIGNATION

Each sampling location will be designated with a unique alphanumeric designation.

2.7.1 Soil and Waste Sample Designation

Soil and waste samples will include the site area or location identifier, as follows:

- BKG = Soil background
- DR = Drainage pathway
- ETF = East Tank Farm
- LPA = Lorraine Process Area
- WPA = Wilcox Process Area.

2.7.1.1 Soil Samples from Borings

Soil borings will include the area designation, followed by "SB" for borings installed by DPT or HSA techniques, the sequential boring number, and the bottom depth for the sample interval (in feet), as follows:

- For example, Soil Boring Sample ID WPA-SB-14-0.5 describes a soil sample collected from a Boring Location No. 14 in the Wilcox Process Area, with the bottom of the sample depth interval at 0.5 ft bgs.

2.7.1.2 Background Soil

The soil sample for determination of background concentrations will be designated by the background ID ("BKG"), followed by the bottom of the sample depth, in feet. As such, the background ICS sample will be labeled BKG-0.5.

The QC replicate samples will be labeled the same as the actual sample, with the extension "-D" for the duplicate and "-T" for the triplicate: BKG-0.5-D and BKG-0.5-T, respectively.

2.7.2 Surface Water and Sediment Sample Designation

For surface water and sediment samples from water bodies, the location identifiers will be assigned based on the associated body of water or pond, as follows:

- SC = Sand Creek
- ET = East Tributary
- WT = West Tributary
- SCPPE = PPE in Sand Creek
- C1 = Confluence of Sand Creek and East Tributary
- C2 = Confluence of Sand Creek and West tributary

- SCUC1, SCUC2, SCUC3 = Upstream conditions for Sand Creek
- ETUC = Upstream conditions for East Tributary
- WTUC = Upstream conditions for West tributary
- SCSP = Seep location along Sand Creek
- SCBR = Sand Creek at 8th Street Bridge
- PX = Pond X, where X = 1, 2, 3, etc.

Samples collected from the body of water will be assigned the appropriate Location ID, followed by the designator "SW" for surface water or "SD" for sediment; for sediment, the bottom of the sediment interval will also be recorded in feet, as follows:

- SC-SW-02 and SC-SD-02-0.5 – surface water and sediment samples collected within Sand Creek from Location 02; the bottom depth of the sediment sample is 0.5 ft bgs.

- ET-SW-07 and ET-SD-07-0.5 – surface water and sediment samples collected in East Tributary from Location 07; the bottom depth of the sediment sample is 0.5 ft bgs.

- SCPPE-SW-04 and SCPPE-SD-04-0.5 – surface water and sediment samples collected from drainage pathway discharging water into Sand Creek at PPE 04; the bottom depth of the sediment sample is 0.5 ft bgs.

- C1-SW and C1-SD-0.5 – surface water and sediment samples collected from the Confluence of Sand Creek and East Tributary; the bottom depth of the sediment sample is 0.5 ft bgs.

- ETUC-SW and ETUC-SD-0.5 – surface water and sediment samples collected for characterization of upstream conditions for the East Tributary; the bottom depth of the sediment sample is 0.5 ft bgs.

- SP-SW-XX – seep water sample collected from location of Seep XX.

- SCSP-SW-XX and SCSP-SD-XX-0.5 – surface water and sediment samples collected from location of Seep XX along Sand Creek; the bottom depth of the sediment sample is 0.5 ft bgs.

- SCBR-SW-XX and SCBR-SD-01-0.5 – surface water and sediment samples collected from Location XX in the vicinity of the bridge; the bottom depth of the sediment sample is 0.5 ft bgs.

- P5-SW-01 and P5-SD-01-0.5 – surface water and sediment samples collected from Location 01 in Pond 5; the bottom depth of the sediment sample is 0.5 ft bgs.

2.7.3 Ground Water Sample Designation

All ground water samples, regardless of provenance, will be designated as "GW" followed by a sequential number associated with the location of the residential well: for example, GW-01.

Water samples collected from piezometers will be will be assigned the appropriate Location ID, followed by the designator "PZ", as follows:

- LPA-PZ-01 – water sample collected within the Lorraine Process Area from Piezometer 01.

2.7.4 Vapor Intrusion Sample Designation

Samples collected for evaluation of vapor intrusion will be designated by area, followed by one of the following designations:

- CS = Crawl space vapor sample
- IA = Indoor air sample
- SG = Soil gas sample
- SGBG = Soil gas background sample
- SS = Sub-slab vapor sample
- VIBG = Vapor intrusion background air sample.

These designations will be followed by a sequential number associated with the sample location; for example, LPA-IA-01.

2.7.5 Field and Laboratory Quality Control Sample Designation

Field and laboratory QC samples will use the designations discussed below.

Field Duplicate Samples

Field duplicate samples will be identified by adding a "D" to the end of the sample designations described above; for example: GW-09-D. The replicate samples for background that will be collected using ICS (duplicate and triplicate) will be labeled as described in the previous section.

Aqueous Field, Trip, and Equipment Rinsate Blank Sample Designation

Aqueous field blank (FB), trip blank (TB), and equipment rinsate blank (ER) samples will be identified by two fields beginning with "FB", "TB", or "ER" respectively, followed by a dash "-", then the date in the following format YYMMDD. For example, a trip blank for samples submitted on 15 July 2016 would have the following sample identification number "TB-160715". If two field, trip, or equipment rinsate blanks will be collected on the same day, an additional, sequential numeric field will be added; for example: TB-160715-1 and TB-160715-2.

Matrix Spike/Matrix Spike Duplicate and Matrix Spike/Matrix Duplicate

MS/MSD and MS/MD samples will not have specific sample identifiers to identify them as such, but the samples will be labeled as described above and will be identified on the chain-of-custody record as having additional aliquots provided for the preparation of these QC samples by the laboratory.

Source Water Blank Sample Designation

Source water blanks (SWB), if applicable, will be identified by SWB followed by a dash "-", then the date in the following format YYMMDD. For example a source water blank submitted on 13 July 2016 would have the following sample identification number "SWB-160713". If two source water blanks will be sent to the laboratory for analysis on the same day, an additional field will be added; for example: SWB-160713-1 and QTB-160713-2.

2.8 SAMPLE CONTAINER, VOLUME, PRESERVATION, AND HOLDING TIME REQUIREMENTS

Table 12 specifies the required sample volume, container type, preservation technique, and holding time for each analysis that is to be conducted during each phase of sampling. Required containers, preservation techniques, and holding times for field QC samples, such as field duplicates, will be the same as for investigative samples, but may require additional volumes.

2.9 SAMPLE HANDLING AND CUSTODY

Each sample collected will be traceable from the point of collection through analysis and final disposition to ensure sample integrity. Sample integrity helps to ensure the legal defensibility of the analytical data and subsequent conclusions. Sample handling will follow CLP protocols as required in EPA's *Contract Laboratory Program Guidance for Field Samplers* (EPA 2014c).

The EA field team will use EPA's data management system known as Scribe to generate chain-of-custody records in the field. Applicable copies of generated Scribe files will be delivered to EPA data management personnel as required by CLP and EPA Region 6 protocols.

2.10 ANALYTICAL METHODS REQUIREMENTS

The source of analytical services to be provided will be determined in part by DQOs and the intended use of the resulting data. EA will use EPA-approved methods for laboratory analyses of the samples.

EA will follow the analytical services request procedures that are outlined EA's Analytical Services Delivery Plan (EA 2005). If an analytical system fails, the EA QA officer will be notified, and corrective action will be taken. In general, corrective actions will include stopping the analysis, examining instrument performance and sample preparation information, and determining the need to re-prepare and reanalyze the samples.

Laboratories that are subcontracted by EA or EPA will conduct definitive laboratory analysis of samples. Table 12 lists the laboratory analytical methods for this project. Appropriate methods of sample preparation, cleanup, and analyses are based on specific analytical parameters of interest, sample matrices, and required quantitation limits. In addition, Appendix B provides the detection and quantitation limits for both CLP and non-CLP analytical methods to demonstrate that the selection of the analytical methods satisfies the project DQOs.

2.10.1 Field Analytical Methods

Water quality parameters that include pH, temperature, specific conductivity, oxidation-reduction potential, and turbidity will be monitored using field-based methods during the collection of ground water and surface water samples. In addition, ground water will also be monitored for dissolved oxygen content. EA will follow manufacturer-recommended procedures for operating field equipment.

2.10.2 Fixed-Laboratory Analytical Methods

Fixed-laboratory analyses will be conducted by EPA Region 6 Laboratory, a designated CLP laboratory, or subcontracted by EA to a commercial laboratory. In the case of ground water, for analyte groups that could be analyzed by either a CLP or subcontract laboratory (e.g., VOCs, SVOCs, metals), the sample will be shipped to the EA subcontracted laboratory if non-aqueous phase liquid (free product) or a strong petroleum odor is observed in the sample; otherwise, the samples may be analyzed by the CLP laboratory. Samples submitted to the analytical laboratory will be analyzed in accordance with analytical methods identified in Table 12. Modifications to analytical methods that may be required to manage atypical matrices or to achieve low quantitation limits are not anticipated. Decisions regarding the use and type of method modifications will be made during the procurement of laboratories, as different laboratories have equipment and SOPs that generate varying quantitation limits.

The analytical method reference sheets and EPA CLP CRQLs for methods to be used for this project are provided in Appendix C.

2.11 QUALITY CONTROL REQUIREMENTS

Various field and laboratory QC samples and measurements will be used to verify that analytical data meet the QA objectives. Field QC samples and measurements will be collected to assess the influence of sampling activities and measurements on data quality. Similarly, laboratory QC samples will be used to assess how the laboratory's analytical program influences data quality. This section describes the QC samples that are to be analyzed during the site sampling activities for: (1) each field and laboratory environmental measurement method and (2) each sample matrix type. Table 4 shows the acceptance criteria for each type of QC sample and Table 13 presents the frequency of QC samples to be collected in support of the sampling activities at the site.

2.11.1 Field Quality Control Requirements

Field QC samples will be collected and analyzed to assess the quality of data that are generated by sampling activities. These samples will include laboratory QC samples collected in the field, field duplicates, trip blanks (for VOCs only), equipment rinsates, MS/MSD/MDs, and temperature blanks. QC samples collected in the field for fixed-laboratory analysis are presented in Table 13.

Field duplicates are independent samples that are collected as close as possible, in space and

time, to the original investigative sample. Field duplicates can measure the influence of sampling and field procedures on the precision of an environmental measurement. They can also provide information on the heterogeneity of a sampling location. Field duplicates will be collected at a minimum frequency of one for every 10 investigative samples, as listed in Table 13. Immediately following collection of the original sample, the field duplicates are collected using the same collection method.

Field blanks are collected to assess: (1) impact from ambient air conditions during sample collection; (2) cross-contamination during sample collection, preservation, and shipment, as well as in the laboratory; and (3) cleanliness of the sample containers and preservatives. Field blank samples consist of sample containers filled with laboratory-grade, organic-free water. Field blank samples are typically associated with ground water sample collection for VOC analysis at a frequency of one field blank per each day of ground water sampling activities or one per site. Field blanks may be collected for other media and analytes as dictated by site conditions during investigative sampling activities. If a contaminant is detected in the blank samples above the method detection limit, the result for associated field samples that contain the same contaminant will be qualified as potentially not detected if the concentration of the field sample is less than five times the concentration found in the blank.

Equipment rinsate blanks are collected when non-dedicated or non-disposable sampling equipment is used to collect samples. These blanks assess the cleanliness of the sampling equipment and the effectiveness of equipment decontamination. Equipment rinsate blanks are collected by pouring analyte-free water over the decontaminated surfaces of sampling equipment that contacts sampling media. Equipment rinsate blanks are collected after sampling equipment has been decontaminated, but before the equipment is reused for sampling. If non-dedicated or non-disposable equipment is used, equipment rinsate blanks will be collected in accordance with the frequency listed in Table 13.

MS/MSD samples are laboratory QC samples that will be collected for organic methods; MS/MD samples will be collected for inorganic methods. QC samples (e.g., MS/MSD, MS/OS/MD) typically require double or triple the normal sample volume, depending on analytical laboratory specifications. In the laboratory, MS/MSD and MS/OS/MD samples are split and MS/MSD samples are spiked with known amounts of analytes. Analytical results for MS/MSD and MS/OS/MD samples are used to measure the precision and accuracy of the laboratory's organic and inorganic analytical methods, respectively. Each of these QC samples will be collected and analyzed at a frequency of one for every 20 (5 percent) investigative samples or one per analytical batch for CLP laboratories, subcontracted commercial laboratories, or in accordance with the requirements of the EPA Region 6 Laboratory.

Trip blanks are analyzed for VOCs only. VOC samples are susceptible to contamination by diffusion of organic contaminants through the Teflon-lined septum of the sample vial; therefore, a VOC trip blank will be analyzed to monitor for possible sample contamination. Also, the trip blank will screen for possible contamination of VOC samples during handling and shipment from the field to the laboratory. One trip blank will be placed in each cooler that contains aqueous VOC samples.

Temperature blanks are containers of deionized or distilled water that are placed in each cooler shipped to the laboratory. The temperature blank is used to monitor sample preservation during shipping and upon receipt at the laboratory. The temperature blank should measure <6°C upon receipt at the laboratory.

2.11.2 Laboratory Quality Control Requirements

Laboratories that perform analytical work under this project must adhere to a QA program that is used to monitor and control laboratory QC activities. Each laboratory must have a written QA manual that describes the QA program in detail. The laboratory QA Manager is responsible for ensuring that laboratory internal QC checks are conducted in accordance with EPA methods and protocols, the laboratory's QA manual, and the requirements of this SAP.

Many of the laboratory QC procedures and requirements are described in EPA-approved analytical methods, laboratory method SOPs, and method guidance documents.

The EPA methods specify the preparation and analysis of QC samples, and may include, but are not limited to, the following types: (1) LCSs; (2) method blanks; (3) MS, MSD, and MD samples; (4) surrogate spikes; and (5) standard reference materials or independent check standards. The following subsections discuss the QC checks that will be required for this project.

2.11.2.1 Laboratory Control Sample

LCSs are thoroughly characterized, laboratory-generated samples that are used to monitor the laboratory's day-to-day performance of analytical methods. The results of LCS analyses are compared to well-defined laboratory control limits to determine whether the laboratory system is in control for the particular method. If the system is not in control, corrective action will be implemented. Appropriate corrective actions will include: (1) stopping the analysis, (2) examining instrument performance or sample preparation and analysis information, and (3) determining whether samples should be re-prepared or reanalyzed.

2.11.2.2 Method Blanks

Method blanks, which are also known as preparation blanks, are analyzed to assess the level of background interference or contamination in the analytical system and the level that may lead to elevated concentration levels or false-positive data. Method blanks are required for all analytical methods and prepared and analyzed at a frequency of one method blank per every 20 samples or one method blank per sample batch, if the batches consist of fewer than 20 samples.

A method blank consists of reagents that are specific to the analytical method and are carried through every aspect of the analytical procedure, including sample preparation, cleanup, and analysis. The results of the method blank analysis will be evaluated in conjunction with other QC information to determine the acceptability of the data generated for that batch of samples. Ideally, the concentration of a target analyte in the method blank will be below the reporting limit for that analyte. For certain known common laboratory contaminants, a higher concentration is allowed in the method blank sample.

If the method blank results do not meet method criteria, the source of contamination must be investigated, and appropriate corrective action must be taken and documented. This investigation includes an evaluation of the data to determine the extent of the contamination and its effect on sampling results. If a method blank is within control limits but analysis indicates a concentration of analytes that is above the reporting limit, an investigation should be conducted to determine whether corrective action could eliminate an ongoing source of target analytes.

For organic and inorganic analyses, the concentration of target analytes in the method blank must be below the CRQL or RL for that analyte for the blank to be considered acceptable. An exception may be made for common laboratory contaminants (such as methylene chloride, acetone, toluene, 2-butanone, and phthalate esters) that may be present in the blank at up to five times the reporting limit. These compounds are frequently detected at low levels in method blanks and associated with sample extraction and analysis for organic parameters.

2.11.2.3 Matrix Spikes

MSs and MSDs are aliquots of an environmental sample for organic analysis to which known concentrations of target analytes have been added. The MS is used to evaluate the effect of the sample matrix on the accuracy of the analysis. If there are many target analytes, they will be divided into two to three spike standard solutions. Each spike standard solution will be used alternately. The MS, in addition to an unspiked aliquot, will be taken through the entire analytical procedure, and the recovery of the analytes will be calculated. Results will be expressed in terms of percent recoveries and RPD. The percent recoveries of the target analytes and compounds are calculated and used to determine the effects of the sample matrix on the precision and accuracy of the analytical method. The RPD between the MS and MSD results is used to evaluate method precision. If results fall outside control limits, corrective action will be performed or data may be qualified.

2.11.2.4 Laboratory (Matrix) Duplicates

MDs, which are also called laboratory duplicates, are prepared and analyzed for inorganic analyses to assess method precision. Two aliquots of sample material are taken from one sample and processed simultaneously without adding spiking compounds. The MD and the original sample aliquot are taken through the entire analytical procedure, and the RPD of the duplicate result is calculated. Results are expressed as RPD and are compared to control limits that have been established for each analyte.

2.11.2.5 Surrogate Spikes

Surrogates are organic compounds that are similar in nature to certain of the target analytes of interest in chemical properties but are not normally found in environmental samples. Surrogates are added to field and QC samples, before the samples are extracted, to assess the efficiency of the extraction procedure and to assess the bias that is introduced by the sample matrix. Results are reported in terms of percent recovery. Individual analytical methods may require sample reanalysis based on surrogate criteria.

The laboratory will use surrogate recoveries mainly to assess matrix effects on sample analysis. Obvious problems with sample preparation and analysis (such as evaporation to dryness or a leaking septum) that can lead to poor surrogate spike recoveries must be eliminated before low surrogate recoveries can be attributed to matrix effects.

2.11.3 Data Quality Indicators

This section describes how QA objectives for precision, accuracy, completeness, and sensitivity are measured, calculated, and reported.

2.11.3.1 Precision

Precision of many analyses is assessed by comparing analytical results of MS and MSD sample pairs for organic analyses, field duplicate samples, laboratory duplicate samples (MDs), and field replicate measurements. If precision is calculated from two measurements, it is normally measured as RPD. If precision is calculated from three or more replicates, relative standard deviation is calculated.

2.11.3.2 Accuracy

The accuracy of many analytical methods is assessed by using the results of MS and MSD samples for organic analyses, MS samples for inorganic analyses, surrogate spike samples, LCSs, standard reference materials, independent check standards, and measurements of instrument responses against zero and span gases.

For measurements in which spikes are used, percent recovery will be calculated.

2.11.3.3 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this SAP, and when QC criteria are met and do not affect data usability.

When data validation is completed, the percent completeness value will be calculated by dividing the number of useable results by the total number of sample results planned for this investigation. The objective for data completeness is 90 percent for the RI.

Completeness will also be evaluated as part of the DQA process (EPA 2006c, 2006d). This evaluation will help determine whether limitations are associated with the decisions to be made based on the data collected.

2.11.3.4 Sensitivity

The achievement of MDLs, CRQLs, and RLs depends on instrument sensitivity and matrix effects. Therefore, it is important to monitor the instrument sensitivity to ensure data quality and to ensure that analyses meet the QA objectives established for sensitivity.

2.11.4 Instrument and Equipment Testing, Inspection, and Maintenance Requirements

This section outlines testing, inspection, and maintenance procedures for field equipment and instruments and for laboratory instruments.

2.11.4.1 General Requirements

Testing, inspection, and maintenance methods and frequency will be based on: (1) the type of instrument; (2) the instrument's stability characteristics; (3) the required accuracy, sensitivity, and precision of the instrument; (4) the instrument's intended use, considering project-specific DQOs; (5) manufacturer's recommendations; and (6) other conditions that affect measurement or operational control. For most instruments, preventive maintenance is performed in accordance with procedures and schedules recommended in (1) the instrument manufacturer's literature or operating manual, or (2) SOPs associated with particular applications of the instrument.

In some cases, testing, inspection, and maintenance procedures and schedules will differ from the manufacturer's specifications or SOPs. This can occur when a field instrument is used to make critical measurements or when the analytical methods that are associated with a laboratory instrument require more frequent testing, inspection, and maintenance.

2.11.4.2 Field Equipment and Instruments

Leased field equipment and instruments will be used to conduct onsite media sampling and preparation. The vendor will be responsible for thoroughly checking and calibrating field equipment and instruments before they are shipped or transported to the field. Copies of testing, inspection, and maintenance procedures will be shipped to the field with the equipment and instruments.

After the field equipment and instruments arrive in the field, they will be inspected for damage. Damaged equipment and instruments will be replaced or repaired immediately. Battery-operated equipment will be checked to ensure full operating capacity; if needed, batteries will be recharged or replaced.

Following use, field equipment will be decontaminated properly before being returned to the source. When the equipment is returned, copies of field notes regarding equipment problems will be included so that problems are not overlooked and necessary equipment repairs are performed.

Table 11 lists the proposed instruments, detectors, and equipment (or their equivalent) to be used onsite during field screening for NORM and TENORM. Table 14 lists all other field equipment and the prescribed calibration, maintenance, testing, and inspection protocols.

2.11.4.3 Laboratory Instruments

Laboratories that analyze samples collected under the EPA Region 6 RAC II program must have a preventive maintenance program that addresses: (1) testing, inspection, and maintenance procedures; and (2) the maintenance schedule for each measurement system and required support

activity. This program is usually documented by a SOP for each analytical instrument that is to be used. Typically, the program will be laboratory-specific; however, it should follow requirements outlined in EPA-approved guidelines. Some of the basic requirements and components of such a program are as follows:

- As a part of its QA/QC program, each laboratory will conduct a routine preventive maintenance program to minimize instrument failure and other system malfunction.

- An internal group of qualified personnel will maintain and repair instruments, equipment, tools, and gauges. Alternatively, manufacturers' representatives may provide scheduled instrument maintenance and emergency repair under a repair and maintenance contract.

- The laboratory will perform instrument maintenance on a regularly scheduled basis. The scheduled service of critical items should minimize the downtime of the measurement system. The laboratory will prepare a list of critical spare parts for each instrument. The laboratory will request the spare parts from the manufacturer and will store the parts.

- Testing, inspection, and maintenance procedures described in laboratory SOPs will be performed in accordance with manufacturer's specifications and the requirements of the specific analytical methods that are used.

- Maintenance and service must be documented in service logbooks (or the site-specific logbook) to provide a history of maintenance records. A separate service logbook should be kept for each instrument; however, due to the limited scope of this project, the service records will be maintained in the site-specific field logbook. Maintenance records will be traceable to the specific instrument, equipment, tool, or gauge.

- The laboratory will maintain and file records that are produced as a result of tests, inspections, or maintenance of laboratory instruments. These records will be available for review by internal and external laboratory system audits that are conducted under the EPA Region 6 RAC II program.

2.12 INSTRUMENT CALIBRATION AND FREQUENCY

This section describes the procedures for maintaining the accuracy of field equipment and laboratory instruments that are used for field tests and laboratory analyses. The equipment and instruments should be calibrated before each use or, when not in use, on a scheduled basis.

2.12.1 Field Equipment

EA will perform calibration of field equipment during the site field activities specified herein. Calibration of the field equipment (e.g., multi-parameter water quality meter) will be conducted on a daily basis following manufacturer recommendations, and will be performed prior to sample analysis activities. Should readings appear to be questionable during sample analysis, EA will

recalibrate the equipment as deemed necessary. The equipment calibration procedures described below will be followed.

Equipment will be maintained and calibrated with sufficient frequency and in such a manner that the accuracy and reproducibility of results are consistent with the manufacturer's specifications and with project-specific DQOs. Upon arrival of the field equipment, EA field personnel will examine it to verify that it is in good working condition. The manufacturer's operating manual and instructions that accompany the equipment will be consulted to ensure that calibration procedures are followed. Measuring and testing equipment may be calibrated either internally—by using in-house reference standards—or externally—by agencies, manufacturers, or commercial laboratories. Calibration records will contain a reference identifying the source of the procedure and, where feasible, the actual procedure. Each piece of measuring and testing equipment will also be accompanied by an equipment use log. The equipment use log (which may be contained within the site-specific field logbook) will be kept current and may contain the following information: (1) date of use; (2) times of use; (3) operating and assisting technicians; (4) calibration status; and (5) comments.

2.12.2 Laboratory Instruments

Laboratory instrumentation that is used to analyze samples collected under the EPA Region 6 RAC II program will be calibrated on the basis of written SOPs that are maintained by the laboratory. Calibration records (including the dates and times of calibration and the names of the personnel performing the calibration) will be filed at the location at which the analytical work was performed and maintained by the laboratory personnel who performed QC activities. Subcontractor laboratories may conduct laboratory work under the EPA Region 6 RAC II program. The laboratory QA Manager is responsible for ensuring that laboratory instruments are calibrated in accordance with the requirements of this SAP.

The laboratories will follow the method-specific calibration procedures and requirements for laboratory measurements. Calibration procedures and requirements will also be provided, as appropriate, for laboratory support equipment, such as balances, mercury thermometers, pH meters, and other equipment that is used to take chemical and physical measurements.

2.13 REQUIREMENTS FOR INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The EA Project Manager is responsible for identifying the types and quantities of supplies and consumables that are needed for field activities and collecting the samples for this Task Order. The EA Project Manager is also responsible for determining acceptance criteria for these items. When supplies are received, the EA field personnel will check packing slips against purchase orders and inspect the condition of supplies before the supplies are accepted for use on a project. If the supplies do not meet the acceptance criteria, deficiencies will be noted on the packing slip and purchase order. Afterward, the item will be returned to the vendor for replacement or repair.

2.14 DATA ACQUISITION REQUIREMENTS (NON-DIRECT MEASUREMENTS)

For this project, EA anticipates acquiring data from non-direct measurements such as databases, spreadsheets, and literature files.

2.15 DATA MANAGEMENT

A comprehensive data management program has been designed to assure that: (1) multiple information sources will result in similar data sets; and (2) data management practices will be adequate for the types of data processing required by a task order. Site team members will follow these protocols to assure results will have uniform units of measure, analytical methods, and reporting forms.

Data for this project will be obtained from a combination of sources, including field measurements, subcontracted fixed laboratories, EPA Region 6 Laboratory, and CLP laboratories. The data-gathering process requires a coordinated effort and will be conducted by project staff members in conjunction with potential data producers. The data will be obtained from the analytical service provider, when appropriate, in the form of an EDD, in addition to the required CLP Level IV type analytical data package. Data verification and validation will be conducted before associated results are presented or are used in subsequent activities.

Data tracking is essential to ensure timely, cost-effective, and high-quality results. Data tracking begins with sample chain-of-custody. When the analytical service provider receives custody of the samples, the provider will send a sample acknowledgment to EA. The sample acknowledgment will confirm sample receipt, condition, and required analyses. The EPA tracking software (Scribe) will contain pertinent information about each sample and can track the data at each phase of the process. The tracking software carries the data through completion of the data validation.

EA will validate 10% of the investigative analytical data received from the subcontractor laboratory to ensure that the confirmatory data are accurate and defensible. A partial review will be conducted on the remaining 90% of the data received from the subcontractor laboratory. All data will be evaluated for usability by EA in accordance with EPA CLP guidelines for data review (EPA 2014a, 2014b).

As a part of the data validation process, EDDs will be reviewed against hard copy deliverables to ensure accurate transfer of data. In addition, data will be reviewed for PARCC and sensitivity indicators to determine whether project DQOs have been met. Subsequent to the data validation, qualifiers will be applied to the data as necessary to indicate the usability of the data. These qualifiers will be placed on the data that is maintained in the project-specific electronic database. Upon completion of the data validation process, the electronic data will be released to the EA Project Manager for reporting.

There are two independent checks to ensure that sample data management is adequate and to ensure that the appropriate quality control samples are collected. The Sample Team Leader provides an initial check of the sampling program to ensure that the appropriate number and type

of quality control samples are collected per the SAP. In addition, it is the Site Manager's responsibility to provide oversight and independent technical review of the sample collection efforts on a daily and weekly basis.

3. ASSESSMENT AND OVERSIGHT

This section describes the field and laboratory assessments that may be conducted during this project, the individuals responsible for conducting assessments, corrective actions that may be implemented in response to assessment results, and how quality-related issues will be reported to EA and EPA.

3.1 ASSESSMENT AND RESPONSE ACTIONS

Under the EPA Region 6 RAC II program, performance and system audits of field and laboratory activities may be conducted to verify that sampling and analysis are performed in accordance with the following:

- Performance and system audits
  - Audit personnel
  - Audit scope of work
  - Audit frequencies
  - Audit reports.

- Corrective action
  - Sample collection and field measurements
  - Laboratory analyses.

Nonconforming items and activities are those that do not meet the project requirements, procurement document criteria, and approved work procedures. Nonconformance may be detected and identified by the following personnel:

- Project personnel—During field operations, supervision of subcontractors, and field inspections

- Testing personnel—During preparation for and performance of tests, equipment calibration, and QC activities

- QA personnel—During the performance of audits, surveillance, and other QA activities.

Each nonconformance that affects quality will be documented by the person who identifies or originates the nonconformance. Documentation of nonconformance will include the following components:

- Description of nonconformance.

- Identification of personnel who are responsible for correcting the nonconformance and, if verification is required, for verifying satisfactory resolution.

- Method(s) for correcting the nonconformance (corrective action) or description of the variance granted.

- Proposed schedule for completing corrective action and the corrective action taken.

Nonconformance documentation will be made available to the EA Project Manager, EA QA Officer, and subcontractor (e.g., subcontracted commercial laboratories) management personnel, as appropriate.

The field personnel and QA personnel, as appropriate, are responsible for notifying the EA Project Manager and the EA QA Officer of the nonconformance. In addition, the EA Project Manager and the project staff, as appropriate, will be notified of significant nonconformance that could affect the results of the work. The EA Project Manager is responsible for determining whether notification to EPA is required.

The completion of corrective actions for significant nonconformance will be documented by QA personnel during future auditing activities. Significant recurring nonconformance will be evaluated by project and QA personnel, as appropriate, to determine its cause. Appropriate changes will be instituted, under corporate or project procedures, to prevent recurrence. When such an evaluation is performed, the results will be documented.

3.2 REPORTS TO MANAGEMENT

Effective management of environmental data collection operations requires timely assessment and review of measurement activities. It is essential that open communication, interaction, and feedback be maintained among project participants, including: (1) the EA QA Officer, EA Program Manager, EA Project Manager, technical staff, and laboratory subcontractors; and (2) the EPA Region 6 TOM and EPA QA Officer.

During the RI field program, EA will prepare weekly reports that summarize the following elements:

- Work progress since the last weekly report

- Site observations, problems, and decisions

- Problems that may impede planned progress

- Safety-related observations, incidents, or potential safety problems and the corrective action(s) taken to mitigate the problem(s)

- Corrective measures and procedures to regain the planned schedule, if required

- QA/QC activities (e.g., number of QC samples)

- Work scheduled for the next work period.

EA prepares monthly progress reports for each Task Order that is conducted under the EPA Region 6 RAC II program. These reports address QA issues that are specific to the Task Order and facilitate timely communication of such issues. QA status reports address the following areas:

- Results of QA audits and other inspections, including quality improvement; opportunities that have been identified for further action
- Instrument, equipment, or procedural problems that affect QA
- Subcontractor performance issues
- Corrective actions
- Status of previously reported activities and quality improvement initiatives
- Work planned for the next reporting period.

At the program level, the EA QA Officer prepares quarterly status reports of QA issues that are related to EA's work on the EPA Region 6 RAC II program. These reports are distributed to EA's President, Corporate QA Officer, Program Manager, and, upon request, the EPA Region 6 Project Officer.

4. DATA VALIDATION AND USABILITY

This section describes the procedures that are planned to review, verify, and validate field and laboratory data. Procedures for verifying that the data are sufficient to meet DQOs and measurement quality objectives for the project are also discussed. Section 4.1 focuses on data review and reduction requirements for work conducted under the EPA Region 6 RAC II program. Section 4.2 addresses data validation and verification requirements. Section 4.3 addresses reconciliation with DQOs.

4.1 DATA REVIEW AND REDUCTION REQUIREMENTS

Data reduction and review are essential functions for preparing data that can be used effectively to support project decisions and achieve DQOs. These functions must be performed accurately and in accordance with EPA-approved procedures and protocol. Data reduction includes computations and data manipulations that produce the final results that are to support the investigation. Data review includes procedures that field or laboratory personnel conduct to ensure that measurement results are correct and acceptable in accordance with the QA objectives stated in this SAP. Field and laboratory measurement data reduction and review procedures and requirements are specified in previously discussed field and laboratory methods, SOPs, and guidance documents.

Field personnel will record, in a field logbook and/or on the appropriate field form (Appendix D), raw data from chemical and physical field measurements (EA SOP 016, Appendix G). The EA field staff has the primary responsibility for: (1) verifying that field measurements were made correctly; (2) confirming that sample collection and handling procedures specified in this project-specific SAP were followed; and (3) ensuring that field data reduction and review procedures and requirements are followed. The EA field staff is also responsible for assessing preliminary data quality and for advising the data user of potential QA/QC problems with field data. If field data are used in a project report, data reduction methods will be fully documented in the report.

The EPA Region 6 Laboratory, CLP laboratory, and/or subcontracted commercial laboratory will complete data reduction for chemical and physical laboratory measurements and will complete an in-house review of laboratory analytical results. The laboratory QA Manager will be responsible for ensuring that laboratory data reduction and review procedures follow the requirements that are stated in this SAP and in the laboratory QA manual. The laboratory QA Manager will also be responsible for assessing data quality and for advising the EA QA Officer of possible QA/QC problems with laboratory data.

4.2 VALIDATION AND VERIFICATION METHODS

Data that are used to support activities under the EPA Region 6 RAC II program must be valid for their intended purposes. This section outlines the basic data validation procedures that will be followed for field and laboratory measurements. The following sections identify personnel who are responsible for data validation and the general data validation process and EPA data validation guidance that will be followed.

4.2.1 Data Validation Responsibilities

When analytical services are provided by laboratories subcontracted by EA, EA is responsible for validation of the analytical data. The EA QA Officer has primary responsibility for coordinating EA's data validation activities. EA will conduct a level III validation on 100 percent of subcontracted laboratory data for investigation samples. Data validation conducted by EA will be detailed in the DESR.

Data validation and review will be completed by one or more experienced data reviewers. When data are generated by the EPA Region 6 Laboratory, it will be used as received from the laboratory, with no further validation. Data from CLP laboratories are validated by EPA's Environmental Services Assistance Team. Data validated by EPA will be summarized in a data validation report.

4.2.2 Data Validation Procedures

The validity of a data set is determined by comparing the data with a predetermined set of QC limits and criteria. EA data reviewers will conduct a systematic review of the data for compliance with established QC limits and data quality indicators (such as sensitivity, precision, and accuracy), on the basis of spike, duplicate, and blank sampling results that are provided by the laboratory. The data review will identify out-of-control data points, discrepancies in results, inaccuracies or omissions. EA data reviewers will evaluate laboratory data for compliance using the following criteria:

- Method and project-specific analytical service requests
- Sample extraction and analysis holding times
- Initial and continuing calibration acceptance criteria
- Field, trip, and method blank acceptance criteria
- Surrogate recovery
- Internal standard recovery
- Field duplicates, MS and MSD acceptance criteria
- MD and laboratory duplicate sample precision
- LCS accuracy
- Other laboratory QC criteria specified by the method or on the project-specific analytical service request form

- Compound identification and quantitation

- Overall assessment of data and completeness in accordance with project-specific objectives.

EA will follow the most current or applicable EPA CLP National Functional Guidelines (EPA 2014a, 2014b) and EPA CLP SOWs (EPA 2014d, 2015c, 2015d) for completing data validation for applicable test methods. Procedures in the CLP guidelines will be modified, as necessary, to fit the specific analytical method that is used to produce the data. In cases, data validation requirements will depend on: (1) DQO levels that are defined in Section 1.3; (2) reporting requirements that are defined in Section 1.4; and (3) data deliverables that are requested from the laboratory, as discussed in Section 1.6.

4.3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

The main purpose of a QA system is to define a process for collecting data that are of known quality, are scientifically valid, are legally defensible, and fully support decisions that will be based on the data. To achieve this purpose, the SAP requires that DQOs be fully defined. Other parts of the QA system must then be planned and implemented in a manner that is consistent with the DQOs. QA system components that follow directly from the DQOs include: (1) documentation and reporting requirements; (2) sample process design and sampling methods requirements; (3) analytical methods and analytical service requests; (4) QC requirements; and (5) data reduction and validation and reporting methods.

After environmental data have been collected, reviewed, and validated, the data will undergo a final evaluation to determine whether the DQOs specified in this SAP have been met. EA will follow EPA's DQA process to verify that the type, quality, and quantity of data that are collected are appropriate for their intended use (EPA 2006c, 2006d).

The DQA process involves: (1) verifying that the data have met the assumptions under which the data collection design and DQOs were developed; (2) taking appropriate corrective action if the assumptions have not been met; and (3) evaluating the extent to which the data support the decision that must be made so that scientifically valid and meaningful conclusions can be drawn from the data. To the extent possible, EA will follow DQA methods and procedures that have been outlined by EPA (EPA 2006c, 2006d).

Following the conclusion of the RI field program and receipt of fixed-laboratory data, the data evaluation will include:

- Data usability evaluation and field QA/QC – The usability of the laboratory analytical data in terms of the CLP data validation summaries and field QA/QC will be evaluated.

- Data Reduction and Tabulation – Field sampling data and analytical results will be reduced and tabulated.

- Data Evaluation Summary Report – A DESR will be submitted that documents and summarizes the analytical data collected during this RI, including the data quality and usability as related to the site-specific DQOs. Field QA/QC results will be summarized in context with fixed-laboratory sample results.

The analytical and field data will be compiled into a format that is compatible with EPA Region 6 or National Electronic Data Management Network. EA will use the data to prepare the RI Report, including the SLERA and HHRA Reports. The data will ultimately also be used to support the FS and ROD for the site.

5. REFERENCES

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Tables

TABLE 1. ELEMENTS OF EPA QA/R-5 IN RELATION TO THIS SAP

EPA QA/R-5 QAPP Element	EA SAP
A1 Title and Approval Sheet	Title and Approval Sheet
A2 Table of Contents	Table of Contents
A3 Distribution List	Distribution List
A4 Project/Task Organization	1.0 Project Description and Management
A5 Problem Definition/Background	1.1 Problem Definition and Background
A6 Project/Task Description	1.2 Description of Project Objectives and Tasks
A7 Quality Objectives and Criteria	1.3 Data Quality Objectives 1.4 Quality Assurance Objectives for Measurement Data
A8 Special Training/Certification	1.5 Special Training and Certification
A9 Documents and Records	1.6 Documents and Records
B1 Sampling Process Design	2.1 Sampling Process Design 2.2 Consent for Property Access
B2 Sampling Methods	2.3 Sampling Methodology 2.4 Sample Processing 2.7 Sample Designation
B3 Sample Handling and Custody	2.8 Sample Container, Volume, Preservation, and Holding Time Requirements 2.9 Sample Handling and Custody
B4 Analytical Methods	2.10 Analytical Methods Requirements
B5 Quality Control	2.11 Quality Control Requirements
B6 Instrument/Equipment Testing, Inspection, and Maintenance	2.11.4 Instrument and Equipment Testing, Inspection, and Maintenance Requirements
B7 Instrument/Equipment Calibration and Frequency	2.12 Instrument Calibration and Frequency
B8 Inspection/Acceptance of Supplies and Consumables	2.13 Requirements for Inspection and Acceptance of Supplies and Consumables
B9 Non-direct Measurements	2.14 Data Acquisition Requirements (Non-direct Measurements)
B10 Data Management	2.15 Data Management
C1 Assessment and Response Actions	3.1 Assessment and Response Actions
C2 Reports to Management	3.2 Reports to Management
D1 Data Review, Verification, and Validation	4.1 Data Review and Reduction Requirements
D2 Validation and Verification Methods	4.2 Validation and Verification Methods
D3 Reconciliation with User Requirements	4.3 Reconciliation with Data Quality Objectives

NOTES:
EA - EA Engineering, Science, and Technology, Inc.
EPA - U.S. Environmental Protection Agency
QAPP - Quality Assurance Project Plan
SAP - Sampling and Analysis Plan

TABLE 2. PREVIOUS INVESTIGATIONS AND SUMMARY OF FINDINGS

Investigation	Agency/ Company	Date	Findings/Summary [1,2,3]
Preliminary Assessment for Wilcox Oil Company	ODEQ	December 1994	Oil waste and sludge were observed on residential yards. No sampling was conducted.
Expanded Site Inspection Report for Wilcox Oil Company	Roy F. Weston	March 1997	Oily, tarry, black-asphalt materials were observed in the former bermed areas. Contaminated soil and contaminated sediments were detected in ponds. Eight soil samples (3 of which were background and 1 was offsite), 8 waste samples, and 10 sediment samples were collected during this investigation. Four soil samples were collected from residential yards (of which 3 are onsite) and 1 on the church property (Lorraine Process Area). All samples, with the exception of the waste samples, were analyzed for VOCs, SVOCs, metals, cyanide, pesticides, and PCBs. Organic compounds and metals elevated above background were detected in the soil samples. Copper and lead were detected at concentrations above what was considered background in Sand Creek sediment samples.
Site Assessment Report for Wilcox Refinery	Ecology & Environment, Inc.	March 1999	Approximately 73,000 cubic yards of oily waste and contaminated soil and 3,000 gallons of liquid waste were identified. The following samples were collected: 55 soil, 4 surface water, and 2 sediment. In addition, 8 samples were collected of the water infiltrated through precipitation and ponding on top of the clay/sand stone layer that underlays the site; this water was called ground water, although it is not representative of the ground water exposure medium. All samples were analyzed for BTEX and TPH, and the soil and sediment samples were also analyzed for PAHs, metals, and pH. However, Table 2-2 of the report notes that pesticides and PCBs were not detected at the site, although it is unclear which samples were analyzed for these compounds. BTEX, PAHs, TPH, and metals were detected in soil samples and low pH values were noted in several samples as well. PAHs and metals were detected in sediment samples. No contamination was detected in surface water samples. The samples of the infiltrated water ponding on top of the clay/sandstone layer had detections of BTEX and TPH.
Preliminary Assessment of the Lorraine Refinery Site	ODEQ	September 2008	No sampling was conducted under this effort. Church and residence were observed to be located on former refinery operations area.
Inspection Report– Lorraine Refinery	ODEQ	August 2009	Soil samples were collected on Lorraine Process Area and sediment samples were collected from Sand Creek. In total, 19 soil, 3 surface water, and 3 sediment samples were collected. Sediment and surface water pairs were also collected upstream and downstream from the site. Samples were analyzed for VOCs, SVOCs, and metals. Metals were detected at concentrations above the value that was considered to be background in soil and sediment samples.
Expanded Site Inspection Report – Lorraine Refinery	ODEQ	September 2010	Soil and waste samples were collected at Wilcox facility from tank farm and residential yards, and soil samples were collected as background. All samples were analyzed for VOCs, SVOCs, and metals. Soil sampling was focused on the eastern portion of the Wilcox Oil site, on the former Lorraine Refinery. The following soil samples were collected: 3 from on residences onsite, 2 from residences north and south of the site, the one on the north side also being considered as background, and 3 from locations onsite where waste was also noted, and thus may not be representative of soil exposure medium. Ground water samples were collected from 3 residential wells onsite, 4 residential wells north of the site, and one residential well also north of the site, but considered to not be under the influence of the site and designated as background. Waste samples were collected from five locations. Metals above what was considered background and SVOCs were detected in waste and soil samples. Metals were detected at concentrations above what was considered background in ground water samples.
Expanded Site Inspection Report – Wilcox Refinery	ODEQ	September 2011	Soil samples collected at Wilcox Refinery property and waste samples were collected from the tank farm area. One soil sample was considered background, located north of the site. One sample was collected from a residential yard, and the remaining 6 samples were collected from where waste was observed; so it appears that these are not representative of soil exposure medium. In addition sediment samples were collected from nine locations in tributaries and Sand Creek, 3 of the locations being upstream from the site; however, 3 of the samples called "sediment" are actually samples of soil exposure medium, as they were collected from drainage pathways that discharge surface runoff into Sand Creek. Metals and SVOCs were detected in waste and soil samples and metals were detected in sediments.
Supplemental Sampling Report for Wilcox Expanded Site Inspection	ODEQ	December 2011	Sediment samples were collected from 3 locations at probable points of entry of surface runoff in Sand Creek, 1 from Pond 1, and 1 in Western Tributary, upstream of Pond 1. All samples were analyzed for VOCs, SVOCs, and metals. Metals were detected in all samples and PAHs were detected in the sediment sample at the entry of Western Tributary into Sand Creek. Bis(2-ethylhexyl)phthalate was detected; however, the concentration was low and this chemical is a common laboratory contaminant.
Residential Soil Sampling	EPA	2016	Residential sampling was performed in June 2015, as follows: (1) areas in the proximity of the five onsite and 4 offsite residences have been sampled by collecting 5-point composites from each cell of grids varying in size from 4 to 8 cells; (2) samples were collected from 0-2 inches bgs, 2-6 inches bgs, 0.6-1 feet bgs, and 1-2 feet bgs; and (3) samples were analyzed for VOCs, SVOCs, PAHs, pesticides, PCBs, and TAL metals.

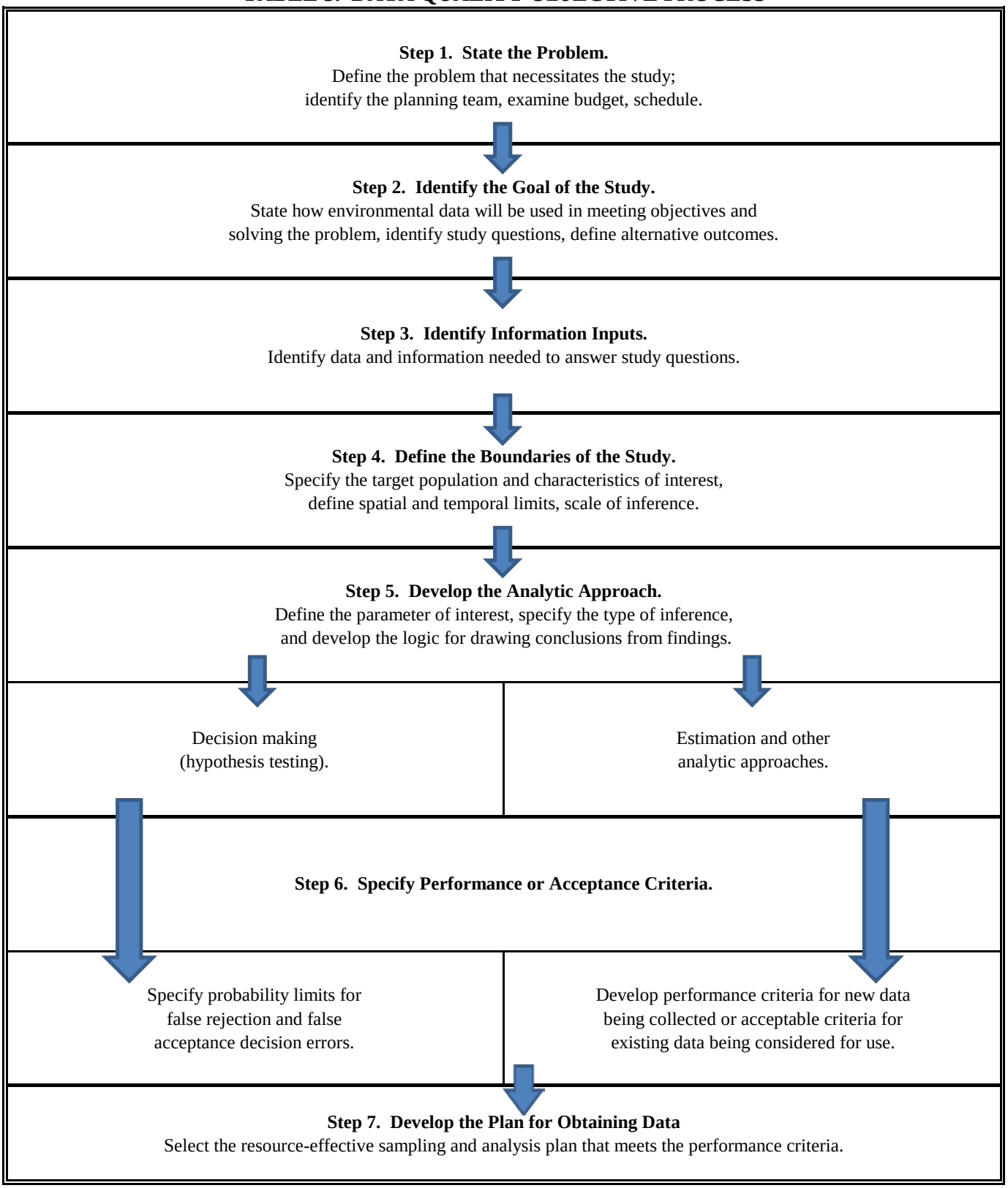
TABLE 2. PREVIOUS INVESTIGATIONS AND SUMMARY OF FINDINGS

Investigation	Agency/ Company	Date	Findings/Summary [1,2,3]
Trip Report: November 30 through December 16, 2016	EPA ERT/ Lockheed Martin SERAS	2016	A December 2015ROST LIF survey covered a significant portion of the site and focused on areas where the contamination was most likely to have occurred. Sampling performed in December 2015 in conjunction with ROST LIF included the following: • 23 soil samples analyzed for SVOCs, VOCs, and total metals; none of these samples were collected from the 0-2 feet bgs interval for residential exposure. • 1 sand sample analyzed for SVOCs, VOCs, and total metals (surface sample) • 1 pond discharge sample analyzed for SVOCs, VOCs, and total and dissolved metals • 6 samples coded as “ground water” analyzed for SVOCs, VOCs, and total and dissolved metals; no depth specified. The ROST LIF Survey resulted in the following general observations • The lithology of the site includes inter-bedded clay layers underlain by bedrock. • The primary areas of petroleum hydrocarbon contamination are on the Lorraine Facility and in the Product Storage area of the Wilcox Facility. XRF: Approximately 170 samples were analyzed for over 20 metals by XRF. Lead was detected at high concentrations; but because split soil samples were not analyzed by a fixed laboratory, a correlation could not be made and quantitative determination of impact could not be assessed.

NOTES:
[1] Investigation data directly tied to the sources areas identified for this site are discussed in Section 1.1.5.
[2] Analysis of samples by the SVOC method yielded elevated detection limits, resulting in no detections of PAHs that may exceed EPA Regional Screening Levels.
[3] A rigorous background study has not been performed for the soil medium.

bgs = Below ground surface
BTEX = Benzene, ethylbenzene, toluene, and xylene
EPA = U.S. Environmental Protection Agency
ERT = Environmental Response Team
LIF = Laser-induced fluorescence
ODEQ = Oklahoma Department of Environmental Quality
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
ROST = Rapid Optical Screening Tool
SERAS = Scientific, Engineering, Response and Analytical Services
SVOC = Semivolatile organic compound
TPH = Total petroleum hydrocarbons
VOC = Volatile organic compound
XRF = X-ray fluorescence

TABLE 3. DATA QUALITY OBJECTIVE PROCESS



Source: U.S. Environmental Protection Agency. 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process*. (QA/G-4). EPA/240/B-06/001. Office of Environmental Information. Washington, D.C. February.

TABLE 4. QUALITY ASSURANCE INDICATOR CRITERIA

Indicator Parameter	Analytical Parameter	QC Sample[a]	Acceptance Criteria for Laboratory Analysis
Accuracy (percent recovery)	VOCs, EDB, SVOCs, PAHs, TPH, PCBs (Aroclors), Pesticides, Dioxins/Furans	MS MSD Blanks[b]	50 to 150 percent recovery (MS/MSD) Less than CRQL (blanks)
	TAL Metals, Mercury, Hexavalent Chromium, Cyanide, AVS-SEM	MS LCS Reference samples Blanks[a]	75 to 125 percent recovery (MS) 80 to 120 percent recovery (LCS) Limits per supplier (reference sample) Less than CRDL (blanks)
Precision (RPD)	VOCs, EDB, SVOCs, PAHs, TPH, PCBs (Aroclors), Pesticides, Dioxins/Furans	MS MSD Field duplicates	30 percent RPD (MS/MSD) 50 percent RPD (field duplicates)
	Background PAHs and Dioxins/Furans via ICS	Field replicates	30 percent RPD (field replicates)
	TAL Metals, Mercury, Hexavalent Chromium, Cyanide, AVS-SEM, Asbestos, General Chemistry Parameters	MS MSD or MD Field duplicates Laboratory duplicates	20 percent RPD (MS, MSD, MD aqueous) 35 percent RPD (MS, MSD, MD solid) 50 percent RPD (field duplicates) 25 percent (laboratory duplicates)
	Background TAL Metals via ICS	Field replicates	30 percent RPD (field replicates)
Sensitivity (quantitation limits)	Analytical tests	MS MD or MSD Field duplicates Laboratory duplicates	Not applicable
Completeness	The objective for data completeness is 90 percent.		
Representativeness	The sampling network and analytical methods for this site are designed to provide data that are representative of site conditions.		
Comparability	The use of standard published sampling and analytical methods, and the use of QC samples, will ensure data of known quality. These data can be compared to other data of known quality.		

NOTES:

[a] Not all listed QC samples apply to all analytical parameters. QC samples are analytical method specific.

[b] May include method blanks, reagent blanks, instrument blanks, calibration blanks, trip blanks and field blanks.

AVS = Acid-volatile sulfide
CRDL = Contract-required Detection Limit
CRQL = Contract-required Quantitation Limit
EDB = Ethylene bromide
ICS = Incremental Composite Sampling
LCS = Laboratory control sample
MD = Matrix duplicate
MS = Matrix spike
MSD = Matrix spike duplicate
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
QC = Quality control
RPD = Relative percent difference
SVOC = Semivolatile organic compound
SEM = Simultaneously-extracted metal
TAL = Target Analyte List
TPH = Total petroleum hydrocarbons
VOC = Volatile organic compound

TABLE 5. STANDARD OPERATING PROCEDURES

SOP Number	SOP Title
001	Labels
002	Chain-of-Custody Form
003	Subsurface/Utility Clearance
004	Sample Packing and Shipping
005	Field Decontamination
006	Summa Canister Sampling
007	Surface Water Sampling
008	pH Measurement
009	Temperature Measurement
010	Water Level and Well Depth Measurements
011	Photoionization Detector (MiniRae)
012	Specific Conductance Measurements
013	Collection of Water Well Samples
014	Collection of Production Well Samples
016	Surface Water, Groundwater, and Soil/Sediment Logbooks
020	Active Soil Gas Sampling
021	Sediment Sampling
022	Sediment and Benthic Sampling
024	Photoionization Detector (Microtip HL-200)
025	Soil Sampling
027A	Passive Soil Gas Surveys – Gore Sorbers
028	Well and Boring Abandonment
030	Radioactive Surveys
032	Piezometer Installation
036	Turbidity Measurements
037	Dissolved Oxygen Measurements
038	Redox Potential Measurements
039	Sample Preservation and Container Requirements
041	Sludge/Lagoon Sampling
042	Disposal of Investigation-derived Material
043	Multi-Probe Water Quality Monitoring Instruments
047	Direct-Push Technology Sampling
048	Low Flow Sampling
051	Low Flow Purge and Sampling with Dedicated Pumps
057	Multi-Incremental Sampling
059	Field Logbook
063	Chemical Data Management
064	Sediment Boring Logs

NOTES:
Redox = Reduction-oxidation
SOP = Standard operating procedure

TABLE 6. PROPOSED FIELD PROGRAM FOR SOIL INVESTIGATION

Sample Location	Sample Medium	Rationale	Number of Sample Locations	Sample Identification	Sampling Tool	Sampling Depth (ft bgs)	Analysis									
							Field Screening by PID	VOCs (includes EDB)	PAHs (SIM)	SVOCs	TAL Metals (includes Mercury)	Cyanide	Hexavalent Chromium	Pesticides	PCBs	Dioxins/ Furans
Lorraine Process Area																
Lorraine Process Area (LPA)	Surface soil	To assess potential source areas and delineate nature and extent	26	LPA-SB-01-0.5 through LPA-SB-26-0.5	Split spoon Continuous sampler PVC/acetate sleeve	0.0 - 0.5	Yes	26	26	26	26	26	0	0	0	0
			26	LPA-SB-01-2.0 through LPA-SB-26-2.0		0.5 - 2.0	Yes	26	26	26	26	26	0	0	0	0
	Subsurface soil		26	LPA-SB-01-6.0 through WPA-SB-26-6.0		2.0 -6.0	Yes	26	26	26	26	26	0	0	0	0
			26	LPA-SB-01-10.0 through LPA-SB-26-10.0		6.0 - 10.0	Yes	26	26	26	26	26	0	0	0	0
			26	LPA-SB-01-?? through LPA-SB-26-??		2 ft interval above refusal	Yes	26	26	26	26	26	0	0	0	0
Lorraine Process Area (LPA) Cooling Pond	Surface soil	To determine if cooling pond is a source area	4	LPA-SB-27-0.5 through LPA-SB-30-0.5	Split spoon Continuous sampler PVC/acetate sleeve	0.0 - 0.5	Yes	4	4	4	4	4	4	0	0	0
			4	LPA-SB-27-2.0 through LPA-SB-30-2.0		0.5 - 2.0	Yes	4	4	4	4	4	0	0	0	0
	Subsurface soil		4	LPA-SB-27-6.0 through WPA-SB-30-6.0		2.0 -6.0	Yes	4	4	4	4	4	0	0	0	0
			4	LPA-SB-27-10.0 through LPA-SB-30-10.0		6.0 - 10.0	Yes	4	4	4	4	4	0	0	0	0
			4	LPA-SB-27-?? through LPA-SB-30-??		2 ft interval above refusal	Yes	4	4	4	4	4	0	0	0	0
Subtotal Lorraine Process Area Soil Samples								**150**	**150**	**150**	**150**	**150**	**4**	**0**	**0**	**0**
Wilcox Process Area																
Wilcox Process Area (WPA)	Surface soil	To assess potential source areas and delineate nature and extent	65	WPA-SB-01-0.5 through WPA-SB-65-0.5	Split spoon Continuous sampler PVC/acetate sleeve	0.0 - 0.5	Yes	65	65	65	65	65	Total 10 samples: 7 Randomly Selected Borings + WPA-SB-01-0.5 WPA-SB-02-0.5 WPA-SB-19-0.5	10	10	10
			65	WPA-SB-01-2.0 through WPA-SB-65-2.0		0.5 - 2.0	Yes	65	65	65	65	65	0	0	0	0
	Subsurface soil		65	WPA-SB-01 -6.0 through WPA-SB-65-6.0		2.0 -6.0	Yes	65	65	65	65	65	0	0	0	0
			65	WPA-SB-01 -10.0 through WPA-SB-65-10.0		6.0 - 10.0	Yes	65	65	65	65	65	0	0	0	0
			65	WPA-SB-01-?? through WPA-SB-65-??		2 ft interval above refusal	Yes	65	65	65	65	65	0	0	0	0
Subtotal Wilcox Process Area Soil Samples								**325**	**325**	**325**	**325**	**325**	**10**	**10**	**10**	**10**
East Tank Farm Area																
East Tank Farm (ETF)	Surface soil	To assess potential source areas and delineate nature and extent	11	ETF-SB-01-0.5 through ETF-SB-11-0.5	Split spoon Continuous sampler PVC/acetate sleeve	0.0 - 0.5	Yes	11	11	11	11	11	0	0	0	0
			11	ETF-SB-01-2.0 through ETF-SB-11-2.0		0.5 - 2.0	Yes	11	11	11	11	11	0	0	0	0
	Subsurface soil		11	ETF-SB-01-6.0 through ETF-SB-11-6.0		2.0 -6.0	Yes	11	11	11	11	11	0	0	0	0
			11	ETF-SB-01-10.0 through ETF-SB-11-10.0		6.0 - 10.0	Yes	11	11	11	11	11	0	0	0	0
			11	ETF-SB-01-?? through ETF-SB-11-??		2 ft interval above refusal	Yes	11	11	11	11	11	0	0	0	0
East Tank Farm (ETF) Tanks 1 and 4	Surface soil	To determine if this is a source area	10	ETF-SB-12-0.5 through ETF-SB-21-0.5	Split spoon Continuous sampler PVC/acetate sleeve	0.0 - 0.5	Yes	10	10	10	10	10	0	0	0	0
	Surface soil		10	ETF-SB-12-2.0 through ETF-SB-21-2.0		0.5 - 2.0	Yes	10	10	10	10	10	0	0	0	0
Subtotal East Tank Farm Soil Samples								**75**	**75**	**75**	**75**	**75**	**0**	**0**	**0**	**0**
Total Soil Samples								**550**	**550**	**550**	**550**	**550**	**14**	**10**	**10**	**10**
Soil Investigation QC																
Field Duplicates	Soil		1 per 10 samples					55	55	55	55	55	2	1	1	1
MS/MSDs	Soil		1 per 20 samples (extra volume only; not included in total sample count)					28	28	28	28	28	1	1	1	1
Total Soil Samples Associated with Soil Investigation								**605**	**605**	**605**	**605**	**605**	**16**	**11**	**11**	**11**
Water QC Samples																
Trip blanks	Water		1 per cooler containing equipment rinsate for equipment used during soil investigation					15	0	0	0	0	0	0	0	0
Equipment blanks	Water		1 per day per set of nondedicated equipment per team					30	30	30	30	30	1	1	1	1
Total Water QC Samples Associated with Soil Investigation								**45**	**30**	**30**	**30**	**30**	**1**	**1**	**1**	**1**

TABLE 6. PROPOSED FIELD PROGRAM FOR SOIL INVESTIGATION

Sample Location	Sample Medium	Rationale	Number of Sample Locations	Sample Identification	Sampling Tool	Sampling Depth (ft bgs)	Analysis								
							Field Screening by PID	VOCs (includes EDB)	PAHs (SIM)	SVOCs	TAL Metals (includes Mercury)	Cyanide	Hexavalent Chromium	Pesticides	PCBs	Dioxins/ Furans
Background Soil																
Background grid	Surface soil	Background	1	BKG-0.5	ICS Methodology Hand auger Slide hammer Scoop	0.0 - 0.5	Yes	0	1	0	1	0	0	0	0	1
						Total Background Soil Samples		**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**
Background Soil QC																
Field Replicates	Soil		1 Duplicate (BKG-0.5-D) and 1 Triplicate (BKG-0.5-T)					0	2	0	2	0	0	0	0	2
MS/MSDs	Soil		1 per 20 samples (extra volume only; not included in total sample count)					0	1	0	1	0	0	0	0	1
						Total Soil Samples Associated with Background		**0**	**3**	**0**	**3**	**0**	**0**	**0**	**0**	**3**
Water QC Samples																
Trip blanks	Water		1 per cooler containing equipment rinsate for equipment used during background soil sampling					0	0	0	0	0	0	0	0	0
Equipment blanks	Water		1 per day per set of nondedicated equipment per team					0	1	0	1	0	0	0	0	1
						Total Water QC Samples Associated with Background Soil		**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**

NOTES:
Sample depth will vary depending upon location of sample and depth of refusal; as a result, the number of samples collected may be less than shown.

bgs = Below ground surface
EDB = Ethylene dibromide
ft = foot (feet)
ICS = Incremental Composite Sampling
MS = Matrix spike
MSD = Matrix spike duplicate
NORM = Naturally-occurring radioactive materials
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
PID = Photoionization detector
PVC = polyvinyl chloride
QC = Quality control
SIM = Selective ion monitoring
SVOC = Semivolatile organic compound
TAL = Target Analyte List
TPH = Total petroleum hydrocarbons
VOC = Volatile organic compound

TABLE 7. PROPOSED FIELD PROGRAM FOR SURFACE WATER AND SEDIMENT INVESTIGATION

Sample Location	Sample Medium	Number of Sample Locations	Sample Identification	Sampling Tool	Sampling Depth [1]	Analyses for Sediment Samples											Analyses for Surface Water Samples													
						VOCs (includes EDB)	PAHs (SIM)	SVOCs	TAL Metals (includes Mercury)	Cyanide	Hexavalent Chromium (10%)	Grain Size (20%)	Total Organic Carbon	AVS	SEM	pH	Field Parameters	VOCs	PAHs (SIM)	SVOCs	TAL Metals (includes Mercury)	Dissolved TAL Metals (includes Mercury)	Cyanide	Total Hexavalent Chromium (10%)	Dissolved Hexavalent Chromium (10%)	Hardness	Total Dissolved Solids	Total Suspended Sediment	Alkalinity	Total Organic Carbon
Confluences of Sand Creek and Tributaries																													
Confluence 1 - Sand Creek and East Tributary	Surface water	1	C1-SW	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Sediment	1	C1-SD-0.5	Core sampler or scoop	0.0 - 0.5	1	1	1	1	1	1	1	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Confluence 2 - Sand Creek and West Tributary	Surface water	1	C2-SW	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Sediment	1	C2-SD-0.5	Core sampler or scoop	0.0 - 0.5	1	1	1	1	1	1	1	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sand Creek																													
Upstream Conditions	Surface water	3	SCUC1a-SW SCUC1b-SW SCUC1c-SW	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	3	3	3	3	3	3	1	1	3	3	3	3	3
	Sediment	3	SCUC1a-SD-0.5 SCUC1b-SD-0.5 SCUC1c-SD-0.5	Core sampler or scoop	0.0 - 0.5	3	3	3	3	3	1	1	3	3	3	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Along Sand Creek	Surface water	8	SC-SW-01 through SC-SW-08	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8	8	8	8	8	8	8	1	1	8	8	8	8	8
	Sediment	8	SC-SD-01-0.5 through SC-SD-08-0.5	Core sampler or scoop	0.0 - 0.5	8	8	8	8	8	1	1	8	8	8	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Seep	Seep water	3	SCSP-01-Water through SCSP-03-Water	Directly into sample container	Not applicable	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	3	3	3	3	3	3	0	0	3	3	3	3	3
	Surface water at seep location	3	SCSP-SW-01 SCSP-SW-02 SCSP-SW-03	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	3	3	3	3	3	3	0	0	3	3	3	3	3
	Sediment at seep location	3	SCSP-SD-01-0.5 SCSP-SD-02-0.5 SCSP-SD-03-0.5	Core sampler or scoop	0.0 - 0.5	3	3	3	3	3	1	1	3	3	3	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Drainages into Sand Creek (drainage pathways are sampled under soil medium)	Surface water	5	SCPPE-SW-01 through SCPPE-SW-05	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	5	5	5	5	5	5	1	1	5	5	5	5	5
	Sediment	5	SCPPE-SD-01-0.5 through SCPPE-SD-05-0.5	Core sampler or scoop	0.0 - 0.5	5	5	5	5	5	1	1	5	5	5	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
East Tributary																													
Upstream Condition for East Tributary	Surface water	1	ETUC-SW	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	1	0	0	1	1	1	1	1
	Sediment	1	ETUC-SD-0.5	Core sampler or scoop	0.0 - 0.5	1	1	1	1	1	1	1	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Along East Tributary	Surface water	8	ET-SW-01 through ET-SW-08	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8	8	8	8	8	8	8	0	0	1	8	8	8	8
	Sediment	8	ET-SD-01-0.5 through ET-SD-08-0.5	Core sampler or scoop	0.0 - 0.5	8	8	8	8	8	0	1	8	8	8	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pond P6	Surface water	7	P6-SW-01 through P6-SW-07	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7	7	7	7	7	7	7	0	0	7	7	7	7	7
	Sediment	7	P6-SD-01-0.5 through P6-SD-07-0.5	Core sampler or scoop	0.0 - 0.5	7	7	7	7	7	0	1	7	7	7	7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
West Tributary																													
Upstream Condition for West Tributary	Surface water	1	WTUC-SW	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Sediment	1	WTUC-SD-0.5	Core sampler or scoop	0.0 - 0.5	1	1	1	1	1	1	1	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Along West Tributary	Surface water	6	WT-SW-01 through WT-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6	6	6	6	6	6	6	1	1	6	6	6	6	6
	Sediment	6	WT-SD-01-0.5 through WT-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	6	6	6	6	6	1	1	6	6	6	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pond P1	Surface water	5	P1-SW-01 through P1-SW-05	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	5	5	5	5	5	5	1	1	5	5	5	5	5
	Sediment	5	P1-SD-01-0.5 through P1-SD-05-0.5	Core sampler or scoop	0.0 - 0.5	5	5	5	5	5	1	1	5	5	5	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 7. PROPOSED FIELD PROGRAM FOR SURFACE WATER AND SEDIMENT INVESTIGATION

						Analyses for Sediment Samples											Analyses for Surface Water Samples													
Sample Location	**Sample Medium**	**Number of Sample Locations**	**Sample Identification**	**Sampling Tool**	**Sampling Depth [1]**	**VOCs (includes EDB)**	**PAHs (SIM)**	**SVOCs**	**TAL Metals (includes Mercury)**	**Cyanide**	**Hexavalent Chromium (10%)**	**Grain Size (20%)**	**Total Organic Carbon**	**AVS**	**SEM**	**pH**	**Field Parameters**	**VOCs**	**PAHs (SIM)**	**SVOCs**	**TAL Metals (includes Mercury)**	**Dissolved TAL Metals (includes Mercury)**	**Cyanide**	**Total Hexavalent Chromium (10%)**	**Dissolved Hexavalent Chromium (10%)**	**Hardness**	**Total Dissolved Solids**	**Total Suspended Sediment**	**Alkalinity**	**Total Organic Carbon**
Isolated Ponds																													
Pond P7 - Reference for Isolated Ponds	Surface water	6	P7-SW-01 through P7-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6	6	6	6	6	6	6	0	0	6	6	6	6	6
	Sediment	6	P7-SD-01-0.5 through P7-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	6	6	6	6	6	0	1	6	6	6	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
P2	Surface water	4	P2-SW-01 through P2-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4	4	4	4	4	4	4	0	0	4	4	4	4	4
	Sediment	4	P2-SD-01-0.5 through P2-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	4	4	4	4	4	0	1	4	4	4	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
P3	Surface water	4	P3-SW-01 through P3-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	NA	4	4	4	4	4	4	4	0	0	4	4	4	4	4
	Sediment	4	P3-SD-01-0.5 through P3-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	4	4	4	4	4	0	1	4	4	4	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
P4	Surface water	4	P4-SW-01 through P4-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4	4	4	4	4	4	4	0	0	4	4	4	4	4
	Sediment	4	P4-SD-01-0.5 through P4-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	4	4	4	4	4	0	0	4	4	4	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
P5	Surface water	4	P5-SW-01 through P5-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4	4	4	4	4	4	4	0	0	4	4	4	4	4
	Sediment	4	P5-SD-01-0.5 through P5-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	4	4	4	4	4	0	0	4	4	4	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
P8 - If water is present	Surface water	2	P8-SW-01 through P8-SW-06	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2	2	0	0	2	2	2	2	2
	Sediment	2	P8-SD-01-0.5 through P8-SD-06-0.5	Core sampler or scoop	0.0 - 0.5	2	2	2	2	2	0	0	2	2	2	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8th Street Bridge																													
Before bridge	Surface water	1	SCBR-SW-01	Directly into sample container	0.0 - 1.0 or shallower	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	1	0	0	1	1	1	1	1
	Sediment	1	SCBR-SD-01-0.5	Core sampler or scoop	0.0 - 0.5	1	1	1	1	1	0	0	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
After bridge	Surface Water	1	SCBR-SW-02	Directly into sample container	0.0 - 0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1	1	1	1	1	0	0	1	1	1	1	1
	Sediment	1	SCBR-SD-02-0.5	Core sampler or scoop	0.0 - 0.5	1	1	1	1	1	0	0	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Where waste is present	Sediment	5	SCBR-SD-03-0.5 through SCBR-SD-07-0.5	Core sampler or scoop	0.0 - 0.5	5	5	5	5	5	0	1	5	1	1	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sediment	5	SCBR-SD-03-1.0 through SCBR-SD-07-1.0	Core sampler or scoop	0.5 - 1.0	5	5	5	5	5	0	1	5	1	1	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Investigative Samples						**85**	**85**	**85**	**85**	**85**	**10**	**17**	**85**	**77**	**77**	**85**	**78**	**78**	**78**	**78**	**78**	**78**	**78**	**8**	**8**	**71**	**78**	**78**	**78**	**78**
QC Samples																													
Field duplicates	Sediment/ Surface Water	1 per 10 samples				9	9	9	9	9	1	2	9	8	8	9	8	8	8	8	8	8	8	1	1	8	8	8	8	8
MS/MSDs	Sediment/ Surface Water	1 per 20 samples (extra volume only; not included in total sample count)				5	5	5	5	0	1	0	0	0	0	0	0	4	4	4	4	4	0	0	0	0	0	0	0	4
Trip blanks	Water	1 per cooler containing aqueous samples for VOC analysis				0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0
Equipment blanks	Water	1 per day per set of for nondedicated equipment per team				0	0	0	0	0	0	0	0	0	0	0	0	17	17	17	17	0	17	0	0	0	0	0	0	0
Field blanks	Water	5% of number of aqueous samples to be analyzed for VOCs				0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Total Samples						**94**	**94**	**94**	**94**	**94**	**11**	**19**	**94**	**85**	**85**	**94**	**86**	**124**	**103**	**103**	**103**	**86**	**103**	**9**	**9**	**79**	**86**	**86**	**86**	**86**

NOTES:
[1] Feet below water surface for surface water samples and feet below ground surface for sediment samples
Analyses for NORM/TENORM parameters may also be performed if proven to be present during the survey.
Analyses for hexavalent chromium may be eliminated if it is not detected in soil or ground water samples.
Field parameters for surface water are pH, temperature, and conductivity, dissolved oxygen, and oxidation reduction potential.

AVS = Acid volatile sulfide
EDB = Ethylene dibromide
MS = Matrix spike
MSD = Matrix spike duplicate
NA = Not applicable
PAH = Polycyclic aromatic hydrocarbon
PVC = Polyvinyl chloride
QC = Quality control
SEM = Simultaneously extracted metals
SIM = Selective ion monitoring
SVOC = Semivolatile organic compound
TAL = Target Analyte List
VOC = Volatile organic compound

TABLE 8. PROPOSED FIELD PROGRAM FOR PRIVATE SUPPLY WELL AND PIEZOMETER SAMPLING

Sample Location	Sample Identification	Sampling Method	Analyses										
			Field Parameters	LNAPL Characterization	VOCs (includes EDB)	PAHs (SIM)	SVOCs	TAL Metals (includes Mercury)	Cyanide	Hexavalent Chromium	Pesticides	PCBs	Dioxins/ Furans
East Tank Farm Residential Wells	GW-01	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-02	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-03	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-04	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
North of East Tank Farm Residential Wells	GW-05	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-06	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-07	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
South of East Tank Farm Residential Wells	GW-08	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-09	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
Lorraine Process Area Church Well	GW-10	Tap or Grab	1	1	1	1	1	1	1	1	0	0	0
North Tank Farm Residential Well	GW-11	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
North of North Tank Farm Residential Well	GW-12	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
Wilcox Residential Well	GW-13	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
East Tank Farm Private Wells Not In Use	GW-14	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
	GW-15	Tap or Grab	1	0	1	1	1	1	1	1	0	0	0
Total Investigation Tap Samples			**15**	**1**	**15**	**15**	**15**	**15**	**15**	**15**	**0**	**0**	**0**
Field duplicate	1 per 10 samples		0	0	2	2	2	2	2	2	0	0	0
MS/MSDs	1 per 20 samples (extra volume only; not included in total sample count)		0	0	1	1	1	1	1	1	0	0	0
Total Private Supply Well Samples			**15**	**1**	**17**	**17**	**17**	**17**	**17**	**17**	**0**	**0**	**0**
Water QC Samples													
Trip blanks	1 per cooler containing aqueous samples for VOC analysis		0	0	1	0	0	0	0	0	0	0	0
Equipment blanks	1 per day per set of for nondedicated equipment per team		0	0	0	0	0	0	0	0	0	0	0
Total Water QC Samples Associated with Private Supply Well Sampling			**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Piezometers													
Piezometers	PW-01 through PW-10	Low Flow	10	0	10	10	10	10	10	1	0	0	0
Total Investigation Tap Samples			**10**	**0**	**10**	**10**	**10**	**10**	**10**	**1**	**0**	**0**	**0**
Field duplicate	1 per 10 samples		0	0	1	1	1	1	1	1	0	0	0
MS/MSDs	1 per 20 samples (extra volume only; not included in total sample count)		0	0	1	1	1	1	1	1	0	0	0
Total Piezometer Samples			**10**	**0**	**11**	**11**	**11**	**11**	**11**	**2**	**0**	**0**	**0**
Water QC Samples													
Trip blanks	1 per cooler containing aqueous samples for VOC analysis		0	0	1	0	0	0	0	0	0	0	0
Equipment blanks	1 per day per set of nondedicated equipment per team		0	0	1	1	1	1	1	1	0	0	0
Total Water QC Samples Associated with Piezometer Sampling			**0**	**0**	**2**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**

NOTES:
Field parameters: pH, temperature, conductivity, dissolved oxygen, oxidation-reduction potential, and turbidity
bgs = Below ground surface
EDB = Ethylene dibromide
MS = Matrix spike
MSD = Matrix spike duplicate
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
QC = Quality control
SIM = Selective ion monitoring
VOC = Volatile organic compound

TABLE 9. PROPOSED FIELD PROGRAM FOR VAPOR INTRUSION INVESTIGATION

Sample Type	Proposed Sample Area	Matrix	Sample Method	Sample Frequency	Sample Interval	Sample Identification	No. of Sample Locations	TO-15 SIM /TO-15
Vapor Instrusion Samples								
Indoor Air/ Sub-Slab or Crawlspace	Lorraine Process Area (LPA) Church	Air/Soil Gas	TO-15: 6-Liter Summa canister with 24-hour regulator	1 sub-slab or crawlspace 1 indoor per location (sampled once in winter and once in summer)	Sub-slab taken below slab Crawlspace taken in crawlspace Indoor air sample collected from within breathing zone (3 to 4 feet above ground surface) of the home	For sub-slab or crawl space air sample: LPA-SS-01 or LPA-CS-01 For indoor air sample: LPA-IA-01	2	2
	Lorraine Process Area Residence					For sub-slab or crawl space air sample: LPA-SS-02 or LPA-CS-02 For indoor air sample: LPA-IA-02	2	2
	Wilcox Process Area (WPA) Residence					For sub-slab or crawl space air sample: WPA-SS-03 or WPA-CS-03 For indoor air sample: WPA-IA-03	2	2
Background	Upwind of sample locations in open area			Locations around perimeter of sampling area	5 to 8 feet off the ground	LPA-VIBG-01, LPA-VIBG-02, WPA-VIBG-03	3	3
Field duplicate	As close as possible, in space and time, to the original sample			1 outdoor location 1 sub-slab 1 indoor	Same as original sample	Same as original with "D" added to the ID, for example LPA or WPA-SS-01D	3	3
Total Vapor Intrusion Samples							**12**	**12**

NOTE:
SIM = Selective ion monitoring

TABLE 10. SUMMARY OF ANALYTICAL PROGRAM FOR SAMPLE MEDIA AND SAMPLE TYPES

SampleType/Media / Analyte	Soil	Ground Water	Surface Water	Sediment	Passive Soil Gas	Indoor Air/ Active Soil Gas	LNAPL	ACM	IDW	Equipment Rinsate Blank (aqueous)	Trip Blank (aqueous)
Volatile Organic Compounds (VOCs)	X	X	X	X						X	X
BTEX, naphthalene, and 2-methylnaphthalene					X						
BTEX and naphthalene						X					
Ethylene Dibromide (EDB)	X	X	X	X						X	X
Semivolatile organic compounds	X	X	X	X						X	
Polycyclic Aromatic Hydrocarbons	X	X	X	X						X	
TAL Metals (including Mercury)	X	X	X	X						X	
Dissolved Metals			X								
Cyanide	X	X	X	X						X	
Hexavalent Chromium	X	X	X	X						X	
Polychlorinated Biphenyls [1]	X									X	
Pesticides [1]	X									X	
Dioxins/Furans [1]	X									X	
Asbestos								X			
Alkalinity			X								
AVS/SEM				X							
Grain Size				X							
Hardness			X								
pH				X							
Total Dissolved Solids			X								
Total Organic Carbon			X	X							
Total Suspended Sediment			X								
Leaded Gasoline Forensics (alkyl leads, EDB, MMT)							X				
Petroleum Forensics (C3-C44 whole oil and C8-C40 full scan)							X				
Corrosivity									X		
Ignitability									X		
Reactivity									X		
TCLP VOCs/SVOCs/Metals									X		
TPH (GRO/DRO/ORO)									X		

NOTES:

[1] Only a subset of surface soil samples will be analyzed.

AVS = Acid volatile sulfide

BTEX = Benzene, toluene, ethyl benzene, and xylenes

DRO = Diesel range organics (C10-C28)

ECD = Electron capture detector

GC = Gas chromatography

GRO = Gasoline range organics (C6-C10)

MMT = Methylcyclopentadienyl manganese tricarbonyl

ORO = Oil range organics (>C28)

SEM = Simultaneously extracted metals

TAL = Target Analyte List

TPH = Total petroleum hydrocarbons

TABLE 11. INSTRUMENTATION FOR SURVEY OF NORM/TENORM

Instrument	Detector	Parameter/Usage
Ludlum Model 2224, or equivalent	Ludlum Model 43-89, 100 cm2 Scintillator	Portable scaler/rate meter (alpha/beta)
Ludlum Model 2221, or equivalent	Ludlum Model 44-10, 2x2 SodiumIodide Scintillator	Portable scaler/rate meter (high energy gamma)
Ludlum Model 2929, or equivalent	Ludlum Model 4310-1	Smear/air filter counter (alpha/beta)
Bicron Microrem, or equivalent	Ludlum Model 44-9 Pancake Frisker	General purpose survey meter (beta/gamma)
Ludlum Model 3, or equivalent	Ludlum Model 4310-1	Smear/air filter counter (alpha/beta)
Ludlum Model 19 Micro-R Meter	1x1 Sodium Iodide Scintillator	Exposure rate survey meter (high energy gamma)

NOTES:
NORM = Naturally-occurring radioactive materials
TENORM = Technologically-enhanced NORM

TABLE 12. PARAMETERS, METHODS, REQUIRED VOLUME, CONTAINERS, PRESERVATIVES, AND HOLDING TIMES

Parameter	Method	Volume and Container [1]	Preservatives	Holding Time [2]
Air Samples				
VOCs	EPA TO-15 SIM	One 6-liter evacuated summa canister	None	30 days
Aqueous Samples				
Alkalinity	Standard Method 2320 B	One 250-milliliter HDPE bottle	Store at <6°C (4+2°C)	7 days
Cyanide	CLP ISM02.3	One 1-liter HDPE bottle	NaOH to pH >12; Store at <6°C (4+2°C)	14 days
Dioxins and Furans	CLP HRSM01.2	Two 1-liter amber glass bottles	Store at <6°C (4+2°C)	360 days
Hardness	EPA Method 130.2	One 100-milliliter HDPE bottle	HNO_3 to pH ≤ 2; Store at <6°C (4+2°C)	6 months
Hexavalent Chromium	EPA Method 218.7	One 125-milliliter HDPE bottle	$NH_4OH/(NH_4)_2SO_4$ (pH>8); Store at <6°C (4+2°C)	14 days
Metals (including Hg)	CLP ISM02.3 (ICS/AES and ICS/MS)	One to two 1-liter HDPE bottles	HNO_3 to pH ≤ 2; Store at <6°C (4+2°C)	180 days (28 days for Hg)
PCBs (Aroclors)	CLP SOM02.3	Two 1-liter amber glass bottles	Store at <6°C (4+2°C)	7 days
Pesticides	CLP SOM02.3	Two 1-liter amber glass bottles	Store at <6°C (4+2°C)	7 days
SVOC SIM (PAHs)	CLP SOM02.3	Four 1-liter amber glass bottles	Store at <6°C (4+2°C)	7 days
SVOCs	CLP SOM02.3	Two 1-liter amber glass bottles	Store at <6°C (4+2°C)	7 days
Total Dissolved Solids	EPA Method 160.1	One 1-liter HDPE bottle	Store at <6°C (4+2°C)	7 days
Total Organic Carbon	Standard Method 5310	One 250-milliliter glass bottle	H_2SO_4 to pH <2; Store at <6°C (4+2°C)	28 days
Total Suspended Sediment	ASTM Method D 3977-97	One 200-milliliter HDPE bottle	Store at <6°C (4+2°C)	7 days
VOCs	CLP SOM02.3	Three 40-milliliter amber glass VOA vials (filled to capacity with no headspace)	HCL to pH <2; Store at <6°C (4+2°C)	14 days
Soil and Sediment Samples				
Asbestos	CARB Method 435	One 16-ounce glass jar	None	Unspecified
AVS/SEM	EPA 821/R-91-100 SW-846 Method 6010C/9034	One 8-ounce amber glass jar (filled to capacity)	Store at <6°C (4+2°C)	14 days
Cyanide	CLP ISM02.3	One 8-ounce glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	14 days
Dioxins and Furans	CLP HRSM01.2	One 8-ounce amber glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	360 days
Grain Size	ASTM Method D422	1-gallon plastic bag	None	Unspecified
Hexavalent Chromium	SW-846 Methods 3060 and 7199	One 8-ounce glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	30 days
Metals (including Hg)	CLP ISM02.3 (ICP/AES and ICP/MS)	One to two 8-ounce glass jars with TeflonTM-lined caps	Store at <6°C (4+2°C)	180 days (28 days for Hg)
PCBs (Aroclors)	CLP SOM02.3	One 8-ounce amber glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	14 days
Pesticides	CLP SOM02.3	One 8-ounce amber glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	14 days
pH	SW9045D	One 8-ounce glass jar with Teflon™-lined cap	Store at <6°C	Analyze immediately
SVOC SIM (PAHs)	CLP SOM02.3	One 8-ounce amber glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	14 days
SVOCs	CLP SOM02.3	One 8-ounce amber glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	14 days
Total Organic Carbon	Walkley- Black	One 8-ounce amber glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	28 days
VOCs	CLP SOM02.3 SW-846 Method 5035 or 5035A (VOC sample preparation)	Three 5-gram coring tool devices (e.g., EnCore) samplers and one 4-ounce glass jar	Store at <6°C (4+2°C)	48 hours
		Three closed-system pre-weighed 40-milliliter amber glass vials with magnetic stir bar (collected with EasyDraw® syringe and PowerStop® handle) One 4-ounce glass jar		
LNAPL Sample				
C3-C44 Whole Oil or C8-C40 Full Scan	ASTM Method D3328 or ASTM Method 5739	Two 40-milliliter VOA vials	Unpreserved	Unlimited
Alkyl Leads, EDB, MMT	EPA 8080 Modified (GC/ECD)	Two 40-milliliter VOA vials	Unpreserved	Unlimited
Investigation-derived Waste				
Reactivity	SW-846 Chapter 7	One 4-ounce glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	72 hours
Corrosivity (pH soil)	SW-846 Method 9045	One 4-ounce glass jar with Teflon™-lined cap	Store at <6°C (4+2°C)	72 hours
Corrosivity (pH liquid)	SW-846 Method 9040	One 500-milliliter glass bottle	Store at <6°C (4+2°C)	72 hours
Corrosivity (steel)	SW-846 Method 1110	One 4-ounce glass jar One 250-milliliter HDPE bottle	Store at <6°C (4+2°C) Store at <6°C (4+2°C)	7 days
Ignitability (solids)	SW-846 Method 1030	One 4-ounce glass jar	Store at <6°C (4+2°C)	14 days
Ignitability (liquid)	SW-846 Method 1010 or 1020	One 250-milliliter HDPE bottle	Store at <6°C (4+2°C)	14 days
TPH GRO	TX Method 1005	One 4-ounce amber glass jar (filled to capacity)	Store at <6°C (4+2°C)	14 days
TPH DRO and ORO			Store at <6°C (4+2°C)	
TCLP Metals[3]	SW-846 Methods 1311, 3010, 6010, and 7470	100 grams minimum (solid) or 1 liter minimum (liquid) Plastic or glass container	Store at <6°C (4+2°C)	180 days (28 days for Hg)
TCLP SVOCs	SW-846 Methods 1311, 3510, and 8270C	100 grams minimum (solid) or 2 liters minimum (liquid) Glass containers	Store at <6°C (4+2°C)	14 days
TCLP VOCs	SW-846 Methods 1311 and 8260B	50 grams minimum (solid) or 120 milliliters minimum (liquid) Glass containers	Store at <6°C (4+2°C)	14 days

NOTES:

[1] It will be necessary to verify container requirements with the laboratory at the time of scheduling.

[2] Holding time is measured from the time of sample collection to the time of sample extraction and/or analysis.

[3] Arsenic, barium, cadmium, chromium, lead, mercury, silver, and selenium

AES = Atomic emission spectroscopy
ASTM = American Society for Testing and Materials
AVS = Acid volatile sulfide
CARB = California Air Resource Board
CLP = Contract Laboratory Program
DRO = Diesel range organics C_{10} - C_{28}
ECD = Electron capture detector
EDB = Ethylene dibromide
GC = Gas chromatography
GRO = Gasoline range organics C_6 - C_{10}
H_2SO_4 = Sulfuric acid
HCL = Hydrochloric acid
HDPE = High-density polyethylene
Hg = Mercury
HNO_3 = Nitric acid
ICP = Inductively-coupled plasma
MMT = Methylcyclopentadienyl manganese tricarbonyl
MS = Mass spectrometry
NaOH = Sodium hydroxide
NH_4OH = Ammonium hydroxide
$(NH_4)_2SO_4$ = Ammonium sulfate
ORO = Oil range organics > C_{28}
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
SEM = Simultaneously extracted metals
SIM = Selective ion monitoring
SVOC = Semivolatile organic compound
TCLP = Toxicity Characteristic Leaching Procedure
TPH = Total petroleum hydrocarbons
VOC = Volatile organic compound

TABLE 13. FREQUENCY OF FIELD QUALITY CONTROL SAMPLES

Field QC Sample	Frequency
Trip blank	1 per cooler containing investigative aqueous VOC samples
Field blank	1 per day, if site conditions render this sample necessary (high winds, volatiles are detected using a photoionization detector, etc.)
Filter blank	1 per 20 primary air samples
Field duplicate	1 per 10 samples
Field replicate	2 per ICS decision unit (duplicate and triplicate); only 1 decision unit anticipated during Mobilization 1
Equipment rinsate blank	1 per non-dedicated equipment set per day or 1 per 20 samples; this criterion is applied for each team using and decontaminating disposable equipment
Source water blank	1 per batch of the last water coming in contact with decontaminated equipment or used for the collection of the equipment rinsate blank; this sample will be collected only if the water used was not provided by an analytical laboratory.
MS/MD[a] (inorganics)	1 per 20 samples or as directed by EPA
MS/MSD[a] (organics)	1 per 20 samples or as directed by EPA
Temperature blank	1 per cooler

NOTES:

[a] MS and MSD analyses are technically not field QC samples; however, they generally require that the field personnel collect additional volumes of samples and are, therefore, included on this table for easy reference. The analytical laboratory will be contacted to determine sample volume requirements.

EPA = U.S. Environmental Protection Agency
ICS = Incremental Composite Sampling
MD = Matrix duplicate
MS = Matrix spike
MSD = Matrix spike duplicate
QC = Quality control
VOC = Volatile organic compound

TABLE 14. FIELD EQUIPMENT CALIBRATION, MAINTENANCE, TESTING AND INSPECTION

Field Equipment	Calibration Activity	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptence Criteria	Corrective Action	Responsible Person	SOP
Turbidity Meter (Hach 2100, HF Scientific, or similar)	Calibrate with Gelex Turbidity Standards	Keep clean and place in hard case between sampling activities	Field test in accordance with the manual	Inspect for external damage (i.e., LCD screen, etc.)	Daily, before use and when unstable readings occur	Within calibration standard(s) range	Recalibration	Field personnel	See equipment manual
Water Quality Meter (QED, Troll, YSI, or Hydrolab)	Follow manufacturer's instructions. Two point calibration for pH, and Specific Conductance	Decontaminate and store in water short term, long term storage according to the manufacturer for each sensor.	Field test in accordance with the manual	Visually inspect probes for cleanliness and wear.	Calibrate daily before use. Maintain and inspect daily when used.	Within calibration standard(s) range.	Cleaning and recalibration	Field personnel	SOP 43 and equipment manual
Electronic Water Level Meter or Oil/water Interface Probe	Not applicable. Operate in accordance with the manufacturer's instructions	Decontaminate between wells	Field test in accordance with the manual	Inspect tape for kinks and cuts, inspect probe for dirt, check batteries	Daily	Response	Replace battery if no response during test button check.	Field personnel	SOP 10
Trimble® GeoXT™ Global Positioning System Unit	Validate accuracy using nearby benchmark	Charge battery and place in case at the end of each day	Field test in accordance with the manual	Inspect for external damage (i.e., LCD screen, dents, etc.).	Daily	Refer to manufacturer's instructions	Refer to manufacturer's instructions	Field personnel	See equipment manual
MiniRAE Lite PID (10.2 eV lamp), or similar	Two-point calibration using fresh air and span gas (100 ppm isobutylene)	Keep clean and replace moisture traps as needed. Place in case at the end of each day	Field test in accordance with the manual	Inspect for external damage (i.e., LCD screen, dents, etc.). Recalibrate as needed.	Daily and when unstable readings occur	Stable reading with no drift	Recalibrate. If necessary, change moisture traps and clean lamp.	Field personnel	SOP 11 and See equipment manual

NOTES:

DO = Dissolved oxygen

eV = Electron volt(s)

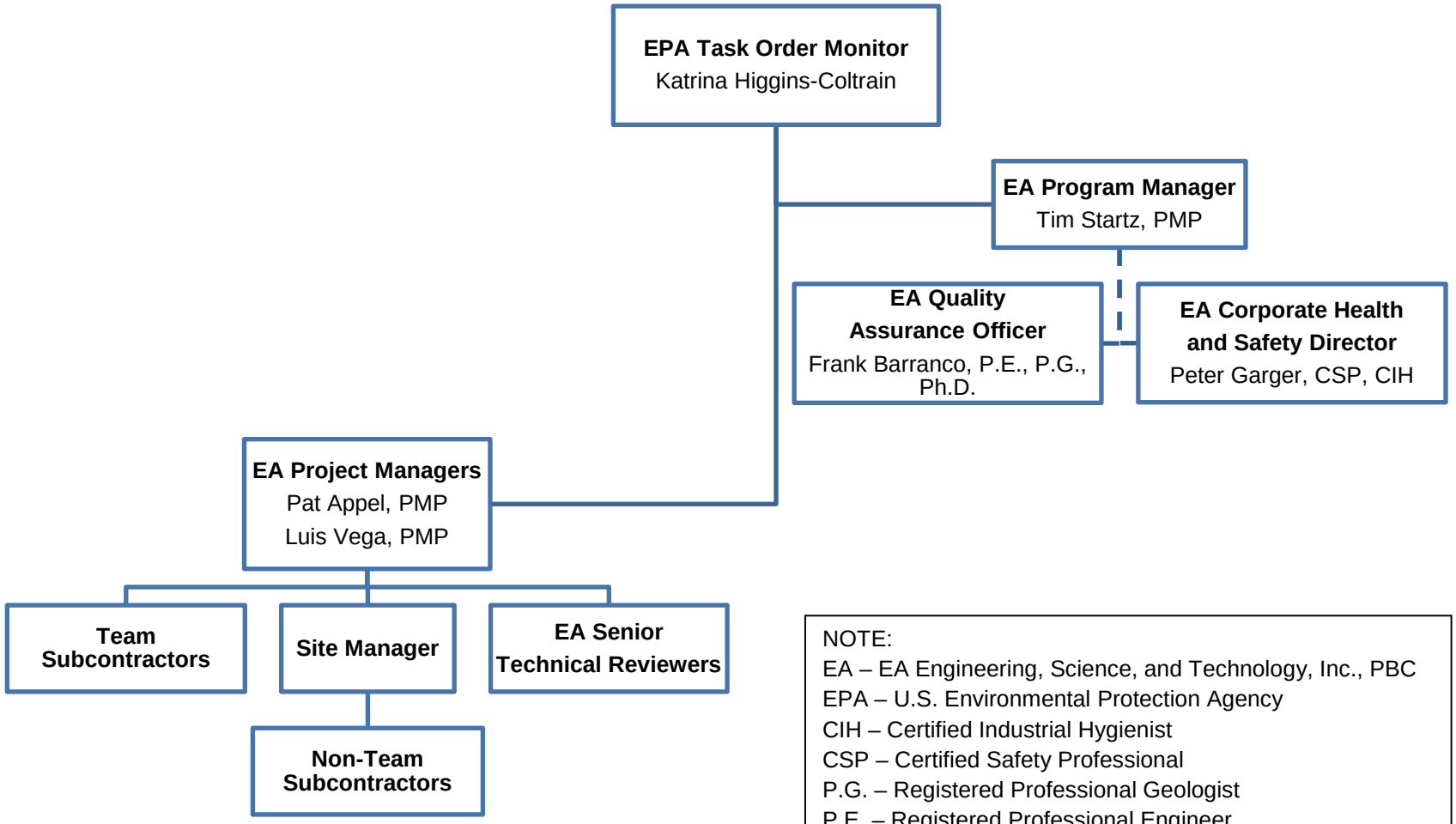
LCD = Liquid crystal display

PID = Photoionization detector

ppm = Part(s) per million

SOP = Standard operating procedure

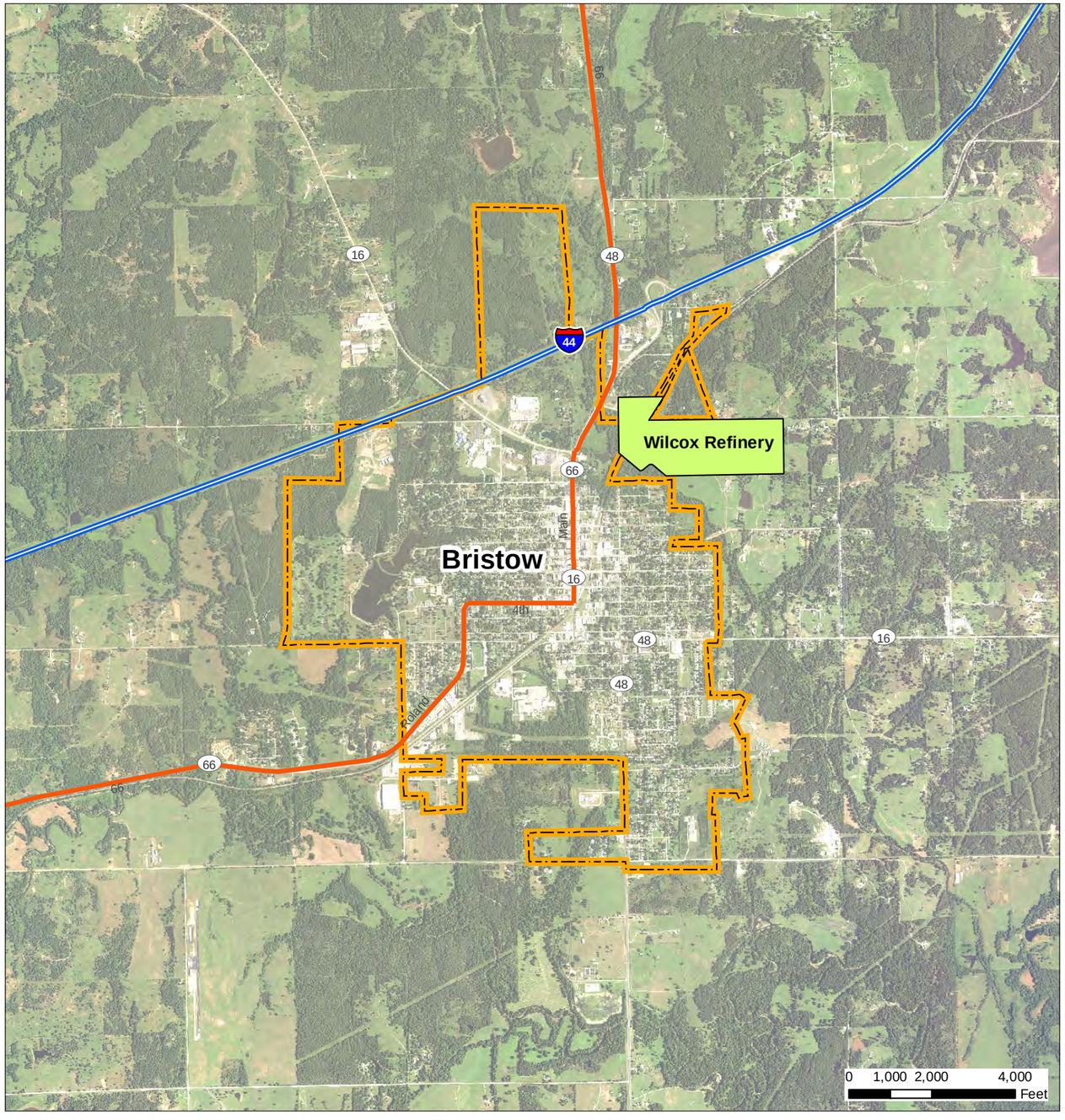
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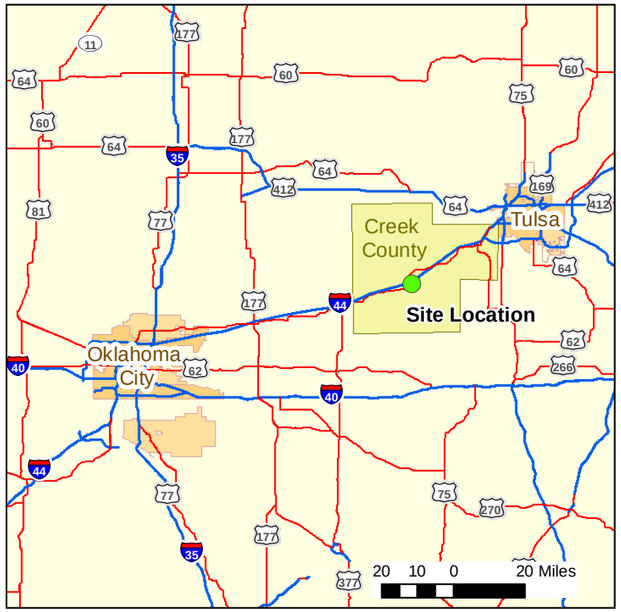


Remedial Investigation/Feasibility Study
Wilcox Oil Company Site
Bristow, Creek County, Oklahoma

Figure 1
Project Organization

P:\gis\Projects\Wilcox\MXDs\SAP\2-Wilcox Location Map.mxd 4/14/2016 EA rmullen







Legend

- Interstate
- Highway
- Bristow City Boundary

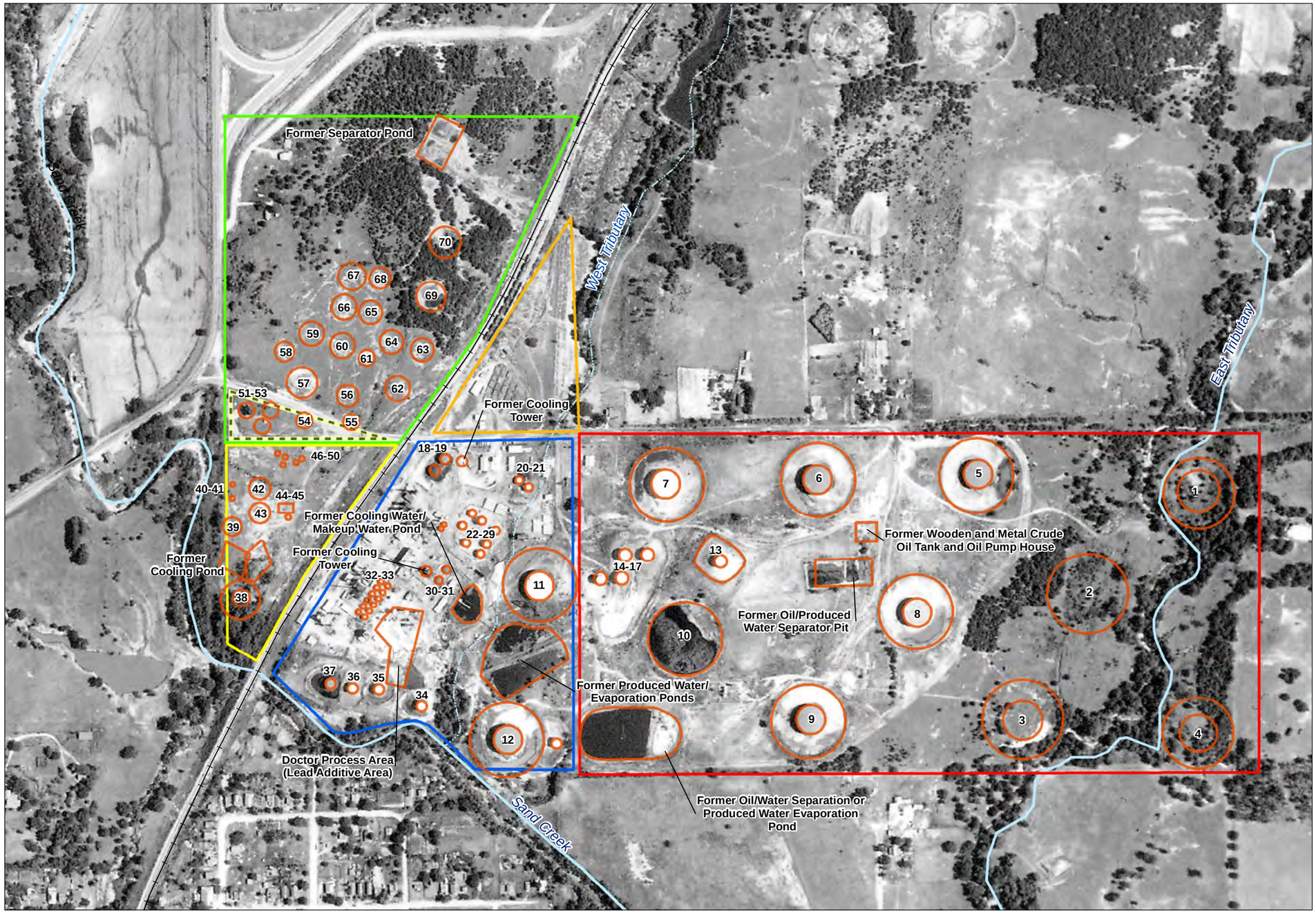
Sampling and Analysis Plan for
Remedial Investigation
for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

Image Source: National Agriculture Imagery Program 2015

FIGURE 2
SITE LOCATION

016323

P:\gis\Projects\Wilcox\MXDs\SAP\02 SAP revised 062016\3-Historical Site Features.mxd 6/17/2016 EA rmullen



0 200 400 800 Feet

1 inch = 400 feet

Legend

- Historical Feature
- Railroad
- Stream, Intermittent
- Stream, Perennial
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area
- Area will be designated as part of Lorraine Process Area for this investigation.

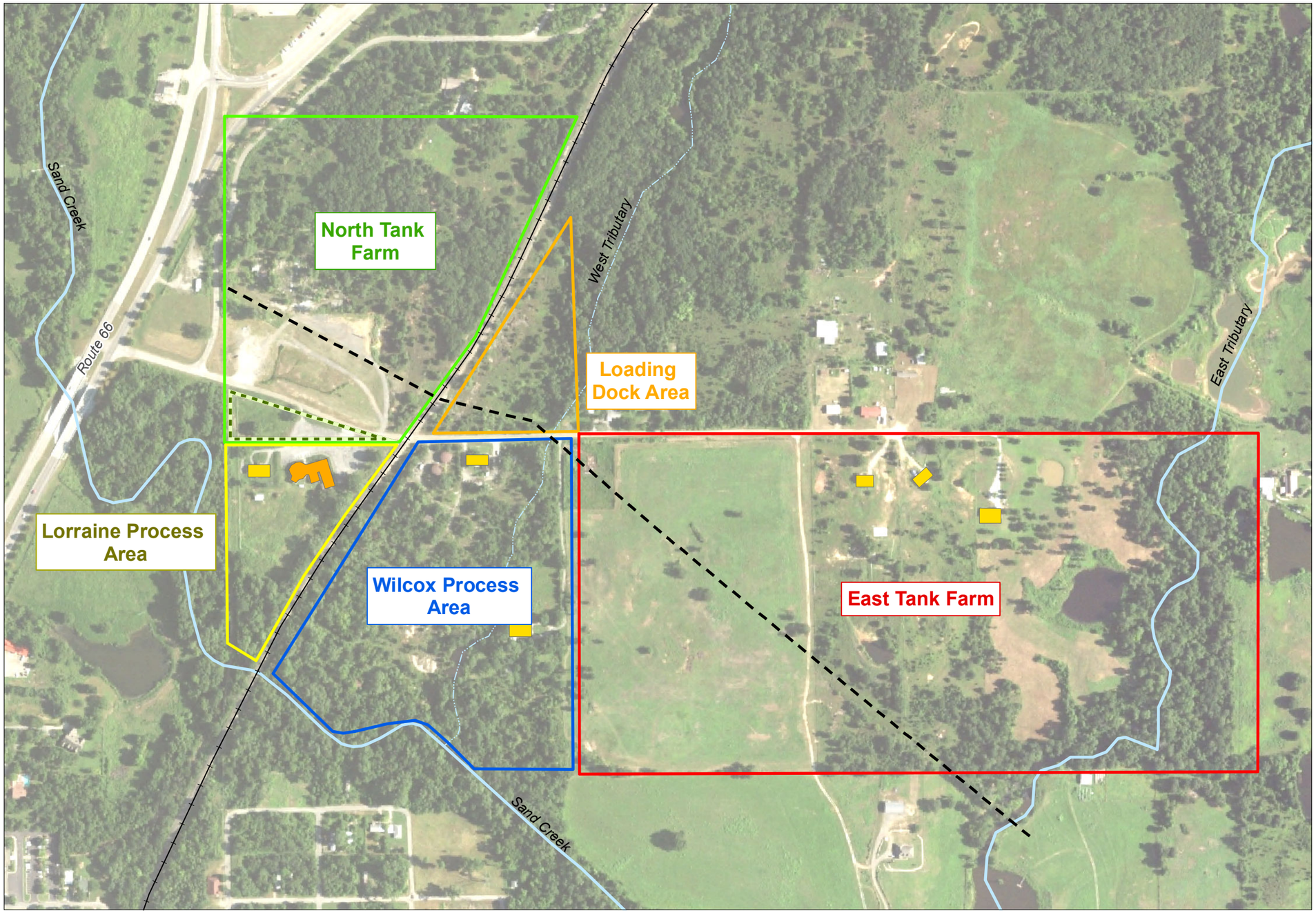
Image Source: 1956 Aerial Photograph.

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FIGURE 3
HISTORICAL SITE FEATURES

016324

P:\gis\Projects\Wilcox\MXDs\SAP\02 SAP revised 062016\4-Site Layout.mxd 6/23/2016 EA rmullen



0 200 400 800 Feet

1 inch = 400 feet

Legend

- Stream, Intermittent
- Stream, Perennial
- Pipeline
- Railroad

On-Site Building

- Church
- Residence
- Area will be designated as part of Lorraine Process Area for this investigation.

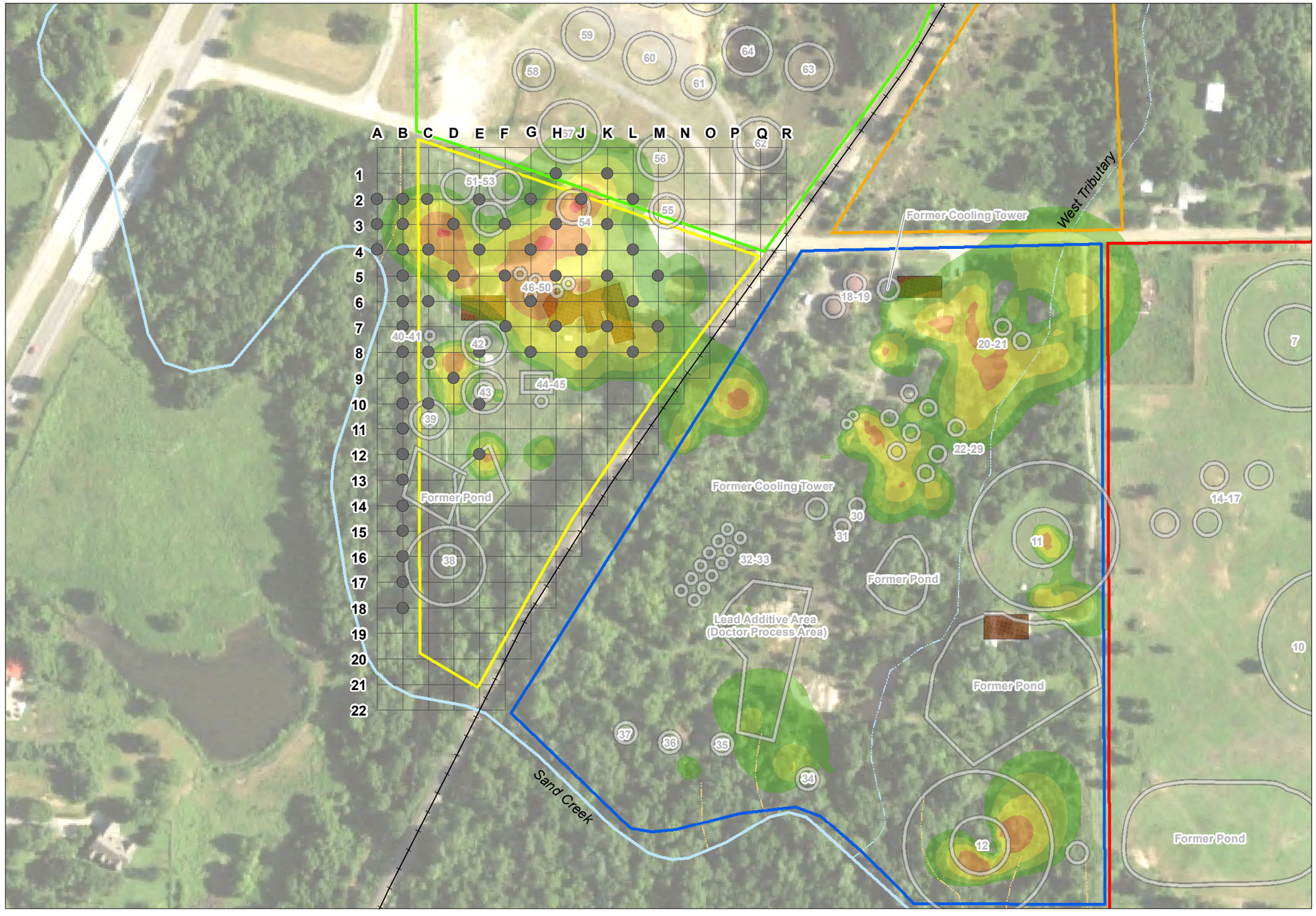
Image Source: National Agriculture Imagery Program 2015.

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FIGURE 4
SITE LAYOUT

016325

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0 50 100 200 300 Feet

1 inch = 200 feet

Legend

- Proposed Passive Soil Gas Sample
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- Sample Grid (Cells 50 feet by 50 feet)
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

ROST Fluorescence (% RE)*

- <5
- 5-10
- 10-25
- 25-100
- >100

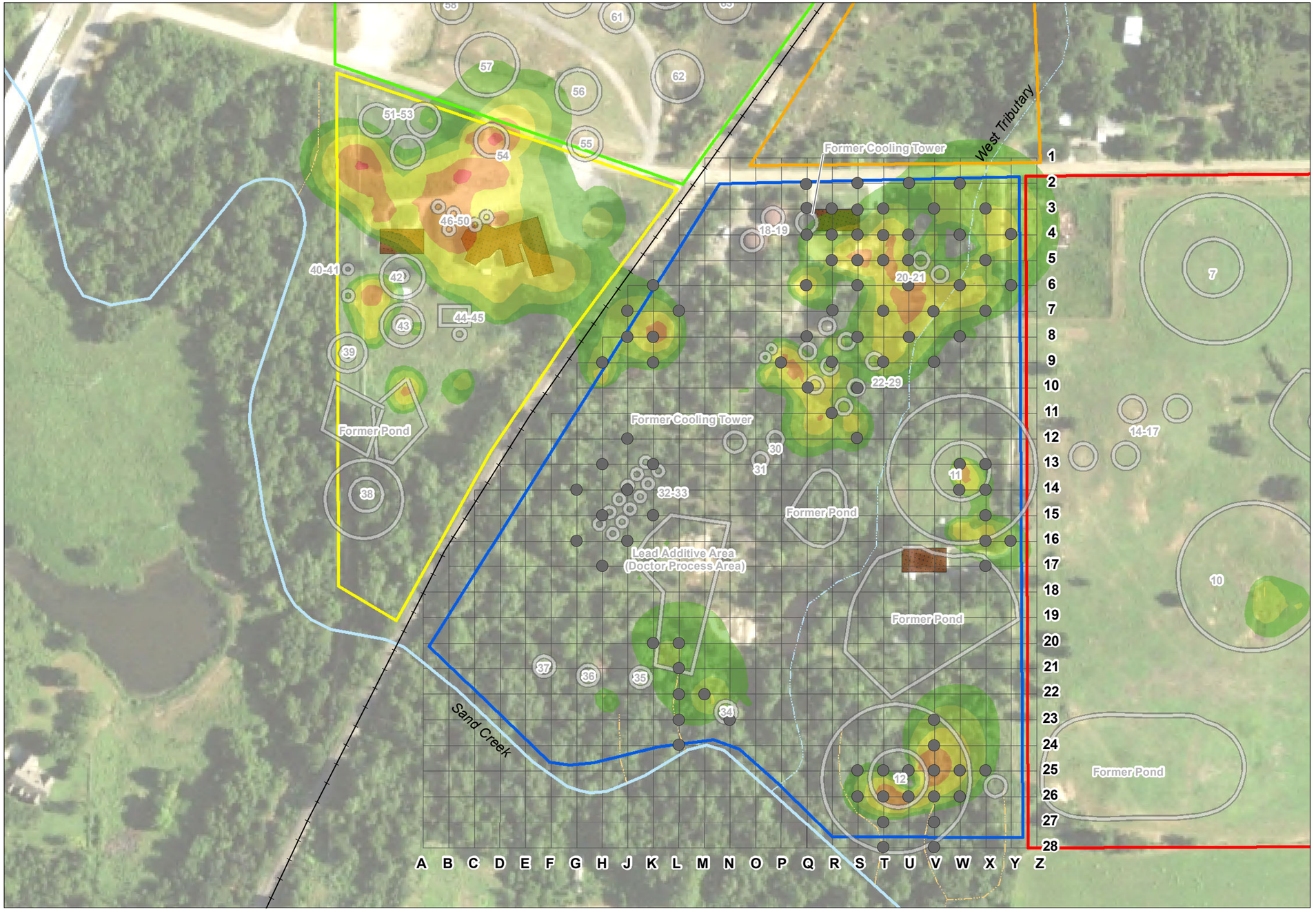
* Source: Lockheed Martin SERAS 2016.
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
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for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

016326

FIGURE 5
PROPOSED PASSIVE SOIL GAS SAMPLE LOCATIONS - LORRAINE PROCESS AREA

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0 50 100 200 300 Feet

1 inch = 200 feet

Legend

- Proposed Passive Soil Gas Sample
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- Sample Grid (Cells 50 feet by 50 feet)
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

ROST Fluorescence (% RE)*

- <5
- 5-10
- 10-25
- 25-100
- >100

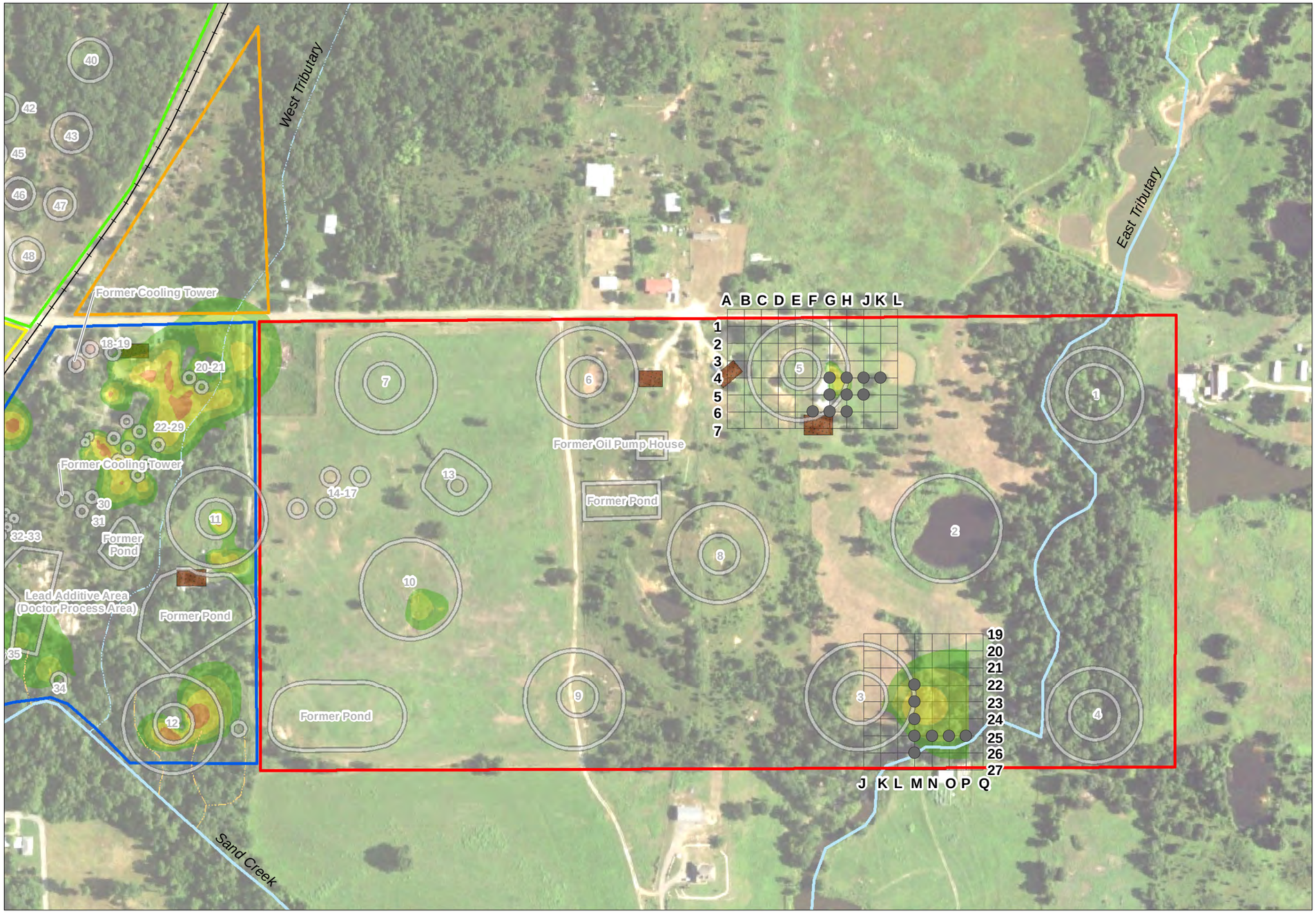
* Source: Lockheed Martin SERAS 2016.
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
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for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

FIGURE 6
PROPOSED PASSIVE SOIL GAS SAMPLE LOCATIONS - WILCOX PROCESS AREA

016327

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0 150 300 600 Feet

1 inch = 300 feet

Legend

- Proposed Passive Soil Gas Sample
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- Sample Grid (Cells 50 feet by 50 feet)
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

ROST Fluorescence (% RE)*

- <5
- 5-10
- 10-25
- 25-100
- >100

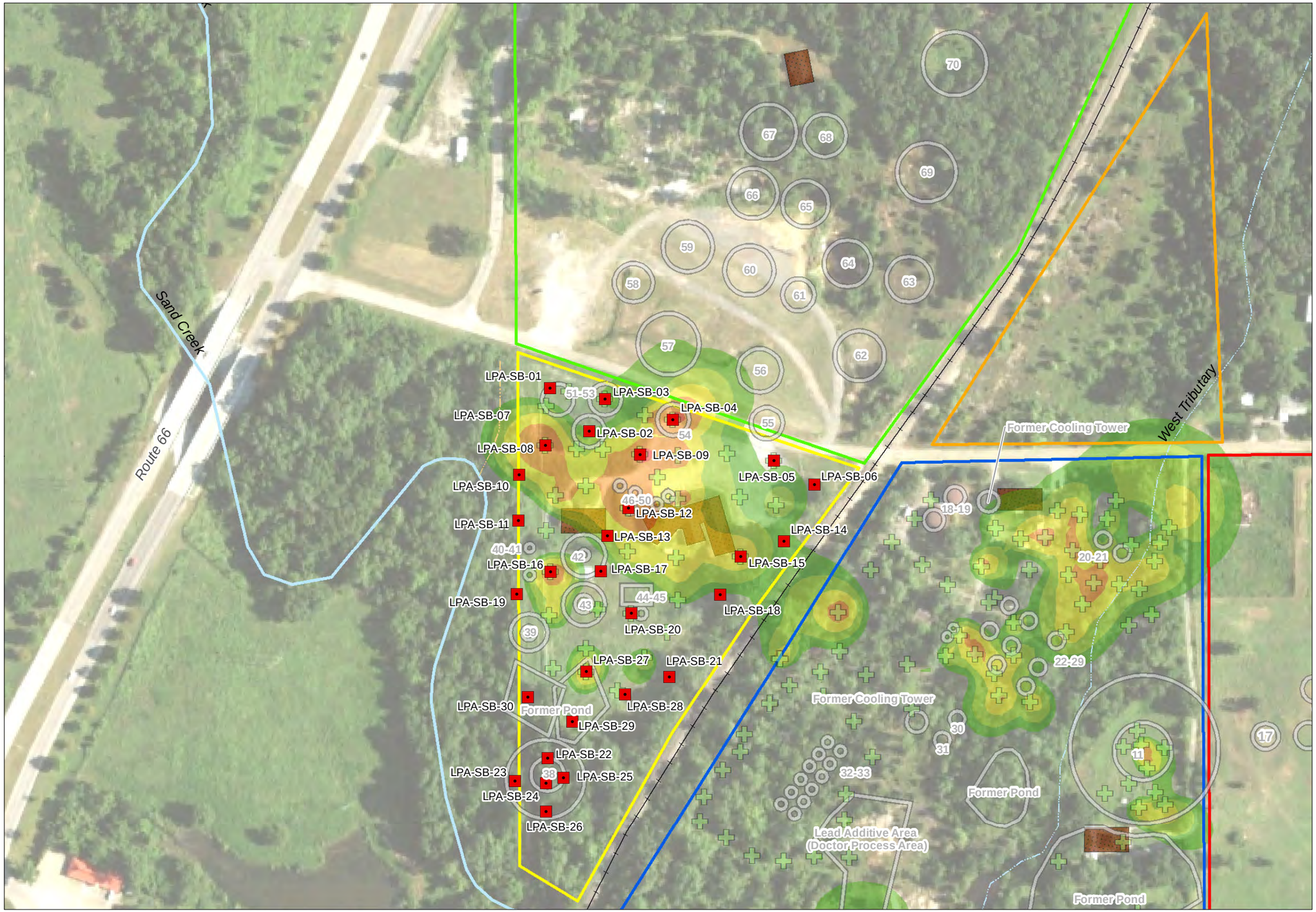
* Source: Lockheed Martin SERAS 2016.
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
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Bristow, Creek County, Oklahoma

016328

FIGURE 7
PROPOSED PASSIVE SOIL GAS SAMPLE LOCATIONS - EAST TANK FARM

P:\gis\Projects\Wilcox\MXDs\SAP\02 SAP revised 062016\8-Soil_Lorraine.mxd 6/27/2016 EA mullen



0 100 200 400 Feet

1 inch = 200 feet

Legend

- Proposed Soil Boring
- 2015 ROST LIF Location*
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

ROST Fluorescence (% RE)*

- <5
- 5-10
- 10-25
- 25-100
- >100

Abbreviations and Acronyms
< - Less than
> - Greater than
% - Percent
LIF - Laser-induced fluorescence
RE - Reference emittance
ROST - Rapid Optical Scanning Tool
SERAS - Scientific, Engineering, Response, and Analytical Services

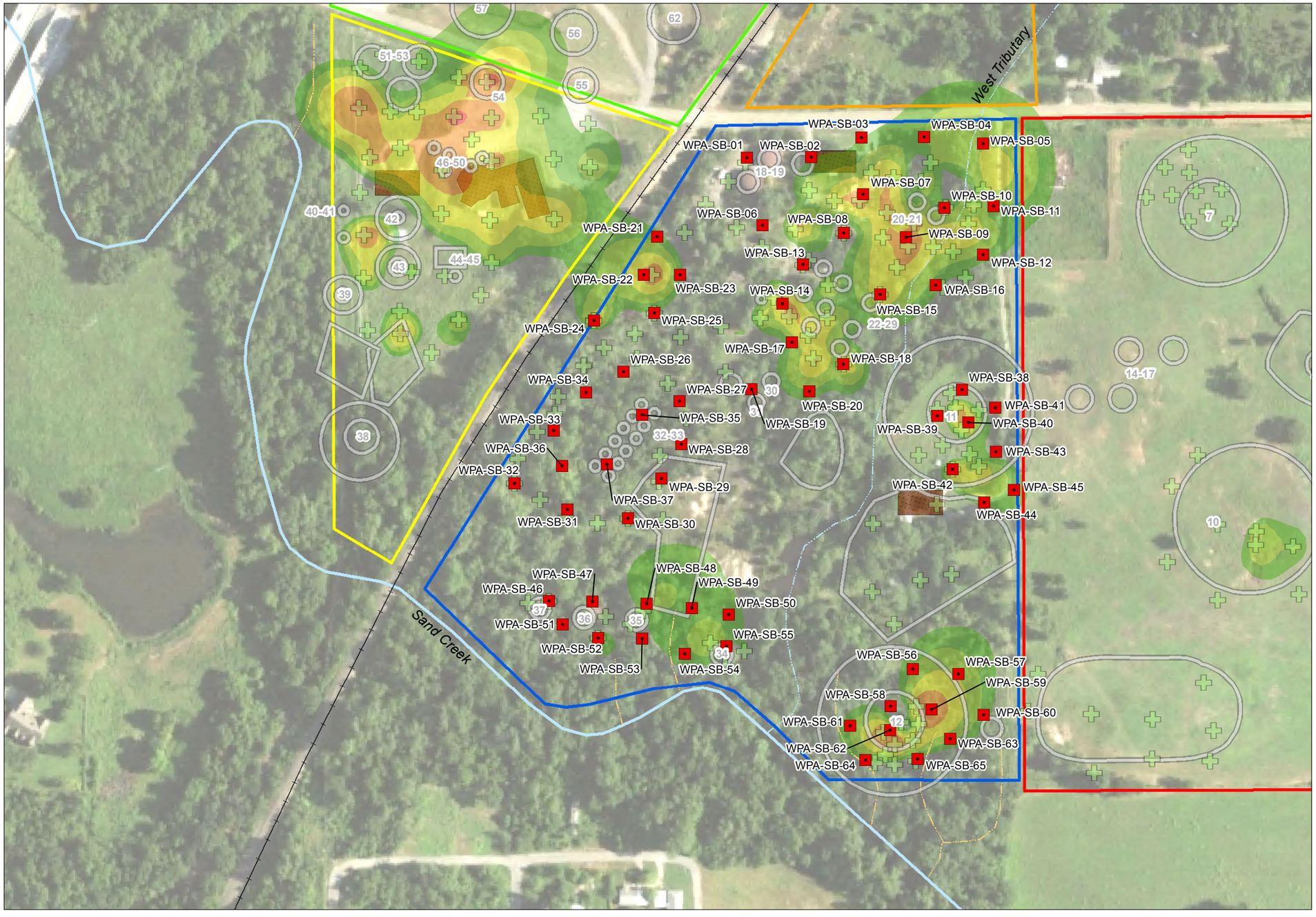
* Source: Lockheed Martin SERAS 2016.
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
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Bristow, Creek County, Oklahoma

FIGURE 8
PROPOSED LOCATIONS FOR SOIL SAMPLES - LORRAINE PROCESS AREA

016329

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Legend

- Proposed Soil Boring
- 2015 ROST LIF Location*
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- On-Site Building
- East Tank Farm
- Loading Dock
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

ROST Fluorescence (% RE)*

- <5
- 5-10
- 10-25
- 25-100
- >100

Abbreviations and Acronyms
< - Less than
> - Greater than
% - Percent
LIF - Laser-induced fluorescence
RE - Reference emitter
ROST - Rapid Optical Scanning Tool
SERAS - Scientific, Engineering, Response, and Analytical Services

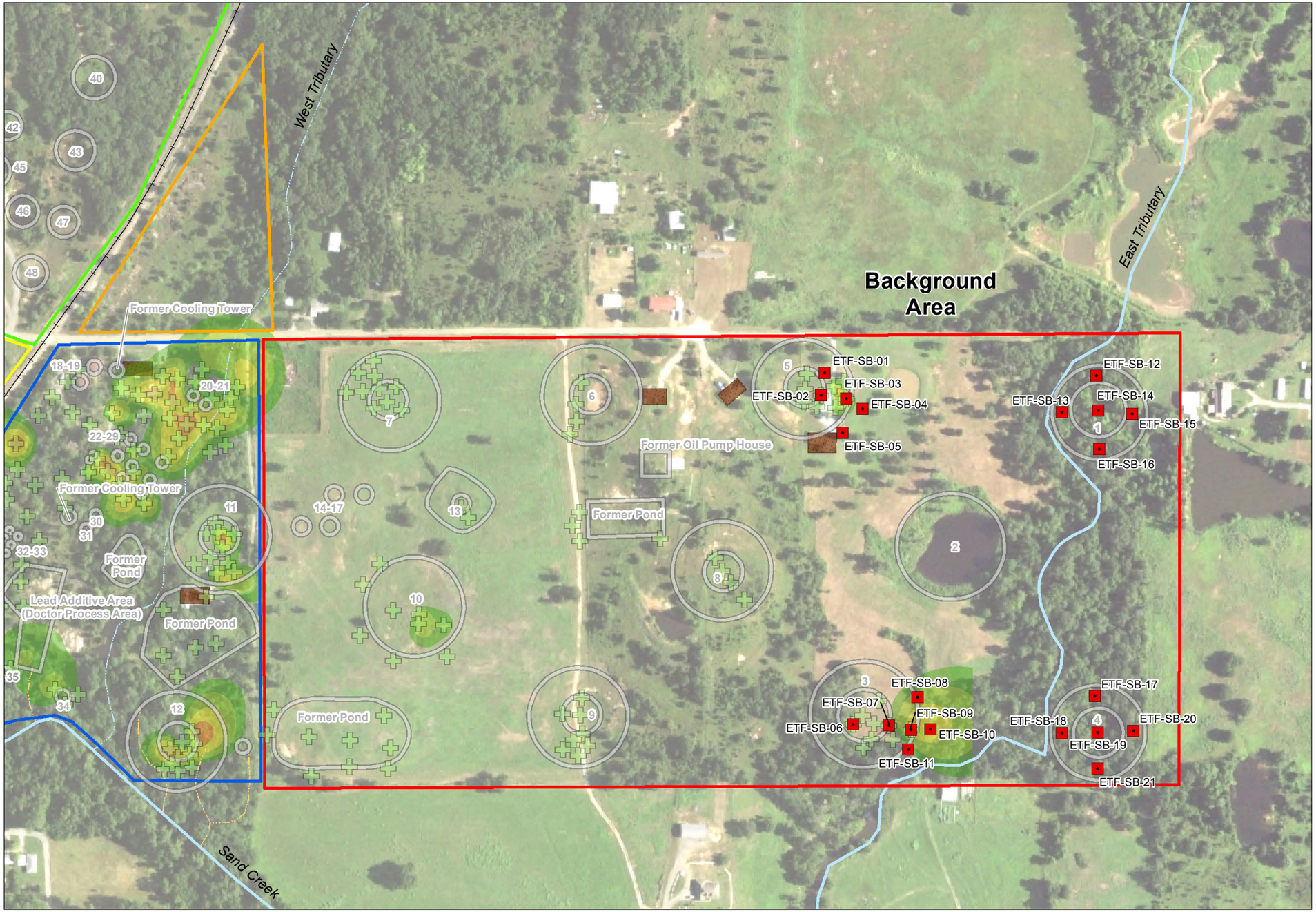
* Source: Lockheed Martin SERAS 2016.
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
Remedial Investigation
for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

FIGURE 9
PROPOSED LOCATIONS FOR SOIL SAMPLES - WILCOX PROCESS AREA

016330

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0 150 300 600 Feet

1 inch = 300 feet

Legend

- Proposed Soil Boring
- 2015 ROST LIF Location*
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

ROST Fluorescence (% RE)*

- <5
- 5-10
- 10-25
- 25-100
- >100

Abbreviations and Acronyms
< - Less than
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LIF - Laser-induced fluorescence
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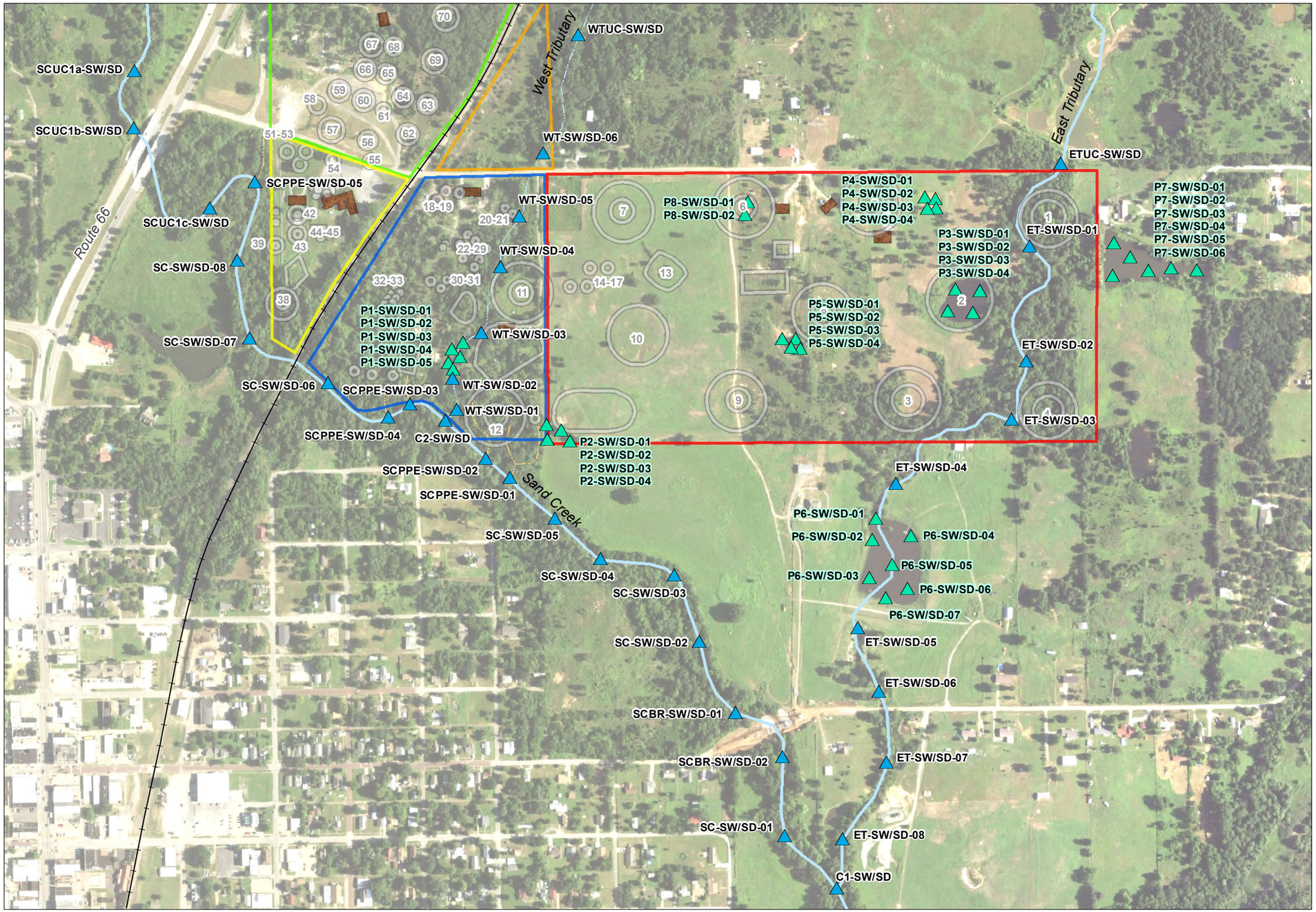
* Source: Lockheed Martin SERAS 2016.
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
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for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

016331

FIGURE 10
PROPOSED LOCATIONS FOR EAST TANK FARM SOIL SAMPLES AND BACKGROUND AREA

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0 200 400 800 Feet

1 inch = 500 feet

Legend

Proposed Sample

- Surface Water/Sediment, Pond
- Surface Water/Sediment, Stream
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

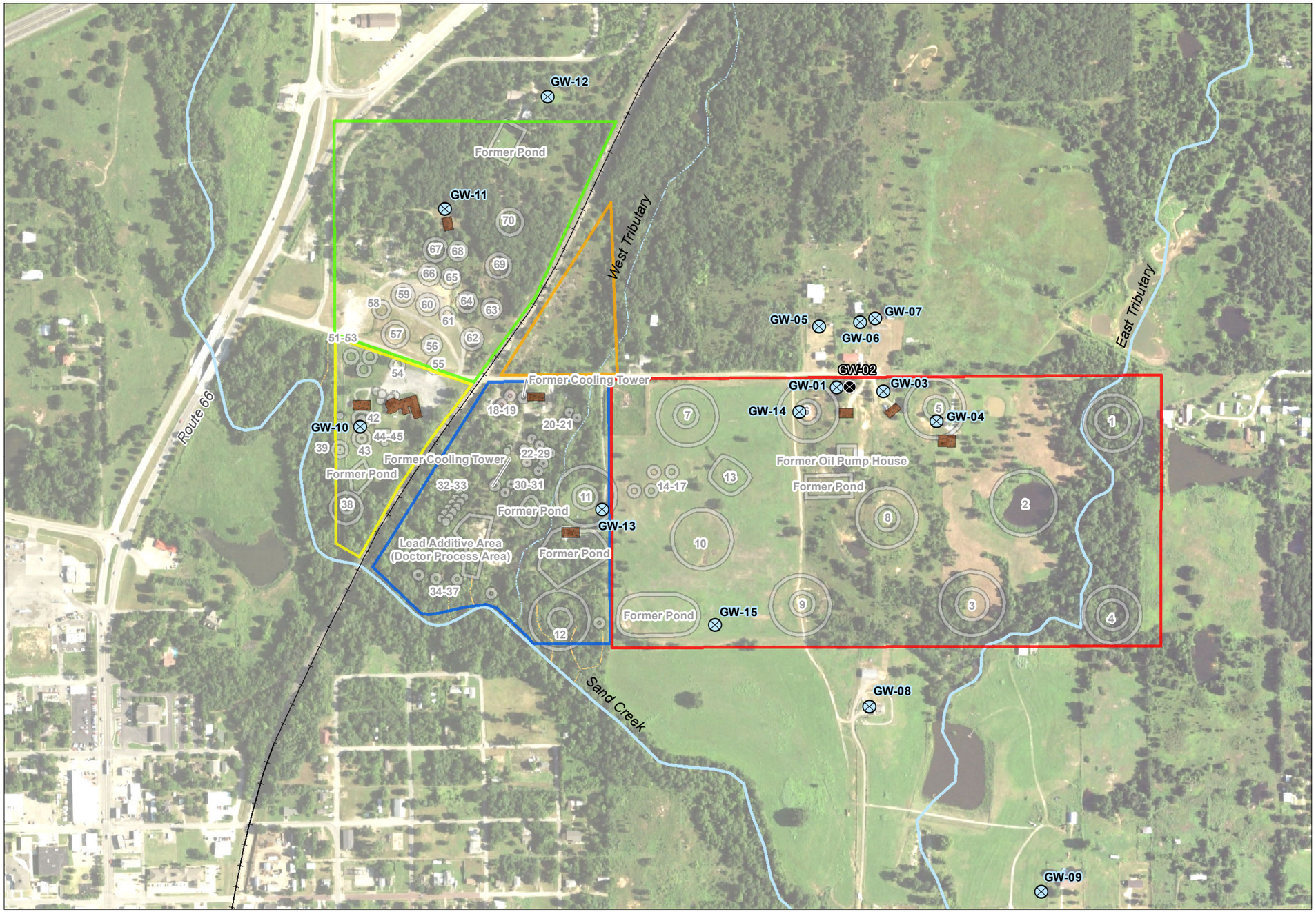
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
Remedial Investigation
for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

016332

FIGURE 11
PROPOSED LOCATIONS FOR SURFACE WATER AND SEDIMENT SAMPLES

P:\gis\Projects\Wilcox\MXDs\SAP\02 SAP revised 062016\12-PrivateWaterSupplySamples.mxd 6/23/2016 EA rmullen



0 200 400 800 Feet

1 inch = 500 feet

Legend

- Former Private Supply Well (Plugged and Abandoned)
- Private Supply Well
- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- On-Site Building
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area

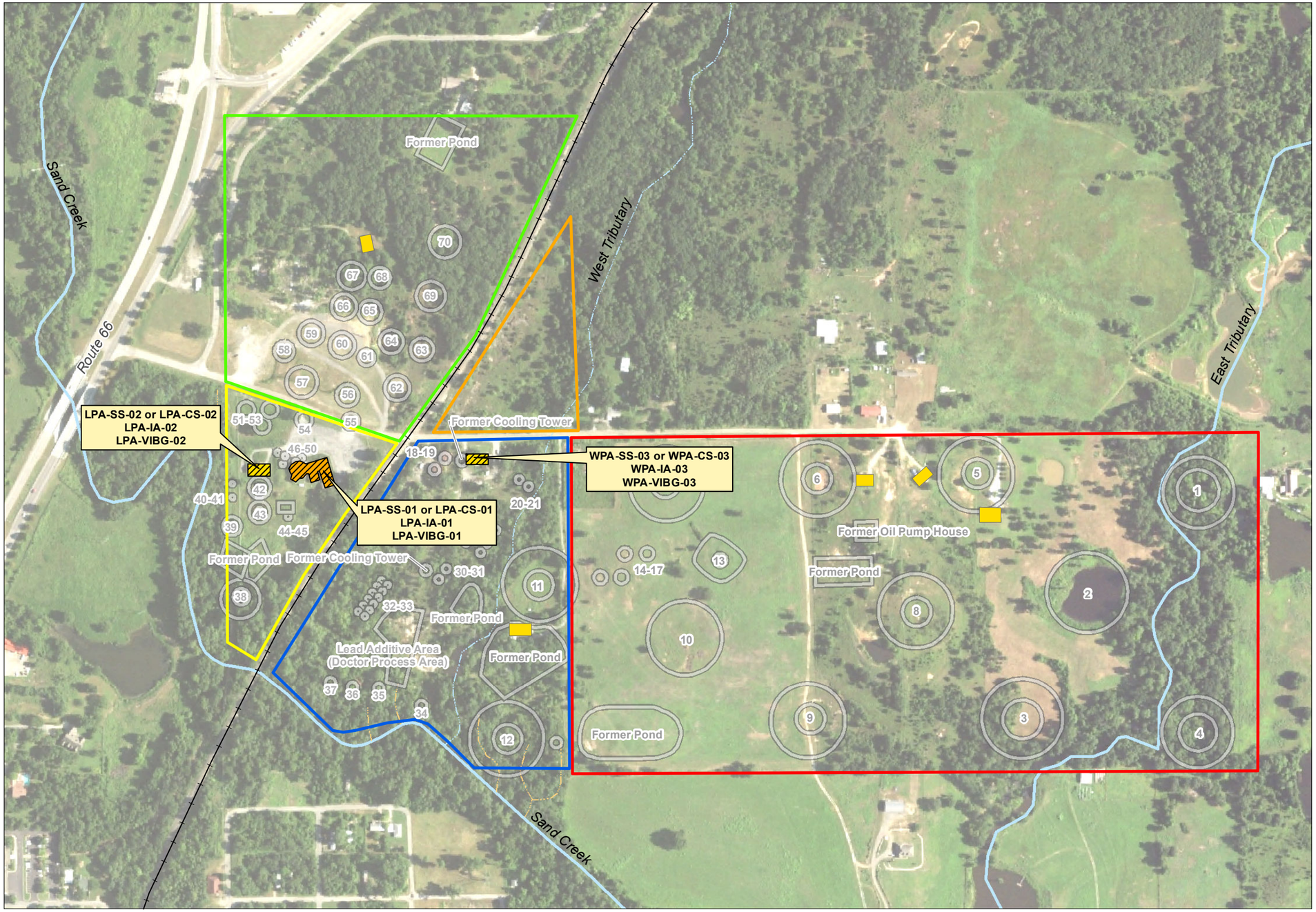
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
Remedial Investigation
for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

FIGURE 12
PROPOSED LOCATIONS FOR PRIVATE WATER SUPPLY WELL SAMPLES

016333

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0 200 400 800 Feet

1 inch = 400 feet

Legend

- Historical Feature
- Railroad
- Drainage
- Stream, Intermittent
- Stream, Perennial
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area
- Proposed Vapor Intrusion Sampling

On-Site Building

- Church
- Residence

Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
Remedial Investigation
for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

FIGURE 13
PROPOSED LOCATIONS FOR VAPOR INTRUSION SAMPLES

016334

Appendix A

Conceptual Site Model Technical Memorandum

Conceptual Site Model Technical Memorandum

Remedial Investigation/Feasibility Study
Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma
EPA Identification No. OK0001010917

Remedial Action Contract 2 Full Service
Contract: EP-W-06-004
Task Order: 0128-RICO-06GG

Prepared for

U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue
Dallas, Texas 75202-2733

Prepared by

EA Engineering, Science, and Technology, Inc. PBC
405 State Highway 121 (Bypass)
Building C, Suite 100
Lewisville, Texas 75067
(972) 315-3922

September 2016
Revision: 01
EA Project No. 14342.128

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LIST OF ACRONYMS AND ABBREVIATIONS

BTAG	U.S. Army Biological Technical Assistance Group
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
DDT	Dichlorodiphenyltrichloroethane
EA	EA Engineering, Science, and Technology, Inc. PBC
E&E	Ecology & Environment, Inc.
ECOS	Environmental Conservation Online System
EDB	Ethylene dibromide
EPA	U.S. Environmental Protection Agency
ESI	Expanded Site Inspection
LC	Lethal concentration
Magellan	Magellan Midstream Partners, LP
NORM	Naturally-occurring radioactive materials
ODEQ	Oklahoma Department of Environmental Quality
ODWC	Oklahoma Department of Wildlife Conservation
ONHI	Oklahoma Natural Heritage Inventory
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
RI	Remedial Investigation
Site	Wilcox Oil Company Superfund Site
SVOC	Semivolatile organic compound
TENORM	Technologically-enhanced naturally-occurring radioactive materials
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
VOC	Volatile organic compound
Wilcox Oil	Wilcox Oil Company Superfund Site
XRF	X-ray fluorescence

1. INTRODUCTION

EA Engineering, Science, and Technology, Inc., PBC (EA) has been authorized by the U.S. Environmental Protection Agency (EPA), under Remedial Action Contract No. EP-W-06-004, Task Order 0128-RICO-06GG, to conduct a Remedial Investigation (RI) at the Wilcox Oil Company Superfund Site (site or Wilcox Oil). EA has prepared this Conceptual Site Model (CSM) Technical Memorandum in accordance with: (1) specifications provided in the EPA Statement of Work, dated 13 July 2015 (EPA 2015); (2) EPA responses to a Request for Clarification, received on 28 July 2015; (3) feedback received during multiple scoping meetings between November 2015 and March 2016; and (4) the EPA partially approved EA Work Plan, dated 31 August 2015 (EA 2015). The project activities will be conducted under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act.

1.1 PURPOSE

The purpose of the CSM is to establish a framework to address the principal study questions outlined below:

- What are the possible sources for contamination?
- What are the nature and extent of contamination?
- What are the potential migration pathways for transport of these contaminants?

Principal study questions are used as a part of the Data Quality Objectives process to ensure the goal of the study has been met with defensible products and decisions (EPA 2006).

1.2 SCOPE

The scope of the CSM includes the following:

- Reviewing existing reports
- Evaluating the site geology and hydrogeology, including definition of the various water-bearing zones
- Detailing the CSM that: (1) describes the source of contamination, (2) describes the nature and extent of contamination, (3) identifies the primary migration transport pathways, (4) identifies likely human health and ecological exposure pathways, and (5) identifies data gaps.

2. BACKGROUND

The Wilcox Oil site is an abandoned and demolished oil refinery and associated tank farm located north of Bristow, Creek County, Oklahoma (Figure 2). The approximate geographic coordinates for the site are 35°50’31” North latitude and 96°23’02” West longitude. The site spans approximately 140 to 150 acres.

The site consists of contaminated areas, including surface water bodies, due to releases from the former Lorraine and former Wilcox Refineries. Properties where refinery waste is present at the

surface are fenced and secured to deter trespassing and potential contact with the waste. These refineries were located in the N ½ of the NW ¼ of S29 T16N R9E and the SW ¼ of the SW ¼ of S20 T16N R9E in Creek County, Oklahoma (Figure 3). Two refinery process facilities and storage tank areas once operated at the two facilities. Historical investigations indicate the presence of contamination from former activities.

A detailed title search in the Creek County Clerk office confirms that the property was used in oil refinery operations from 1915 until November 1963. A skimming and cracking plant was constructed in 1929. The main components of the plant consisted of a skimming plant, cracking unit, and re-distillation battery with a vapor recovery system and treatment equipment. The Wilcox Oil Company expanded when it acquired the Lorraine Refinery in 1937, which was located west of the railroad. Oil refining began in 1915 at the Lorraine Refinery. Wilcox sold the property to a private individual in 1963. Most of the equipment and storage tanks were auctioned or salvaged for scrap metal by the new property owners. Wilcox Oil Company no longer operates in Oklahoma. Based on information from the Oklahoma Secretary of States' office, the company merged with Tenneco Oil Company in 1967.

A modern skimming and cracking plant was constructed in 1929. The upgraded facility had an operating capacity of 4,000 barrels of crude oil per day. The main components of the system consisted of a skimming plant, cracking unit, and re-distillation battery with a vapor recovery system and continuous treating equipment. The crude oil was brought directly from the field, eliminating storage and handling facilities, but resulting in crude oil with high sediment and water.

Sanborn fire insurance maps can be used to understand historical property usage. The Wilcox Oil and Gas Company and Lorraine Refining Company Sanborn Insurance Maps indicate that the properties contained approximately 80 storage tanks of various sizes, a cooling pond, and approximately 10 buildings housing refinery operations. The maps also indicate that crude oil, fuel oil, gas oil, distillate, kerosene, naptha, and benzene (petroleum ether) were all stored on the property.

2.1 SITE DESCRIPTION

The location of the releases from the two refineries is considered to be a single site composed of a commingled release from the combined refinery operations threatening the same targets. The release from the two refineries is comingled and/or the contamination is contiguous. The Wilcox Oil site is composed of a release from the combined facility operations.

The site includes remnants of former oil refining operations and tank farms. The facility can be divided into five (5) major former operational areas (Figures 3 and 4): the Wilcox and Lorraine Process Areas, the East and North Tank Farms, and the Loading Dock Area. An active railroad divides the two former process areas and product storage areas.

- Wilcox Process Area – The Wilcox Process Area is fenced and spans approximately 26 acres. Most of the equipment and storage tanks that remained onsite in 1963 were auctioned and salvaged for scrap iron by private land owners; any remaining structures are in ruins. Four aboveground storage tanks (12,500-gallon capacity each) remain standing, in addition to a number of discarded drums and pieces of scrap iron and piping.

A former Lead Additive area is present that is barren. There are multiple areas of stressed vegetation, barren areas, and visible, black tarry waste of a hydrocarbon nature. A building in the northern part of the former refinery has been converted to a residence, which is currently vacant. A second residence located in the eastern portion of the process area is also unoccupied. An intermittent creek (West Tributary) flows southward across the eastern portion of the refinery process area through a small pond in the southeast corner of the refinery area into Sand Creek.

- Lorraine Process Area – The Lorraine Process Area spans approximately 8 acres and covers the southwestern portion of the site, south of West 221st Street South (formerly Refinery Road) and west of the railroad tracks. No refinery structures remain in either the processing area or refined product storage area. The First Assembly of God Church (currently vacant), a playground, and a vacant residence are located in this area. A drainage feature borders the western boundary of the Lorraine Process Area and drains south to Sand Creek. There are multiple areas of stressed vegetation, barren soil, and visible, black tarry waste of a hydrocarbon nature. For the purposes of the RI, a portion of the North Tank Area has been re-designated as part of the Lorraine Process Area (Figure 4); the triangular-shaped section is south of Refinery Road and is located within the fenced compound that comprises the vacant First Assembly of God Church.

- East Tank Farm – The East Tank Farm spans approximately 80 acres and includes pits, ponds, and a number of circular berms that surrounded former tank locations. All of the former crude oil storage tanks have been removed; however, remnants of the former tank locations remain and are visible. It is not known if all of the piping associated with the tanks remains or was removed. Many of the berms surrounding the pits, ponds, and former tanks have been breached or leveled. There are three occupied residences located on or directly next to former tank locations in the East Tank Farm. There are multiple areas of stressed vegetation, barren soil, and visible, black tarry waste of a hydrocarbon nature. Hydrocarbon waste was also observed in several drainage channels that empty into Sand Creek. The East Tributary is located along the eastern boundary of the East Tank Farm and perennially flows south through a series of ponds to Sand Creek. Magellan Midstream Partners, LP operates a pumping station in the north-central portion of the East Tank Farm Area, as well as an active pipeline that transects the East Tank Farm, Loading Dock, and North Tank Farm Areas from the southeast to the northwest. Magellan Midstream Partners, LP has been known to pump several different petroleum products through the active pipeline, including kerosene, gasoline, jet fuel, and diesel.

- North Tank Farm – The North Tank Farm is located north of Refinery Road and west of the railroad tracks and spans approximately 20 acres. The North Tank Farm included crude oil and fuel oil storage tanks associated with the Lorraine Refinery. All of the tanks and other structures have since been removed. An occupied residence is located in the center of the North Tank Farm. There are areas of stressed vegetation, and visible, black tarry waste of a hydrocarbon nature.

- Loading Dock Area – The triangular-shaped Loading Dock Area spans approximately 7 acres and is located north of Refinery Road and east of the railroad tracks. The Loading Dock Area was used for loading and unloading product by rail. There are multiple areas

of stressed vegetation, barren areas, and visible black tarry waste of a hydrocarbon nature.

Current access to the property is not controlled, although portions of the site are fenced. A vacant church and seven residences (four of which are occupied) are presently located on the facility. The seven residences are located on former crude oil storage tank or refinery operations areas. The three occupied residences located on the East Tank Farm are known to use water from domestic/private wells located onsite; the occupied residence in the North Tank Farm also uses water from a private well. The site is flanked by Route 66 to the west; a residential area and Turner Turnpike to the northwest and north; Sand Creek to the southwest; and residential, agricultural, and wooded areas to the east and south. The topography in the vicinity of the site slopes to the south. The drainage pattern of the property is primarily towards Sand Creek, which borders the western and southwestern boundaries of the property. An intermittent stream, a perennial stream, and several drainage channels transect the property east of the railroad (Wilcox Process Area and East Tank Farm), all of which flow into Sand Creek.

2.2 SITE HISTORY AND PREVIOUS INVESTIGATIONS

Several investigations have occurred at the site starting in 1994. The historical documents are as follows:

- Preliminary Assessment of the Wilcox Oil Company (Oklahoma Department of Environmental Quality [ODEQ] 1994)
- Expanded Site Inspection (ESI) Report – Wilcox Oil Company (Roy F. Weston 1997)
- Site Assessment Report for Wilcox Refinery (Ecology & Environment, Inc. [E&E] 1999)
- Preliminary Assessment of the Lorraine Refinery Site (ODEQ 2008)
- Site Inspection Report – Lorraine Refinery (ODEQ 2009)
- ESI Report – Lorraine Refinery (ODEQ 2010)
- ESI Report – Wilcox Refinery (ODEQ 2011a)
- Supplemental Sampling Report for Wilcox ESI (ODEQ 2011b)
- Trip Report (Draft): November 30 through December 16, 2015, Wilcox Oil Company Superfund Site (Lockheed Martin SERAS 2016).

The main body of the Sampling and Analysis Plan presents the most significant findings from these investigations, as well as the more recent investigations conducted by EPA under the Scientific, Engineering, Response and Analytical Services contract. Under this contract, EPA's contractor conducted additional activities, such as a geophysical survey, and performing a Rapid Optical Scanning Tool (ROST) laser-induced fluorescence (LIF) and field-portable X-ray fluorescence (XRF) surveys across portions of Wilcox and Lorraine Process Areas and the East Tank Farm in 2015. Soil, surface water, and infiltrated water were collected for laboratory analysis.

3. SITE CHARACTERISTICS

This preliminary site characterization summary will be revised as new information develops and details can be refined.

3.1 SURFACE FEATURES

The site slopes to the southwest and southeast with sandstone outcrops throughout. The North Tank Farm is located in the northwestern portion of the property. It is located west of the railroad and north of West 221st Street South/Refinery Road, and is rural land containing one occupied residence.

The Loading Dock Area is located immediately east of the North Tank Farm and along the railroad tracks. There is visible hydrocarbon staining of the soil in this area.

In the northeastern portion of the Lorraine Process Area sits the Bristow First Assembly of God Church. A playground is located just south of the building and one residence is located to the west. All buildings are presently unoccupied.

In the Wilcox Process Area, several refined product storage tanks, refinery-related debris, dilapidated buildings and structures remain on the property. There are two residences in this portion of the site, which are currently not occupied. The West Tributary is an intermittent stream that runs north to south in the eastern portion of the area.

Three occupied residences are located in the East Tank Farm area, as well as five ponds and the East Tributary (a perennial stream), which runs north to south on the east side of the area. An active railroad divides the former Wilcox and Lorraine Process Areas. Throughout the site, there are multiple areas of stressed vegetation, barren areas, and visible black tarry waste.

3.2 DEMOGRAPHICS

According to the U.S. Census Bureau, the population of Bristow, Oklahoma, was approximately 4,250 in 2014. There were 1,722 households with an average size of 2.40 persons per household. The population was 75.7 percent white, 9.2 percent black, 10.2 percent American Indian and Alaskan Native, and 4.9 percent being of two are more races. The median household income in 2014 was estimated to be $29,710. The U.S. Census Bureau also estimated that 26.7 percent of the population has an income below the poverty level (U.S. Census Bureau 2010).

3.3 METEOROLOGY AND CLIMATE

In nearby Tulsa, Oklahoma, the average mean temperature is 60.7 degrees Fahrenheit (F). The coldest month on average is January, with an average mean temperature of 37.7 degrees. The warmest month on average is July, with an average mean temperature of 82.9 degrees F (National Weather Service 2016).

The average precipitation in Tulsa, Oklahoma, is 40.97 inches per year, and average annual snowfall is 9.6 inches. The month with the most precipitation on average is May with 5.91

inches (National Weather Service 2016). Severe local storms, including tornadoes, strike in or near the area occasionally.

The climate of the site is classified as humid subtropical, based on the Köppen-Geiger climate classification system (Kottek et al. 2006).

3.4 LAND USE

Land in Creek County is primarily agriculture land: 54.9 percent of the county is pasture, 20.5 percent is cropland, 20.7 percent is woodland, and 3.9 percent is considered other use (U.S. Department of Agriculture [USDA] 2012a). Agricultural land in Creek County is primarily used for grain production and forage crop, with a small percentage of the county's agriculture land being used for food crops (USDA 2012b). Agriculture, livestock production, and the oil industries comprise most of the economic activity in Creek County (USDA 1959).

3.5 SOIL

According to the Creek County Soil Survey, the specific soil series on the site are Stephenville and Darnell fine sandy loam with a 4-7 percent slope, oil waste land, and Verdigris silt loam (ODEQ 2008).

The Stephenville and Darnell fine sandy loam, sloping, is a shallow upland soil that developed over reddish-yellow to red sandstone or interbedded sandstone and sandy shale. The parent materials were slightly acidic to neutral. The Stephenville Darnell fine sandy loams, sloping, are droughty and low in natural productivity. This soil is highly susceptible to erosion. About 60 percent of the acreage consists of Stephenville soil and 40 percent of Darnell soil. The Stephenville soil depth ranges from 20-40 inches. The first 4 inches of the Stephenville soil is a grayish-brown fine sandy loam with a weak granular structure and slight acidity. From 4 to 12 inches, the soil is a pale-brown light fine sandy loam that is very friable when moist and loose when dry and maintains a slight acidity. From 12-28 inches, the soil is a yellowish-red sandy clay loam with massive structure. At this point the soil is crumbly and friable when moist and slightly sticky when wet. The soil is porous and permeable, and maintains a medium acidity. From 28-35 inches, the soil is a yellow-red sandy clay loam that is friable, permeable, and contains small, soft fragments of slightly weathered sandstone with medium to slight acidity. The bedrock typically begins at 35 inches and is a yellowish-red sandstone that is slightly acidic to neutral. The depth of the Darnell soil ranges from 5-20 inches. The Darnell soil is a pale-brown, light, fine sandy loam that is structureless and slightly acidic to a depth of about 10 inches. From 10-16 inches, the Darnell soil is a medium acidic, reddish-yellow fine sandy loam with a lower part that is slightly heavier and contains small fragments of partly weathered sandstone. Past 16 inches, the soil is a neutral, reddish-yellow bedrock (ODEQ 2008).

Oil-waste land is listed as having contamination by oil and saltwater waste from oil wells. This land is typically gullied and eroded and bare of vegetation (ODEQ 2008).

The Verdigris silt loam is mapped on flood plains of streams. The parent material consisted of slightly acid to weakly alkaline alluvial sediments washed from dark soil of the prairies. Runoff is slow and internal drainage is moderate. The soil is flooded one to three times per year. The surface layer of soil runs about 16 inches deep, and is a dark grayish-brown silt loam that is

friable when moist and hard when dry, and maintains a slight acidity. From 16-36 inches, the soil is a dark grayish-brown clay loam that is crumbly and friable when moist and hard when dry. At this level, the soil is porous and permeable and maintains a slight acidity to neutral pH. From 36 inches on, the soil is a dark grayish-brown clay loam that is friable, permeable, and weakly alkaline (ODEQ 2008).

3.6 GEOLOGY

The site sits on the Pennsylvanian-aged Barnsdall Formation, which is composed of fine-grained sandstone overlain by shale. Thickness ranges from 80 to 200 ft (ODEQ 2008), but is approximately 200 feet thick at the site. Sandstone outcrops of the Barnsdall Formation are common throughout the site. At approximately 0.25 mile to the southeast of the former refinery, the underlying Pennsylvanian-aged Wann Formation and underlying Iola Limestone are exposed. The Wann Formation varies in thickness from 40 to 180 feet and is comprised of shale and fine- to medium-grained sandstone. The Iola Limestone ranges in thickness from 15 to 20 feet and consists of a calcareous fine-grained sandstone and limestone with some shale. Approximately 0.25 mile to the southeast of the former refinery, Sand Creek is associated with Quaternary-aged alluvial deposits consisting of sand, silt, clay, and lenticular beds of gravel. Thickness in these deposits ranges from 5 to 50 feet (25 feet average). Because Sand Creek borders the site to the south, localized alluvium may be present (ODEQ 2009).

3.7 SURFACE WATER

The drainage pattern of the property is primarily towards Sand Creek that follows the western and southwestern boundaries of the property. Sand Creek meanders approximately 3.5 miles east from the site until it merges with Little Deep Fork Creek, which is a fishery (EPA 2013). East Tributary and West Tributary are intermittent streams that cross the property and flow into Sand Creek. There are several additional drainage channels as well.

3.8 GROUND WATER

Sandstone outcrops of the Barnsdall Formation are common throughout the site, and potentially receive ground water recharge from downward infiltration of direct precipitation at the surface, as well as infiltration from shallow, perched ground water zones. The Barnsdall Formation is a bedrock aquifer but is not considered to be a Principal Ground Water Resource by the Oklahoma State Department of Health (ODEH 1994). However, the site is located on the border between the recharge and potential recharge area of the Vamoosa-Ada aquifer, an important central Oklahoma regional drinking water aquifer, located west of the site (E&E 1999).

The upper part of the Barnsdall Formation and the Sand Creek alluvial aquifer are unconfined, with a shallow water table. The site is in a potential recharge area and thus is susceptible to ground water contamination from petroleum waste or contaminated soil. Depths to seasonal perched water zones are less than 10 feet and the shallowest regional water-bearing formation is reportedly less than 25 feet below ground surface (ODEQ 1994). However, the first saturated sandstone was encountered at a depth of 45 to 60 feet during drilling at a nearby former domestic water well (E&E 1999). In summary, the possible ground water contamination mechanisms occurring at the site are (1) recharge to the shallow part of the Barnsdall Formation on site, (2)

low potential recharge to the Vamoosa-Ada aquifer west of the site, and (3) discharge of perched ground water to the alluvial aquifer along Sand Creek to the south (E&E 1999).

3.9 ECOLOGICAL SETTING

The site is approximately 125 acres and consists of 75 percent open, grassy areas with the remaining 25 percent of the site being covered with various tree species. There are several barren areas that may be indicative of plant stress due to contamination. In Creek County, the principal tree species are blackjack oak, post oak, and hickory, which are often found on upland areas consisting of sandy soil. Tree species often found in bottomland areas or along stream channels include elm, hackberry, pecan, and cottonwood (USDA 1959).

During the site visit in December 2015, the only wildlife observed were birds. However, portions of the site likely offer suitable habitat for deer, small mammals, and birds. In addition to Sand Creek and Little Deep Fork Creek, the following water features have been identified onsite: the East and West Tributaries (intermittent), intermittent drainage pathways, wetlands, and small ponds; a single fish was the only aquatic wildlife observed in Sand Creek during the December 2015 site visit.

Central Oklahoma is located within the Central Lowland physiographic province, which is an area of rolling plains and low hills extending across the central portion of the United States from north-central Texas to Kansas. Creek County is also within the Osage plains of the Central Lowlands physiographic province. This part of the Central Lowlands is an area of well dissected-sandstone hills covered primarily with prairie grasses and select areas with remnants of Cross Timber and scrubby forests (USDA 1959).

3.10 THREATENED AND ENDANGERED SPECIES

According to the U.S. Fish and Wildlife Service (USFWS) Environmental Conservation Online System, or ECOS (USFWS 2016a), there are two threatened bird species, one endangered bird species, one bird species in recovery status, and one threatened invertebrate species that are known or believed to occur in Creek County. The table below is a full list of species that are currently state or federally listed as endangered or threatened, and rare and vulnerable in Creek County, Oklahoma (Oklahoma Department of Wildlife Conservation [ODWC] 2016; USFWS 2016; Oklahoma Natural Heritage Inventory [ONHI] 2016). The listed species above may occur within Creek County; however, there have been no known documentation of the species or their habitat identified at the site (Weston 1997). During development of this section, the Oklahoma National Heritage Inventory was contacted for review of the project area information.

Species	Scientific Name	Federal Status	State Status
Vertebrate Species			
Least tern	*Sterna antillarum*	Endangered	Endangered
Piping plover	*Charadrius melodus*	Threatened	Threatened
Red knot	*Calidris canutus rufa*	Threatened	Threatened
Arkansas River Shiner*	*Notropis girardi*	Threatened	Threatened
American peregrine falcon	*Falco peregrinus anatum*	Recovery	Recovery
Invertebrate Species			
American burying beetle	*Nicrophorus americanus*	Endangered	Endangered
Plant Species			
Hammock Sedge	*Carex fissa*	Rare and Vulnerable	Rare and Vulnerable
Note: * - Per Oklahoma Natural Heritage Inventory employee the Arkansas River Shiner has been sighted in Creek County (T. Faggin, Personal communication. 15 March 2016).			

Identifiable elements of concern are listed in the reports discussed in this section. Information provided in the *Preliminary Assessment of the Wilcox Oil Company* report (ODEQ 1994) and the *Expanded Site Inspection Report – Wilcox Oil Company* (Weston 1997) indicate that small wetland frontages occurred along surface water pathways downstream from the site. Onsite, two types of wetland communities were identified using the USFWS National Wetlands Inventory online mapper. A scalene triangular-shaped, palustrine forested, broad-leaved deciduous, temporarily-flooded wetland community was identified along southwestern perimeter of the site where the Lorraine and Wilcox Process Areas border Sand Creek, and up to six palustrine, unconsolidated bottom, permanently flooded, diked impoundment type wetland communities were identified at various locations throughout the East Tank Farm area (EPA 2013; USFWS 2016b). The two creek systems that drain the site, Sand Creek and Deep Fork Creek, were identified as elements of concern in the *Expanded Site Inspection Report – Wilcox Oil Company* (Weston 1997) and are discussed in this section. Sand Creek is considered a "habitat limited aquatic community" that is fish and wildlife propagation beneficial and recreational beneficial, and Little Deep Fork Creek is considered a "warm water aquatic community" that is fish and wildlife propagation beneficial and recreational beneficial (Weston 1997; EPA 2013).

4. NATURE AND EXTENT OF CONTAMINATION

The following subsections regarding nature and extent of contamination include: (1) comparison criteria, (2) identification of chemicals of potential concern (COPCs), (3) discussion of potential source materials, and (4) evaluation of nature and extent of contaminants based on existing data.

4.1 COMPARISON CRITERIA

To provide a basis for evaluating existing and future chemical concentration data, human health and ecological risk levels are identified as protective comparison values for chemical concentrations in soil, sediment, surface water, and ground water. These criteria are discussed in Section 1.3.4.1 of the Sampling and Analysis Plan.

4.2 CHEMICALS OF POTENTIAL CONCERN

The list of COPCs at the site will be initially applied conservatively to all media across the investigation due to the numerous data gaps discussed. The set of COPCs cannot be refined until source characterization has been completed, although more details on COPCs are presented in Section 1.1.5 of the Sampling and Analysis Plan. The current COPCs at the site are as follows:

- Volatile organic compounds (VOCs)
- Ethylene dibromide (EDB)
- Polycyclic aromatic hydrocarbons (PAHs)
- Semivolatile organic compounds (SVOCs)
- Target Analyte List metals (including mercury)
- Cyanide.

In addition, for completeness, a select number of shallow surface soil samples (0.0–0.5 ft bgs) from the process areas will undergo the following analyses:

- Hexavalent chromium
- Polychlorinated biphenyls (PCBs)
- Pesticides
- Dioxins/furans
- Naturally-occurring radioactive materials (NORM) and technologically-enhanced naturally-occurring radioactive materials (TENORM) (if necessary, based on survey results).

4.3 SOURCE

Source material is a media that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration to other media or for direct exposure (EPA 1991). The EPA identifies source material as either a principal threat waste or a low-level threat waste, as described below.

- **Principal Threat Wastes** – Source materials that are considered highly toxic or highly mobile and that generally cannot be reliably contained or would present a significant risk to human health or the environment if exposure were to occur.
- **Low-level Threat Wastes** – Source materials that exhibit low toxicity and low mobility and can be reliably contained or would present only a low risk to human health or the environment if exposure were to occur.

Potential sources have not been adequately characterized to define their status as principal or low-level threat wastes. Waste status at the site will be determined after further investigation. Information on the sources of contamination is discussed in Section 1.1.5 of the Sampling and Analysis Plan.

4.4 EXTENT OF CONTAMINATION

Because of limitations on the usability of historical data, nature and extent of contamination are currently undefined. A complete review of historical data is provided in the Sampling and Analysis Plan. Data gaps are addressed in Section 6 of this document.

5. CONTAMINANT FATE AND TRANSPORT

The nature and extent of contamination is combined with source identification and physical characteristic information to evaluate migration pathways. The following migration pathways may be present. Further site evaluation will be necessary to definitively conclude which are present.

5.1 SURFACE WATER TRANSPORT

Contaminant transport of particulates and dissolved phase contaminants via surface water transport may occur in Sand Creek, East Tributary, and West Tributary. Surface water transport may also occur periodically in drainages leading from the site into these water bodies.

5.2 LEACHING TO GROUND WATER

As water percolates through vadose zone soil to the underlying ground water, it can carry dissolved phase constituents. Additionally, source material in contact with ground water can leach directly to ground water.

5.3 GROUND WATER TRANSPORT

As ground water migrates laterally through the saturated zone, it can carry dissolved phase constituents.

5.4 GROUND WATER TO SURFACE WATER

Ground water may emanate as surface water at various points (e.g., gaining streams) around the site. This has yet to be confirmed for Sand Creek at the site.

5.5 AIR PARTICULATE MIGRATION

Generally, soil is not considered mobile because ground cover or vegetation often precludes migration. Nonetheless, it may be possible for high wind events to carry fine-grained surface materials and particulates from source areas, particularly from barren areas of the site.

5.6 SOIL VAPOR TO AIR

VOCs in soil can migrate from the soil to ambient air, where they can then be transported in the atmosphere. More significantly, vapor intrusion into residences and the vacant church may pose a human health risk.

5.7 GROUND WATER TO AIR

VOCs can volatilize from ground water to ambient air.

6. DATA GAPS

Data from previous investigations were not sufficient to define nature and extent of contamination for the following reasons:

- Samples for all media were not analyzed for the full set of potential COPCs at the site; the specific analytical suites are specified under the medium-specific discussion in the body of the SAP.
- Detection limits for a number of historical analyses are too high in some cases to allow evaluation of data with respect to current risk-based screening levels; newer analytical methods are able to quantify to significantly lower concentrations.
- For metals (and potentially NORM/TENORM), detections are anticipated in all media sampled. Analytical results for metals indicate contamination likely occurred; however, no rigorous background or upstream concentrations have been derived, and for this reason, a quantitative evaluation of background metals and NORM/TENORM is necessary.
- XRF survey was performed *in situ* and no soil samples were sent to the analytical laboratory for confirmation; thus, these data are qualitative, and cannot be used in a risk assessment.

In order to support the development of the RI, additional ground water, surface and subsurface soil, sediment, surface water, and air data will be collected as documented in the Sampling and Analysis Plan. This additional data will help (1) delineate the source areas, (2) delineate the lateral and vertical extent of contamination, and (3) define the nature of the contamination.

7. HUMAN HEALTH CONCEPTUAL EXPOSURE PATHWAY ANALYSIS

This section presents the preliminary human health CSM and summarizes information on sources of site chemicals, affected environmental media, chemical release and transport mechanisms, potentially exposed receptors, and potentially complete exposure pathways for each receptor. Figure 3 presents the preliminary human health CSM.

7.1 SOURCES OF SITE CHEMICALS

Section 4 summarizes the nature and extent of contamination. As shown in Figure 3, sources for chemical exposure may include surface soil, subsurface soil, sediment, surface water, ground water, and air. Residual soil source areas are a result of historic site activities and have been tentatively identified in the Lorraine Process Area, North Tank Farm, Loading Dock Area, Wilcox Process Area, and East Tank Farm. Sampling activities will be completed as part of the RI to further define residual source areas and fill existing data gaps.

7.2 AFFECTED ENVIRONMENTAL MEDIA

Residual soil source areas have resulted in chemical releases to soil (e.g., vadose zone), sediment, surface water, ground water, and air.

7.3 CHEMICAL RELEASES AND TRANSPORT MECHANISMS

Figure 3 summarizes the chemical release and transport mechanisms for the detected chemicals. Release and transport mechanisms include migration to ground water, migration to subsurface soil, runoff/erosion, volatilization, sedimentation, resuspension, and uptake by plants.

7.4 POTENTIALLY EXPOSED RECEPTORS

Construction or maintenance activities may occur that would require excavation, construction, or regrading; therefore, a construction worker scenario was considered. Current access to the property is not controlled, although portions of the site are fenced. The trespasser and occasional recreational user scenarios were included in the event that a receptor intrudes onto an impacted portion of the property. Finally, both the residential and commercial/industrial scenarios will be evaluated. The residential scenario is considered because there are six residences currently located on the site and the potential for future residents exists. The commercial/industrial scenario is considered to reflect the possibility that other less restrictive land uses may be designated for those areas of the site that were formerly heavily industrialized (e.g., process areas).

7.5 POTENTIALLY COMPLETE EXPOSURE PATHWAYS

According to EPA guidance (1989), a complete exposure pathway consists of four elements:

- A source and mechanism of chemical release
- A retention or transport medium (or media in cases involving transfer of chemicals)
- A point of potential human contact with the contaminated medium (referred to as the "exposure point")
- An exposure route (such as ingestion) at the exposure point.

If any of these elements are missing, then the exposure pathway is considered incomplete. For example, if receptor contact with the source or transport medium does not occur, then the exposure pathway is considered incomplete and is not quantitatively evaluated. Similarly, if human contact with an exposure medium is not possible, the exposure pathway is considered incomplete and is not evaluated.

The preliminary CSM (Figure 3) summarizes information on sources of COPCs, affected environmental media, COPC release and transport mechanisms, potentially exposed receptors, and potential exposure pathways for each receptor. Potentially complete exposure pathways are designated by a solid circle in the preliminary CSM. Incomplete exposure pathways are designated by a hollow circle. Because some of these pathways are based on hypothetical-future

exposure, they are considered potentially complete, but may not actually be complete for all receptors in the future.

Exposure routes for each receptor associated with the potentially complete exposure pathways are described in the following sections for the following potential receptors:

- Construction Worker
- Trespasser
- Residential (current and future)
- Commercial/Industrial.

Construction Worker Exposure

The following exposure pathways for surface and subsurface soil are potentially complete for the construction worker scenario:

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of chemicals adsorbed to windblown soil in outdoor air (i.e., fugitive dust).

The following exposure pathways for ground water are potentially complete for the construction worker scenario:

- Dermal contact with ground water and subsequent incidental ingestion
- Inhalation of chemicals volatilized from ground water into a trench.

Trespasser Exposure

The following exposure pathways for surface soil are potentially complete for the trespasser scenario:

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of chemicals adsorbed to windblown soil released to outdoor air.

The following exposure pathways for surface water and sediment are potentially complete for the trespasser scenario:

- Incidental ingestion of surface water
- Dermal contact with sediment and surface water.

Ingestion of wild foods is an additional exposure pathway for trespassers that is potentially complete through exposure to contaminated biota. However, this exposure pathway is not anticipated to result in significant exposure to contamination for the trespasser scenario.

Residential Exposure

The following exposure pathways for surface and subsurface soil are potentially complete for the residential scenario:

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of chemicals adsorbed to windblown soil released to outdoor air
- Inhalation of indoor air vapors from soil vapor intrusion.

The following exposure pathways for surface water and sediment are potentially complete for the residential scenario:

- Incidental ingestion of surface water
- Dermal contact with sediment and surface water.

The following exposure pathways for ground water are potentially complete for the residential scenario:

- Ingestion of ground water
- Dermal contact with ground water
- Inhalation of chemicals volatilized from ground water during domestic use
- Inhalation of indoor air vapors from ground water vapor intrusion.

Ingestion of wild foods is an additional exposure pathway for the residential scenario that is potentially complete through exposure to contaminated biota.

Commercial/Industrial Exposure

The following exposure pathways for surface soil are potentially complete for the commercial/industrial scenario:

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of chemicals adsorbed to windblown soil in outdoor air (i.e., fugitive dust)
- Inhalation of indoor air vapors from soil vapor intrusion.

The following exposure pathways for ground water are potentially complete for the commercial/industrial scenario:

- Ingestion of ground water
- Dermal contact with ground water
- Inhalation of chemicals volatilized from ground water during domestic use
- Inhalation of indoor air vapors from ground water vapor intrusion.

8. ECOLOGICAL CONCEPTUAL EXPOSURE PATHWAY ANALYSIS

Figure 4 presents the ecological CSM, including potential exposure pathways evaluated for ecological receptors. These were divided into exposures for aquatic and terrestrial habitats. The CSM illustrates both potential and quantifiable pathways through which receptors may be exposed to COPCs. EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997) provides guidance for designing and conducting technically defensible ecological risk assessments for the Superfund program.

8.1 IDENTIFICATION OF EXPOSURE PATHWAYS

Exposure routes link chemicals in exposure media to ecological receptors. The following sections describe the major exposure routes. Ecological receptors potentially present at the site include plants, terrestrial invertebrates, wildlife (birds, mammals, etc.), and aquatic and benthic organisms. The following sections identify the major routes of exposure and their applicability to each of these receptor groups.

8.1.1 Direct Contact/Dermal Contact

Plants, invertebrates, aquatic and benthic organisms, and wildlife may all be exposed to environmental media through direct contact. Plants may absorb chemicals from surface soil via their roots. They may also absorb chemicals from air or airborne particles through their leaves. Absorption through the roots is expected to be the most significant pathway. Absorption of chemicals from air or airborne particles is expected to be an insignificant pathway (EPA 2005; U.S. Army Center for Health Promotion and Preventive Medicine [CHPPM] 2004); although this pathway may be re-evaluated if new data indicate that significant airborne contamination is present. It is also possible that deep rooting plants come into direct contact with ground water; however, the ground water onsite is likely too deep for this to be a complete pathway. Plants are known to uptake metals and some organics; however, uptake of hydrophobic and/or large molecular weight compounds by plants is limited. Based on this information, direct exposure to surface soil is considered a complete and significant pathway for plants (Figure 4).

Aquatic and benthic organisms may be exposed to chemicals in sediment and surface water through direct contact. Chemicals may be absorbed from water or sediment through the skin and gills. This exposure pathway is considered to be complete and significant for both media (Figure 4).

For soil invertebrates, direct contact with soil is identified as a significant exposure pathway as these organisms live in constant contact with the soil. The invertebrates may also be exposed to chemicals in air through direct contact; however, this exposure is not significant in relation to exposure from soil and is not quantifiable. Chemicals may be absorbed from soil through the skin. Therefore, for soil invertebrates, this exposure pathway is considered to be complete and significant for soil (Figure 4).

Wildlife may be exposed to chemicals in air, soil, sediment, or water via direct contact during foraging or burrowing. However, absorption and uptake through this contact is likely to be insignificant, as shown by example calculations in EPA guidance (EPA 2005). Most wildlife are

equipped with protective outer coverings such as fur, feathers, or scales that prevent or limit the dermal absorption of chemicals from environmental media (CHPPM 2004). Amphibians and reptiles may not be as well protected from dermal exposure. EPA guidance identifies that, in most cases, dermal exposures are likely to be less significant than exposures through ingestion and their evaluation involves considerable uncertainty (EPA 2005). The guidance provides example calculations for an example species showing that less than 0.2 percent of the total chemical dose to wildlife is likely to come from dermal contact. This exposure route is considered complete for reptiles, amphibians, and other wildlife receptors, but is considered insignificant (Figure 4).

8.1.2 Inhalation

Inhalation is a potentially complete pathway for both terrestrial invertebrates and wildlife. These animals may inhale chemicals which have volatilized or which are adsorbed to airborne particulates. Currently, it is unclear whether volatile compounds are present at the site in high enough concentrations to cause significant exposures, additional data collected during the remedial investigation will assist in this determination. Similarly, it is unclear whether suspension of airborne particulates occurs with sufficient duration or frequency to result in significant inhalation exposures. EPA guidance indicates that, in general, inhalation pathways are likely to be insignificant compared to ingestion pathways (EPA 2005). This guidance states that most chemicals inhaled with dust are trapped in mucus membranes and ingested; therefore, their impact is captured through analysis of incidentally ingested soil. It also provides example calculations showing that less than 0.1 percent of the total risk to wildlife is likely to come from inhalation. Finally, a large number of assumptions are required for quantification of inhalation exposures, leading to significant uncertainties. Based on this information, inhalation exposures are considered to be a complete, but a non-quantifiable, exposure pathway for the site (Figure 4).

8.1.3 Ingestion

The most significant exposure route for wildlife is ingestion of chemicals in contaminated media (EPA 2005). Wildlife may ingest chemicals in environmental media by drinking surface water or by incidentally ingesting soil and sediment while grooming or foraging. As discussed above, chemicals may bioaccumulate in the tissue of plants and animals. Therefore, wildlife may also ingest chemicals in plants and animals that they consume as food. Herbivores may be exposed to chemicals that have bioaccumulated in plant tissue. Carnivores may be exposed to chemicals that have bioaccumulated in prey. Omnivores may be exposed to chemicals in both plant and animal food items. Although no wildlife other than birds and insects were observed during recent reconnaissance, the site would be expected to support a range of wildlife that spans several trophic levels and feeding guilds. This includes both primary and secondary consumers, and species which consume plants, invertebrates, small birds and mammals, and fish or aquatic organisms. Ingestion of chemicals in soil, sediment, surface water, and food are considered complete and potentially significant exposure pathways (Figure 4).

8.1.4 Exposure to Subsurface Soil and Ground Water

For aquatic and terrestrial receptors, exposure to ground water and subsurface soil are considered incomplete pathways. Aquatic receptors are expected to receive most of their exposure in the top 1 foot of sediments and terrestrial receptors in the top 1 foot of the surface soil. However,

subsurface soil and ground water contamination may contaminate surface media, which ecological receptors will be exposed to, via exfiltration and seeps. The subsurface soil and ground water are considered potential sources but not exposure media.

8.1.5 Media of Concern

The expected media of concern include surface soil and sediment in areas covered by trees and grasses; sediment and surface water in ponds; the East and West intermittent tributaries; intermittent drainages; and sediment and surface water in Sand and Deep Fork Creeks. Complete, significant exposure pathways for receptors are expected to be limited to exposure to surface soil, sediment, surface water, and terrestrial and aquatic food chains.

8.2 ASSESSMENT ENDPOINTS

EPA guidance stresses the importance of ecologically significant endpoints. As EPA indicates, "Assessment endpoints are explicit expressions of the actual environmental value that are to be protected, operationally defined by an ecological entity and its attributes" (EPA 1998; U.S. Army Biological Technical Assistance Group [BTAG] 2002). The selection of assessment endpoints is based on the fundamental knowledge of local ecology. Assessment endpoints typically relate to an effect on a population or community. Survival of a specific species of insect is an example of a population level assessment endpoint. Community level assessment endpoints could include survival of benthic invertebrates or maintenance of multiple populations of birds.

Based on the CSM, ecological receptors may be exposed to COPCs from food, surface water, soil, and sediment. Based on the identified ecological receptors, habitats, and the above observations, the following ecological assessment endpoints are defined:

1. Protection of **terrestrial plant** survival, growth, and reproduction from adverse effects of COPCs in soil.
2. Protection of **wetland and aquatic plants** survival, growth, and reproduction from adverse effects of COPCs in sediment and surface water.
3. Protection of **soil invertebrates** exposed to COPCs in soil from adverse effects on survival, growth, and reproduction.
4. Protection of **aquatic and benthic communities** (e.g., fish and crustaceans) exposed to COPCs in sediment, surface water, and food from adverse effects on survival, growth, and reproduction.
5. Protection of **herbivorous mammals** to ensure that ingestion of COPCs in soil, sediment, and food do not have adverse effects on survival, growth, and reproduction.
6. Protection of **herbivorous birds** to ensure that ingestion of COPCs in soil, sediment, and food do not have adverse effects on survival, growth, and reproduction.
7. Protection of **insectivorous mammals** to ensure that ingestion of COPCs in soil and food do not have adverse effects on survival, growth, and reproduction.
8. Protection of **insectivorous birds** to ensure that ingestion of COPCs in soil and food do not have adverse effects on survival, growth, and reproduction.

9. Protection of **piscivorous mammals** to ensure that ingestion of COPCs in sediment and food do not have adverse effects on survival, growth, and reproduction.
10. Protection of **piscivorous birds** to ensure that ingestion of COPCs in sediment and food do not have adverse effects on survival, growth, and reproduction.
11. Protection of **predatory mammals** to ensure that ingestion of COPCs in soil and food do not have adverse effects on survival, growth, and reproduction.
12. Protection of **predatory birds** to ensure that ingestion of COPCs in soil and food do not have adverse effects on survival, growth, and reproduction.
13. Protection of **reptiles and amphibians** to ensure that ingestion of COPCs through contact with soil, sediment, and food does not have adverse effects on survival, growth, and reproduction.

EPA guidance (EPA 1999) specifies that the goal is to protect the above receptor groups from population impacts. The use of individuals to assess impacts is a highly conservative estimator of potential impacts on populations. This is a source of uncertainty that may lead to the overestimation of risks.

8.3 SELECTION OF REPRESENTATIVE RECEPTORS

Specific receptor groups and representative receptor species are selected to represent each of the ecological resource categories identified above. Selection of representative receptor species is based primarily on several factors: (1) the likelihood of a species to use the site, (2) the potential for exposure to site-related contaminants based on the feeding habits and life history of the organisms/guild represented by the receptor species, (3) the availability of life history and exposure information for the selected receptor species, and (4) the availability of toxicity information for the representative receptor species. The rationale for use of representative receptor species is summarized below. In cases where available toxicity data are of a general nature, communities or trophic levels were selected for evaluation as a whole. Although currently it does not appear to be the case, if it is determined that a protected species exists at the site, a suitable surrogate species will be identified and used as a representative receptor throughout the risk evaluation. When evaluating risk to a protected species via a surrogate, it is important that the individual be protected. The representative receptor groups are summarized below.

8.3.1 Aquatic Species

Wetland and Aquatic Plants

These receptors are exposed to chemical contaminants by direct contact with sediments and surface waters; these are the only complete exposure pathways identified (Figure 4). The roots of wetland and aquatic plants are in continuous contact with bottom sediments and active uptake of contaminants by roots can occur. Stems and other immersed tissues could uptake contaminants from surface water through stomata. There are limited benchmarks available for surface water exposure to plants (Suter and Tsao 1996; Efroymson et al. 1997). Wetland and aquatic plants can be assumed to be protected in the event that no phytotoxicity data are available if it can be shown that surface water concentrations meet water quality benchmarks. No other

exposure pathways are complete, because root systems are not deep enough to penetrate to subsurface layers or ground water. Transfer of particulates from air to the surface of the plant is expected but this is not likely to be a route of exposure because of the relatively impermeable nature of plant cell walls.

Based on the general nature of available plant toxicity data, no specific plant species are selected for evaluation. Instead, the assessments evaluate the potential for adverse effects to wetland and aquatic plant communities.

Aquatic and Benthic Organisms

These receptors are exposed to chemical contaminants by direct contact with and ingestion of sediment and surface water, as well as consumption of fish and benthos (Figure 4). Exposure to ground water and subsurface soil are incomplete pathways, because these organisms live in the bottom sediments or within surface waters. Because of the aquatic nature of these receptors, exposure to airborne particulates is also an incomplete pathway.

The toxicity data being used in the risk assessment are designed to evaluate the potential for adverse effects to aquatic and benthic organisms. Therefore, individual species are not selected for evaluation, and the assessments evaluate the potential for adverse effects to the overall aquatic and benthic populations.

Herbivorous Wildlife

Herbivorous birds and mammals are exposed to chemical contaminants from surface water, sediment, and vegetative matter, chiefly during foraging. These receptors are exposed to contaminants via direct contact with and ingestion of surface water and sediment and the ingestion of food (plant tissue). All of these represent complete pathways, but only the incidental ingestion of sediment and the consumption of food will be considered significant (Figure 4).

The muskrat (*Ondatra zibethicus*) is selected as the mammalian receptor species for evaluating potential adverse effects to mammals from the ingestion of plants. The muskrat diet includes significant amounts of plant food items (EPA 1993). Therefore, the muskrat is selected as a representative receptor species for the evaluation of potential adverse effects to mammals from feeding at the site.

The Canada goose (*Branta canadensis*) is selected as the representative receptor species to evaluate the potential for adverse effects to herbivorous birds from the ingestion of chemicals in plant material. It is more conservative to include an avian receptor since according to Sample et al (1996), birds can be more sensitive to certain contaminants. The Canada goose is selected as a representative receptor species because its diet is mostly comprised of plant material (EPA 1993) and this species can be an important part of the diet of predatory mammals.

Piscivorous Wildlife

Piscivorous birds and mammals are exposed to chemical contaminants chiefly during foraging and feeding. These receptors are exposed to contaminants via direct contact with surface water and sediment as well as the ingestion of food (fish and benthos), surface water, and sediment.

All of these represent complete pathways, but only the incidental ingestion of sediment and the consumption of food will be considered significant (Figure 4). To identify potentially impacted piscivorous species groups, the feeding guilds of the mammals, invertebrates, and birds known to occur in the study area were reviewed. Those identified as having the greatest potential to be adversely affected are selected for detailed evaluation.

The North American river otter (*Lutra canadensis*) was selected as the mammal species for evaluating potential adverse effects to mammals from the ingestion of fish and benthic and aquatic invertebrates at the Site. Since a large proportion of their diet is comprised of fish, the river otter was selected as the representative piscivorous mammal.

The great blue heron (*Ardea herodias*) is selected as the avian receptor species for evaluating potential adverse effects to birds from the ingestion of fish, amphibians, and crayfish from the area. The great blue heron is selected for evaluation, because a large proportion of the diet is comprised of fish (including game fish) and larger aquatic invertebrates, and the heron may forage in the areas bordering these sites. In some areas, game fish (such as large-mouth bass) can comprise one-quarter of a heron's diet (Cottam and Uhler 1945).

8.3.2 Terrestrial Species

Terrestrial Plants

Complete exposure pathways have been identified for plants, which may be exposed to chemicals at the site through direct contact with soil (Figure 4). Based on the general nature of available plant toxicity data, no specific plant species are selected for evaluation. Instead, the assessments evaluate the potential for adverse effects to terrestrial plant communities and crops.

Soil Invertebrates

Complete exposure pathways for soil invertebrates include direct contact with soil and the ingestion of soil and food (Figure 4). The site is expected to provide habitat for a range of invertebrates, including earthworms and arthropods. The earthworm was selected as the representative receptor species for soil invertebrates. Earthworms are an ideal receptor because they are in constant contact with the soil, have a significant lipid content that may accumulate chemicals, and do not have an exoskeleton; as such, they represent a precautionary estimate of exposure.

Herbivorous Wildlife

Herbivorous birds and mammals are exposed to chemical contaminants from soil and vegetative matter, chiefly during foraging. These receptors are exposed to contaminants via direct contact with soil, ingestion of food (plant tissue), and incidental ingestion of soil. All of these represent complete pathways but only the ingestion of soil and food are considered significant (Figure 4).

The white-footed mouse (*Peromyscus leucopus*) was selected as the representative receptor species to evaluate the potential for adverse effects to herbivorous mammals. The white-footed mouse is an appropriate receptor species because it is likely to occur at the site, it is a potential food source for other animals, and has a life history similar to that of many other small mammals. Also, sufficient data is available for this species to support quantitative evaluation of

food web exposures.

The song sparrow (*Melospiza melodia*) was selected as the representative receptor species to evaluate the potential for adverse effects to herbivorous birds. Song sparrows are an appropriate representative receptor because they are expected to be present at the site and have a life history similar to that of many other songbirds. Also, sufficient data is available for this species to support quantitative evaluation of food web exposures.

Insectivorous Wildlife

Insectivorous birds and mammals are exposed to chemical contaminants chiefly during foraging and feeding. These receptors are exposed to contaminants via direct contact with soil and airborne dust, ingestion of food (animal tissue), incidental ingestion of soil, and inhalation of airborne dust. All of these represent complete pathways but only the ingestion of soil and food are considered significant (Figure 4).

The American robin (*Turdus migratorius*) was selected as the representative receptor species to evaluate the potential for adverse effects to insectivorous birds. The American robin is an appropriate receptor because it occurs in a wide range of habitat types, is expected to be present at the site, feeds primarily on invertebrates, and has a life history similar to that of many other passerine birds. Also, sufficient data is available for this species to support quantitative evaluation of food web exposures.

The southern short tailed shrew (*Blarina carolinensis*) was selected as the representative receptor species to evaluate the potential for adverse effects to insectivorous mammals. The shrew is an appropriate receptor species because it is a potential food source for other animals, is likely to occur around the site, and has a life history similar to that of many other small mammals. Also, sufficient data is available for this species to support quantitative evaluation of food web exposures.

Predatory Wildlife

Predatory birds and mammals are exposed to chemical contaminants from soil, airborne particulates, and prey. These receptors are exposed to contaminants via direct contact with soil and airborne dust, ingestion of food (animal tissue), incidental ingestion of soil, and inhalation of airborne dust. All of these represent complete pathways but only ingestion of soil and food are considered significant (Figure 4). Because these organisms are commonly not herbivorous, direct and indirect exposure to contaminants in plant tissue is not a complete pathway. Consumption of fish and benthos is also not a major exposure pathway for predatory wildlife. Predatory species identified as having the greatest potential to be adversely affected are selected for detailed evaluation.

Red fox (*Vulpes vulpes*) was selected as the representative receptor for predatory mammals because it is expected to be present at the site, feeds primarily on small mammals, has a high potential for exposure due to bioaccumulation though the food chain, and is a valuable component to ecosystem structure by regulating the abundance, reproduction, distribution, and recruitment of lower trophic level prey (EPA 1999). Also, sufficient data is available for this species to support quantitative evaluation of food web exposures.

The red-tailed hawk (*Buteo jamaicensis*) was selected as the representative receptor for predatory birds because it is likely to be present at the site. The red-tailed hawk is selected as a suitable representative for a predatory bird receptor, because it feeds predominantly on small mammals (such as mice, shrews, voles, rabbits, and squirrels). Also, sufficient data is available for this species to support quantitative evaluation of food web exposures.

8.3.3 Reptiles and Amphibians

Reptiles and amphibians are exposed to chemical contaminants from surface water, sediment, soil, airborne dust, and prey. These receptors are exposed to contaminants via direct contact with and ingestion of sediment, surface water, airborne dust, and soil as well as ingestion of food (prey tissue). All of these represent complete pathways but only the ingestion of food and the ingestion of and direct contact with sediment and soil are considered significant (Figure 4). Although oral dose toxicity data are largely unavailable for these taxa, some toxicological information for amphibians and reptiles are available. Immersion and dermal absorption may also be available and are appropriate pathways for evaluation of, or in conjunction with, oral dose data particularly for amphibians. Amphibians can be assumed to be protected in the event that no amphibian toxicity data (e.g., lethal concentration [LC]50 data) for specific contaminants can be found; if it can be shown that surface water concentrations meet water quality benchmarks; and if sediment concentrations are protective of benthic invertebrates.

The American bullfrog (*Rana catesbeiana*) was selected as the representative receptor for amphibians because it is likely to be present at the site, given its home range and habitat needs. Also, there is sufficient data available to support quantitative evaluation of food web exposures. Bullfrogs are carnivorous and eat a wide variety of food items including small mammals, fish, snakes, birds, insects, and tadpoles. This amphibian is a common prey item of piscivorous wildlife.

The glossy crayfish snake (*Regina rigida*) was selected as the representative receptor for reptiles because the site is within its range and it utilizes wetlands and aquatic habitats (Willson [no date]); so, it is possible individuals would use the habitat provided by the site. Like all snakes, the glossy crayfish snake is carnivorous, but the species primarily feeds on crayfish (Willson [no date]).

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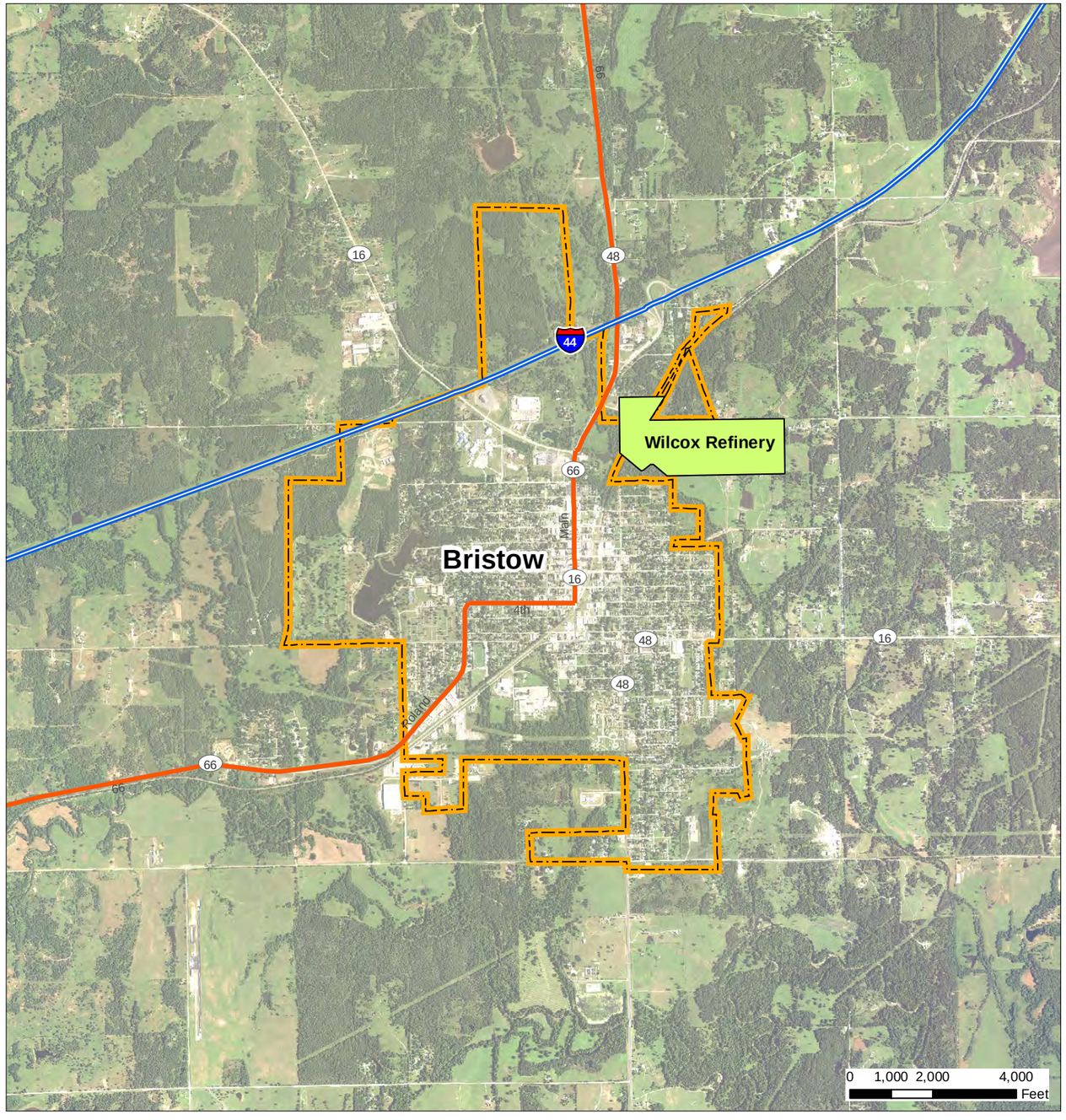
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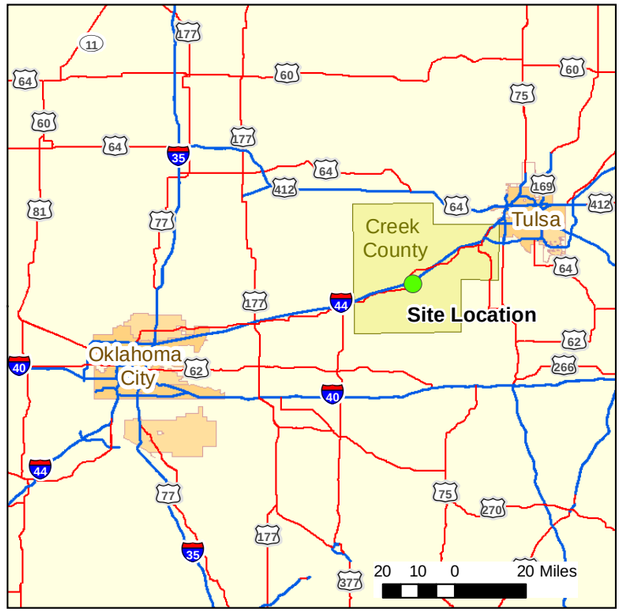
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Figures

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Legend

- Interstate
- Highway
- Bristow City Boundary

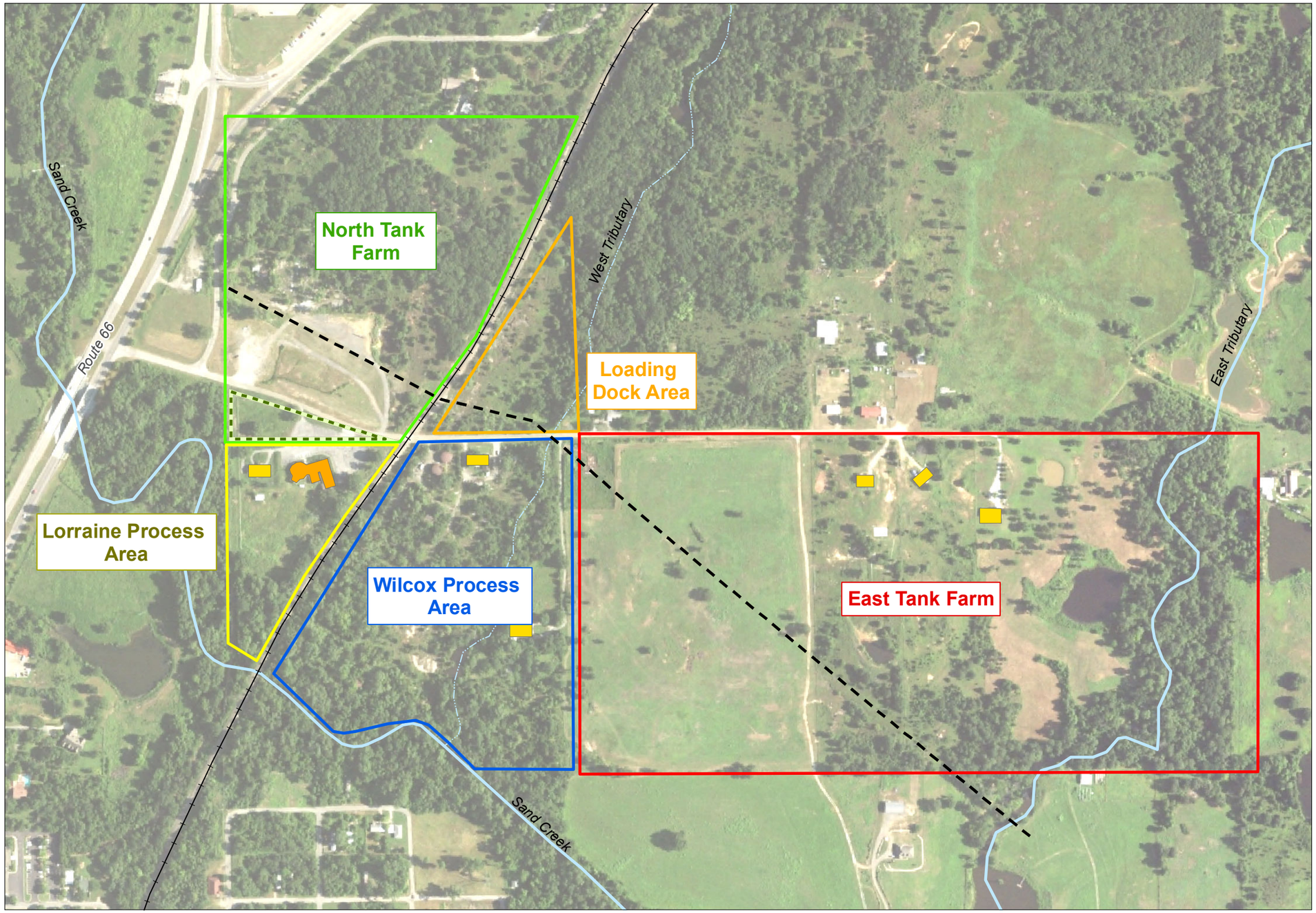
Sampling and Analysis Plan for
Remedial Investigation
for Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

Image Source: National Agriculture Imagery Program 2015

FIGURE 1
SITE LOCATION

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0 200 400 800 Feet

1 inch = 400 feet

Legend

- Stream, Intermittent
- Stream, Perennial
- Pipeline
- Railroad

On-Site Building

- Church
- Residence
- Area will be designated as part of Lorraine Process Area for this investigation.

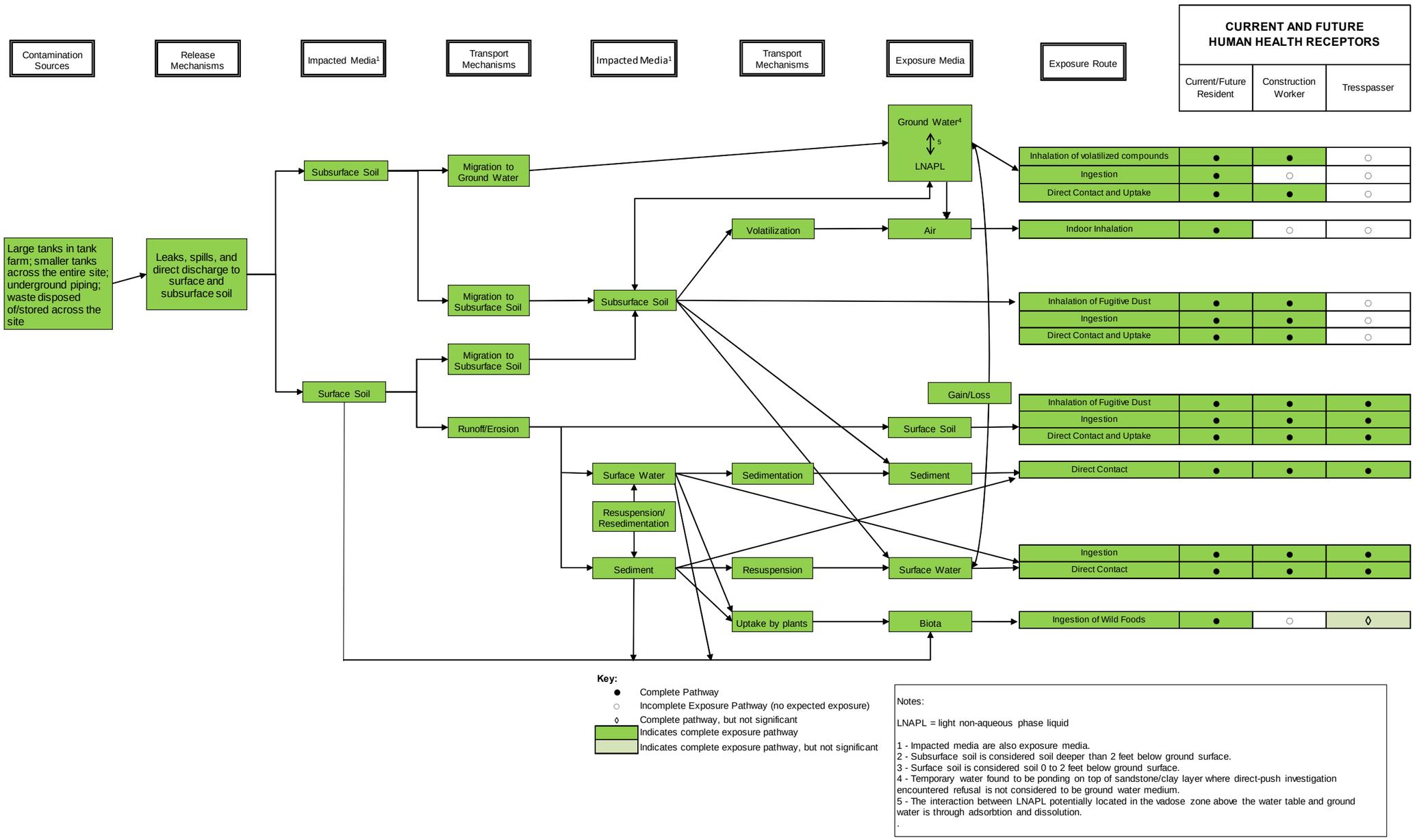
Image Source: National Agriculture Imagery Program 2015.

Sampling and Analysis Plan for
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FIGURE 2
SITE LAYOUT

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Key:

- ● Complete Pathway
- ○ Incomplete Exposure Pathway (no expected exposure)
- ◊ Complete pathway, but not significant
- Indicates complete exposure pathway
- Indicates complete exposure pathway, but not significant

Notes:

LNAPL = light non-aqueous phase liquid

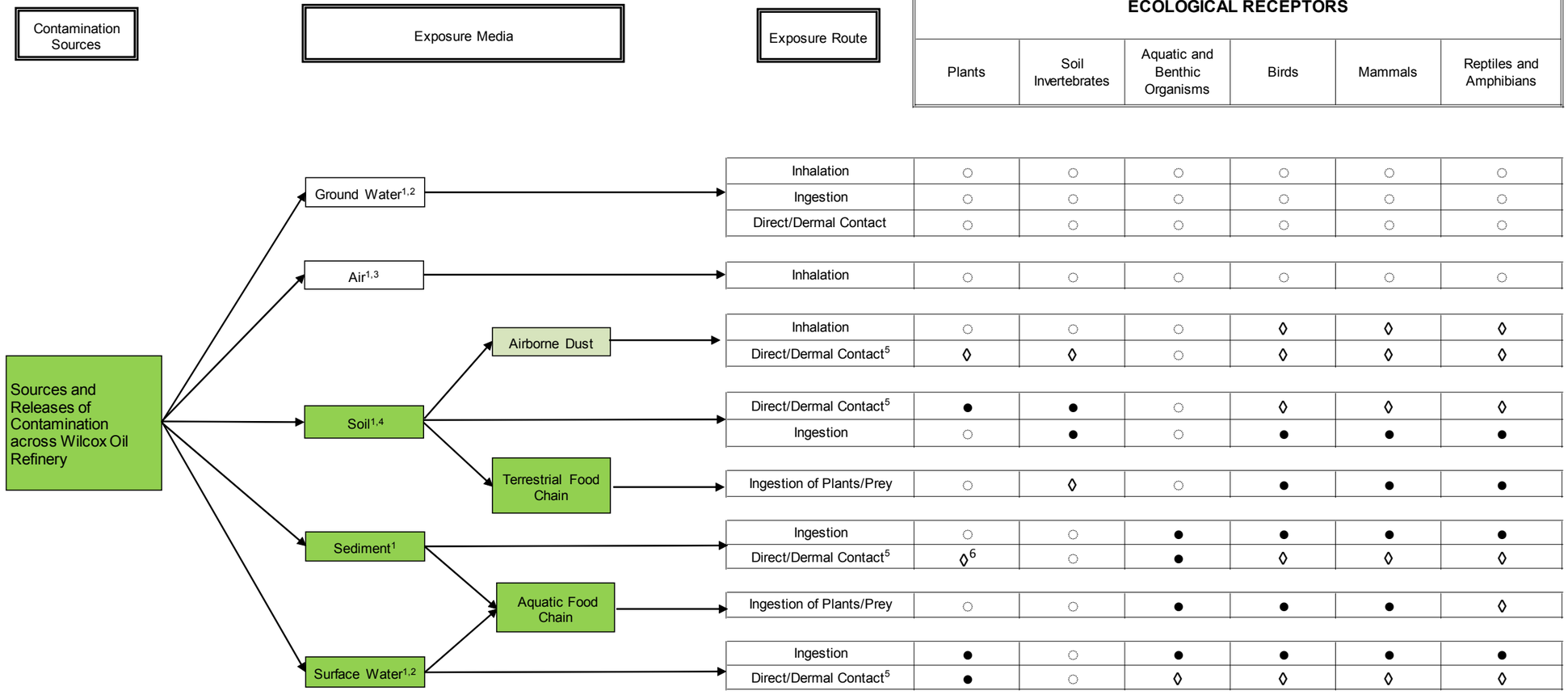
1 - Impacted media are also exposure media.
2 - Subsurface soil is considered soil deeper than 2 feet below ground surface.
3 - Surface soil is considered soil 0 to 2 feet below ground surface.
4 - Temporary water found to be ponding on top of sandstone/clay layer where direct-push investigation encountered refusal is not considered to be ground water medium.
5 - The interaction between LNAPL potentially located in the vadose zone above the water table and ground water is through adsorbtion and dissolution.
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Conceptual Site Model Technical Memorandum
Remedial Investigation
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FIGURE 3
PRELIMINARY HUMAN HEALTH CONCEPTUAL SITE MODEL

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Notes:
1 - For the release and transport mechanisms that lead to these exposure media, see the CSM for the human health receptors.
2 - The ground water and surface water interaction will be studied as part of this remedial investigation; if these two media are interacting, then daylighting ground water will be investigated as surface water.
3 - The air exposure pathway for inhalation by terrestrial critters iis complete; however, it is not quantifiable.
4 - Ecological receptors are only exposed to surface soil (<1 ft bgs).
5 - Inhalation and direct contact are identified as complete pathways for higher trophic level wildlife. However, example calculations and information provided in EPA and other exposure modeling guidance demonstrates that these pathways are insignificant compared to ingestion
6 - Rooted plants are in contact with the sediment and the exposure pathway is complete; however, this pathway is not quantifiable.

Conceptual Site Model Technical Memorandum
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FIGURE 4
PRELIMINARY ECOLOGICAL CONCEPTUAL SITE MODEL

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Appendix B

Screening Criteria and CLP/Private Laboratory Reference Limits

TABLE B-1A. SCREENING CRITERIA FOR SOIL AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Soil Screening Level: EPA Regional Screening Level (1) c/nc	Residential	Industrial	Ecological Screening Level (2): Lowest RAIS Screening Value (3)	EPA Eco-SSL Lowest Value (4)	EPA Eco-SSL Additional Value (4)	Project Screening Level (5)	CRQL (6): Low Soil by SIM	Low Soil	Medium Soil
Volatile Organic Compounds (VOCs)													
1,1,1-Trichloroethane	SOM02.3	71-55-6	mg/kg	ns	8100	36000	0.07	NS	NS	0.07	--	0.005	0.25
1,1,2-Trichloro-1,2,2-trifluoroethane	SOM02.3	76-13-1	mg/kg	ns	40000	170000	NS	NS	NS	40,000	--	0.005	0.25
1,1,2,2-Tetrachloroethane	SOM02.3	79-34-5	mg/kg	c	0.6	2.7	0.127	NS	NS	0.127	--	0.005	0.25
1,1,2-Trichloroethane	SOM02.3	79-00-5	mg/kg	n	1.1	5	0.4	NS	NS	0.4	--	0.005	0.25
1,1-Dichloroethane	SOM02.3	75-34-3	mg/kg	c	3.6	16	0.02	NS	NS	0.02	--	0.005	0.25
1,1-Dichloroethene	SOM02.3	75-35-4	mg/kg	n	230	1000	0.1	NS	NS	0.1	--	0.005	0.25
1,2,3-Trichlorobenzene	SOM02.3	87-61-6	mg/kg	n	63	930	0.01	NS	NS	0.01	--	0.005	0.25
1,2,4-Trichlorobenzene	SOM02.3	120-82-1	mg/kg	n	24	110	0.01	NS	NS	0.01	--	0.005	0.25
1,2-Dibromo-3-chloropropane	SOM02.3	96-12-8	mg/kg	c	0.0053	0.064	0.035	NS	NS	0.0053	--	0.005	0.25
1,2-Dibromoethane (EDB)	SOM02.3	106-93-4	mg/kg	c	0.036	0.16	1.23	NS	NS	0.036	--	0.005	0.25
1,2-Dichlorobenzene	SOM02.3	95-50-1	mg/kg	ns	1800	9300	0.01	NS	NS	0.01	--	0.005	0.25
1,2-Dichloroethane	SOM02.3	107-06-2	mg/kg	c*	0.46	2	0.02	NS	NS	0.02	--	0.005	0.25
1,2-Dichloropropane	SOM02.3	78-87-5	mg/kg	c*	1	4.4	0.002	NS	NS	0.002	--	0.005	0.25
1,3-Dichlorobenzene	SOM02.3	541-73-1	mg/kg	ns	1800	9300	0.03	NS	NS	0.03	--	0.005	0.25
1,4-Dichlorobenzene	SOM02.3	106-46-7	mg/kg	c	2.6	11	0.01	NS	NS	0.01	--	0.005	0.25
2-Butanone (Methyl ethyl ketone)	SOM02.3	78-93-3	mg/kg	n	27000	190000	35	NS	NS	35	--	0.01	0.5
2-Hexanone	SOM02.3	591-78-6	mg/kg	n	200	1300	12.6	NS	NS	12.6	--	0.01	0.5
4-Methyl-2-pentanone (Methyl-isobutyl ketone)	SOM02.3	108-10-1	mg/kg	ns	33000	140000	443	NS	NS	443	--	0.01	0.5
Acetone	SOM02.3	67-64-1	mg/kg	n	61000	670000	2.5	NS	NS	2.5	--	0.01	0.5
Benzene	SOM02.3	71-43-2	mg/kg	c*	1.2	5.1	0.01	NS	NS	0.01	--	0.005	0.25
Bromochloromethane	SOM02.3	74-97-5	mg/kg	n	150	630	NS	NS	NS	150	--	0.005	0.25
Bromodichloromethane	SOM02.3	75-27-4	mg/kg	c	0.29	1.3	0.54	NS	NS	0.29	--	0.005	0.25
Bromoform	SOM02.3	75-25-2	mg/kg	c*	19	86	15.9	NS	NS	15.9	--	0.005	0.25
Bromomethane	SOM02.3	74-83-9	mg/kg	n	6.8	30	0.235	NS	NS	0.235	--	0.005	0.25
Carbon Disulfide	SOM02.3	75-15-0	mg/kg	ns	770	3500	0.094	NS	NS	0.094	--	0.005	0.25
Carbon Tetrachloride	SOM02.3	56-23-5	mg/kg	c	0.65	2.9	0.4	NS	NS	0.4	--	0.005	0.25
Chlorobenzene	SOM02.3	108-90-7	mg/kg	n	280	1300	0.03	NS	NS	0.03	--	0.005	0.25
Chloroethane	SOM02.3	75-00-3	mg/kg	ns	14000	57000	NS	NS	NS	14,000	--	0.005	0.25
Chloroform	SOM02.3	67-66-3	mg/kg	c	0.32	1.4	0.001	NS	NS	0.001	--	0.005	0.25
Chloromethane	SOM02.3	74-87-3	mg/kg	n	110	460	10.4	NS	NS	10.4	--	0.005	0.25
cis-1,2-Dichloroethene	SOM02.3	156-59-2	mg/kg	n	160	2300	NS	NS	NS	160	--	0.005	0.25
cis-1,3-Dichloropropene (7)	SOM02.3	10061-01-5	mg/kg	c*	1.8	8.2	0.398	NS	NS	0.398	--	0.005	0.25
Cyclohexane	SOM02.3	110-82-7	mg/kg	ns	6500	27000	NS	NS	NS	6,500	--	0.005	0.25
Dibromochloromethane	SOM02.3	124-48-1	mg/kg	c	8.3	39	2.05	NS	NS	2.05	--	0.005	0.25
Dichlorodifluoromethane	SOM02.3	75-71-8	mg/kg	n	87	370	39.5	NS	NS	39.5	--	0.005	0.25
Ethylbenzene	SOM02.3	100-41-4	mg/kg	c	5.8	25	0.03	NS	NS	0.03	--	0.005	0.25
Isopropylbenzene (Cumene)	SOM02.3	98-82-8	mg/kg	ns	1900	9900	NS	NS	NS	1,900	--	0.005	0.25
Methyl Acetate	SOM02.3	79-20-9	mg/kg	ns	78000	1200000	NS	NS	NS	78,000	--	0.005	0.25
Methylcyclohexane	SOM02.3	108-87-2	mg/kg	ns	6500	27000	NS	NS	NS	6500	--	0.005	0.25
Methyl tert Butyl Ether	SOM02.3	1634-04-4	mg/kg	c	47	210	100	NS	NS	47	--	0.005	0.25
Methylene Chloride	SOM02.3	75-09-2	mg/kg	n	57	1000	0.4	NS	NS	0.4	--	0.005	0.25
Styrene	SOM02.3	100-42-5	mg/kg	ns	6000	35000	0.1	NS	NS	0.1	--	0.005	0.25
Tetrachloroethene	SOM02.3	127-18-4	mg/kg	n	24	100	0.002	NS	NS	0.002	--	0.005	0.25
Toluene	SOM02.3	108-88-3	mg/kg	ns	4900	47000	0.01	NS	NS	0.01	--	0.005	0.25
trans-1,2-Dichloroethene	SOM02.3	156-60-5	mg/kg	n	1600	23000	0.784	NS	NS	1	--	0.005	0.25
trans-1,3-Dichloropropene (7)	SOM02.3	10061-02-6	mg/kg	c*	1.8	8.2	0.398	NS	NS	0.398	--	0.005	0.25
Trichloroethene	SOM02.3	79-01-6	mg/kg	n	0.94	6	0.001	NS	NS	0.001	--	0.005	0.25
Trichlorofluoromethane	SOM02.3	75-69-4	mg/kg	ns	23000	350000	16.4	NS	NS	16.4	--	0.005	0.25
Vinyl Chloride	SOM02.3	75-01-4	mg/kg	c	0.059	1.7	0.01	NS	NS	0.01	--	0.005	0.25
m,p-Xylene	SOM02.3	179601-23-1	mg/kg	ns	580	2500	NS	NS	NS	580	--	0.005	0.25
o-Xylene	SOM02.3	95-47-6	mg/kg	ns	650	2800	0.1	NS	NS	0.1	--	0.005	0.25
Semivolatile Organic Compounds (SVOCs)													
1,1'-Biphenyl	SOM02.3	92-52-4	mg/kg	n	47	200	60	NS	NS	47	--	0.17	5
1,2,4,5-Tetrachlorobenzene	SOM02.3	95-94-3	mg/kg	n	23	350	0.01	NS	NS	0.01	--	0.17	5
1,4-Dioxane	SOM02.3	123-91-1	mg/kg	c	5.3	24	2.05	NS	NS	2.05	--	0.067	2
2,2'-Oxybis (1-chloropropane)	SOM02.3	108-60-1	mg/kg	ns	3100	47000	19.9	NS	NS	19.9	--	0.33	10
2,3,4,6-Tetrachlorophenol	SOM02.3	58-90-2	mg/kg	n	1900	25000	0.01	NS	NS	0.01	--	0.17	5
2,4,5-Trichlorophenol	SOM02.3	95-95-4	mg/kg	n	6300	82000	0.01	NS	NS	0.01	--	0.17	5
2,4,6-Trichlorophenol	SOM02.3	88-06-2	mg/kg	n	49	210	0.01	NS	NS	0.01	--	0.17	5
2,4-Dichlorophenol	SOM02.3	120-83-2	mg/kg	n	190	2500	0.01	NS	NS	0.01	--	0.17	5
2,4-Dimethylphenol	SOM02.3	105-67-9	mg/kg	n	1300	16000	0.01	NS	NS	0.01	--	0.17	5
2,4-Dinitrophenol	SOM02.3	51-28-5	mg/kg	n	130	1600	0.0609	NS	NS	0.0609	--	0.33	10
2,4-Dinitrotoluene	SOM02.3	121-14-2	mg/kg	c*	1.7	7.4	1.28	NS	NS	1.28	--	0.17	5
2,6-Dinitrotoluene	SOM02.3	606-20-2	mg/kg	c*	0.36	1.5	0.033	NS	NS	0.033	--	0.17	5
2-Chloronaphthalene	SOM02.3	91-58-7	mg/kg	n	4800	60000	0.012	NS	NS	0.012	--	0.17	5
2-Chlorophenol	SOM02.3	95-57-8	mg/kg	n	390	5800	0.01	NS	NS	0.01	--	0.17	5
2-Methylnaphthalene	SOM02.3	91-57-6	mg/kg	n	240	3000	3.24	29	LMW-PAH based on soil invertebrates (100 for mammalian)	3.24	0.0033	0.17	5
2-Methylphenol	SOM02.3	95-48-7	mg/kg	n	3200	41000	0.5	NS	NS	0.5	--	0.33	10
2-Nitroaniline	SOM02.3	88-74-4	mg/kg	n	630	8000	74.1	NS	NS	74.1	--	0.17	5
2-Nitrophenol	SOM02.3	88-75-5	mg/kg	c	NS	NS	1.6	NS	NS	1.6	--	0.17	5
3,3'-Dichlorobenzidine	SOM02.3	91-94-1	mg/kg	c	1.2	5.1	0.646	NS	NS	0.646	--	0.33	10
3-Nitroaniline	SOM02.3	99-09-2	mg/kg	nc	NS	NS	3.16	NS	NS	3.16	--	0.33	10
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	SOM02.3	534-52-1	mg/kg	n	5.1	66	0.144	NS	NS	0.144	--	0.33	10
4-Bromophenyl-phenylether	SOM02.3	101-55-3	mg/kg	-	NS	NS	NS	NS	NS	NS	--	0.17	5
4-Chloro-3-methylphenol	SOM02.3	59-50-7	mg/kg	n	6300	82000	7.95	NS	NS	7.95	--	0.17	5
4-Chloroaniline	SOM02.3	106-47-8	mg/kg	c*	2.7	11	0.03	NS	NS	0.03	--	0.33	10
4-Chlorophenyl-phenylether	SOM02.3	7005-72-3	mg/kg	-	NS	NS	NS	NS	NS	NS	--	0.17	5
4-Methylphenol	SOM02.3	106-44-5	mg/kg	n	6300	82000	0.05	NS	NS	0.05	--	0.33	10
4-Nitroaniline	SOM02.3	100-01-6	mg/kg	n	27	110	21.9	NS	NS	21.9	--	0.33	10
4-Nitrophenol	SOM02.3	100-02-7	mg/kg	c	NS	NS	5.12	NS	NS	5.12	--	0.33	10
Acenaphthene	SOM02.3	83-32-9	mg/kg	n	3600	45000	20	29	LMW-PAH based on soil invertebrates (100 for mammalian)	20.0	0.0033	0.17	5
Acetophenone	SOM02.3	98-86-2	mg/kg	ns	7800	120000	300	NS	NS	300	--	0.33	10
Acenaphthylene	SOM02.3	208-96-8	mg/kg	n	3600	45000	682	29	LMW-PAH based on soil invertebrates (100 for mammalian)	29.0	0.0033	0.17	5
Anthracene	SOM02.3	120-12-7	mg/kg	n	18000	230000	0.1	29	LMW-PAH based on soil invertebrates (100 for mammalian)	0.1	0.0033	0.17	5
Atrazine	SOM02.3	1912-24-9	mg/kg	c	2.4	10	0.00005	NS	NS	0.00005	--	0.33	10
Benzaldehyde	SOM02.3	100-52-7	mg/kg	ns	7800	120000	NS	NS	NS	7,800	--	0.33	10
Benzo(a)anthracene	SOM02.3	56-55-3	mg/kg	c	0.16	2.9	5.21	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.16	0.0033	0.17	5
Benzo(a)pyrene	SOM02.3	50-32-8	mg/kg	c	0.016	0.29	0.1	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.016	0.0033	0.17	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	mg/kg	c	0.16	2.9	59.8	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.16	0.0033	0.17	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	mg/kg	n	1800	23000	119	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	1.1	0.0033	0.17	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	mg/kg	c	1.6	29	148	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	1.1	0.0033	0.17	5
bis(2-Chloroethoxy)methane	SOM02.3	111-91-1	mg/kg	n	190	2500	0.302	NS	NS	0.302	--	0.17	5
bis(2-Chloroethyl)ether	SOM02.3	111-44-4	mg/kg	c	0.23	1	23.7	NS	NS	0.23	--	0.33	10
bis(2-Ethylhexyl)phthalate	SOM02.3	117-81-7	mg/kg	c*	39	160	0.1	NS	NS	0.1	--	0.17	5
Butylbenzylphthalate	SOM02.3	85-68-7	mg/kg	c*	290	1200	0.1	NS	NS	0.1	--	0.17	5
Caprolactam	SOM02.3	105-60-2	mg/kg	n	31000	400000	NS	NS	NS	31,000	--	0.33	10
Carbazole	SOM02.3	86-74-8	mg/kg	-	NS	NS	NS	NS	NS	NS	--	0.33	10
Chrysene	SOM02.3	218-01-9	mg/kg	c	16	290	4.73	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	1.1	0.0033	0.17	5
Di-n-butylphthalate	SOM02.3	84-74-2	mg/kg	n	6300	82000	0.1	NS	NS	0.1	--	0.17	5
Di-n-octylphthalate	SOM02.3	117-84-0	mg/kg	n	630	8200	0.1	NS	NS	0.1	--	0.33	10
Dibenz(a,h)anthracene	SOM02.3	53-70-3	mg/kg	c	0.016	0.29	18.4	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.016	0.0033	0.17	5
Dibenzofuran	SOM02.3	132-64-9	mg/kg	n	73	1000	NS	NS	NS	73	--	0.17	5
Diethylphthalate	SOM02.3	84-66-2	mg/kg	n	51000	660000	0.1	NS	NS	0.1	--	0.17	5
Dimethylphthalate	SOM02.3	131-11-3	mg/kg	-	NS	NS	0.1	NS	NS	0.1	--	0.17	5
Fluoranthene	SOM02.3	206-44-0	mg/kg	n	2400	30000	0.1	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.1	0.0033	0.33	10
Fluorene	SOM02.3	86-73-7	mg/kg	n	2400	30000	30	29	LMW-PAH based on soil invertebrates (100 for mammalian)	29	0.0033	0.17	5
Hexachlorobenzene	SOM02.3	118-74-1	mg/kg	c	0.21	0.96	0.0025	NS	NS	0.0025	--	0.17	5
Hexachlorobutadiene	SOM02.3	87-68-3	mg/kg	c*	1.2	5.3	0.04	NS	NS	0.04	--	0.17	5
Hexachlorocyclopentadiene	SOM02.3	77-47-4	mg/kg	n	1.8	7.5	0.755	NS	NS	0.755	--	0.33	10
Hexachloroethane	SOM02.3	67-72-1	mg/kg	c*	1.8	8	0.596	NS	NS	0.596	--	0.17	--
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	mg/kg	c	0.16	2.9	109	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.16	0.0033	0.17	5
Isophorone	SOM02.3	78-59-1	mg/kg	c*	570	2400	139	NS	NS	139	--	0.17	5
N-Nitroso-di-n-propylamine	SOM02.3	621-64-7	mg/kg	c	0.078	0.33	0.544	NS	NS	0.078	--	0.17	5
N-Nitrosodiphenylamine	SOM02.3	86-30-6	mg/kg	c	110	470	0.545	NS	NS	0.545	--	0.17	5
Naphthalene	SOM02.3	91-20-3	mg/kg	c*	3.8	17	0.099	29	LMW-PAH based on soil invertebrates (100 for mammalian)	0.099	0.0033	0.17	5
Nitrobenzene	SOM02.3	98-95-3	mg/kg	c*	5.1	22	1.31	NS	NS	1.31	--	0.17	5
Pentachlorophenol	SOM02.3	87-86-5	mg/kg	c	1	4	0.002	2.1	Based on avian receptors (2.8 for mammalian, 5.0 for plants, 31 for soil invertebrates)	0.002	0.0067	0.33	10
Phenanthrene	SOM02.3	85-01-8	mg/kg	n	1800	23000	0.1	29	LMW-PAH based on soil invertebrates (100 for mammalian)	0.1	0.0033	0.17	5
Phenol	SOM02.3	108-95-2	mg/kg	n	19000	250000	0.05	NS	NS	0.05	--	0.33	10
Pyrene	SOM02.3	129-00-0	mg/kg	n	1800	23000	0.1	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.1	0.0033	0.17	5
Polycyclic Aromatic Hydrocarbons (PAHs)													
Acenaphthene	SOM02.3	83-32-9	mg/kg	n	3600	45000	20	29	LMW-PAH based on soil invertebrates (100 for mammalian)	20	0.0033	0.17	5
Acenaphthylene	SOM02.3	208-96-8	mg/kg	n	3600	45000	682	29	LMW-PAH based on soil invertebrates (100 for mammalian)	29	0.0033	0.17	5
Anthracene	SOM02.3	120-12-7	mg/kg	n	18000	230000	0.1	29	LMW-PAH based on soil invertebrates (100 for mammalian)	0.1	0.0033	0.17	5
Benzo(a)anthracene	SOM02.3	56-55-3	mg/kg	c	0.16	2.9	5.21	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.16	0.0033	0.17	5
Benzo(a)pyrene	SOM02.3	50-32-8	mg/kg	c	0.016	0.29	0.1	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.016	0.0033	0.17	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	mg/kg	c	0.16	2.9	59.8	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.16	0.0033	0.17	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	mg/kg	n	1800	23000	119	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	1.1	0.0033	0.17	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	mg/kg	c	1.6	29	148	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	1.1	0.0033	0.17	5
Chrysene	SOM02.3	218-01-9	mg/kg	c	16	290	4.73	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	1.1	0.0033	0.17	5
Dibenz(a,h)anthracene	SOM02.3	53-70-3	mg/kg	c	0.016	0.29	18.4	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.016	0.0033	0.17	5
Fluoranthene	SOM02.3	206-44-0	mg/kg	n	2400	30000	0.1	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.1	0.0033	0.33	10
Fluorene	SOM02.3	86-73-7	mg/kg	n	2400	30000	30	29	LMW-PAH based on soil invertebrates (100 for mammalian)	29	0.0033	0.17	5
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	mg/kg	c	0.16	2.9	109	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.16	0.0033	0.17	5
Naphthalene	SOM02.3	91-20-3	mg/kg	c*	3.8	17	0.099	29	LMW-PAH based on soil invertebrates (100 for mammalian)	0.099	0.0033	0.17	5
Phenanthrene	SOM02.3	85-01-8	mg/kg	n	1800	23000	0.1	29	LMW-PAH based on soil invertebrates (100 for mammalian)	0.1	0.0033	0.17	5
Pyrene	SOM02.3	129-00-0	mg/kg	n	1800	23000	0.1	1.1	HMW-PAH based on mammalian receptors (18 for soil invertebrates)	0.1	0.0033	0.17	5
2-Methylnaphthalene	SOM02.3	91-57-6	mg/kg	n	240	3000	3.24	29	LMW-PAH based on soil invertebrates (100 for mammalian)	3.24	0.0033	0.17	5
Organochlorine Pesticides													
Aldrin	SOM02.3	309-00-2	mg/kg	c*	0.039	0.18	0.00006	NS	NS	0.00006	--	0.0017	--
Alpha BHC	SOM02.3	319-84-6	mg/kg	c	0.086	0.36	0.0025	NS	NS	0.0025	--	0.0017	--
Alpha Chlordane	SOM02.3	5103-71-9	mg/kg	c*	1.7	7.5	0.00003	NS	NS	0.00003	--	0.0017	--
Beta BHC	SOM02.3	319-85-7	mg/kg	c	0.3	1.3	0.001	NS	NS	0.001	--	0.0017	--
Delta BHC	SOM02.3	319-86-8	mg/kg	c	0.086	0.36	0.005	NS	NS	0.005	--	0.0017	--
Dieldrin	SOM02.3	60-57-1	mg/kg	c*	0.034	0.14	0.0005	0.0049	Based on mammalian receptors (0.022 for avian)	0.0005	--	0.0033	--
Endosulfan I (8)	SOM02.3	959-98-8	mg/kg	n	470	7000	0.00001	NS	NS	0.00001	--	0.0017	--
Endosulfan II (8)	SOM02.3	33213-65-9	mg/kg	n	470	7000	0.00001	NS	NS	0.00001	--	0.0033	--
Endosulfan Sulfate (8)	SOM02.3	1031-07-8	mg/kg	n	470	7000	0.036	NS	NS	0.036	--	0.0033	--
Endrin	SOM02.3	72-20-8	mg/kg	n	19	250	0.00004	NS	NS	0.00004	--	0.0033	--
Endrin Aldehyde	SOM02.3	7421-93-4	mg/kg	n	19	250	0.0105	NS	NS	0.0105	--	0.0033	--
Endrin Ketone	SOM02.3	53494-70-5	mg/kg	n	19	250	NS	NS	NS	19	--	0.0033	--
Gamma BHC - Lindane	SOM02.3	58-89-9	mg/kg	c*	0.57	2.5	0.00005	NS	NS	0.00005	--	0.0017	--
Gamma Chlordane	SOM02.3	5103-74-2	mg/kg	c*	1.7	7.5	0.00003	NS	NS	0.00003	--	0.0017	--
Heptachlor	SOM02.3	76-44-8	mg/kg	c	0.13	0.63	0.0007	NS	NS	0.0007	--	0.0017	--
Heptachlor Epoxide	SOM02.3	1024-57-3	mg/kg	c*	0.07	0.33	0.0000002	NS	NS	0.0000002	--	0.0017	--
Methoxychlor	SOM02.3	72-43-5	mg/kg	n	320	4100	0.02	NS	NS	0.02	--	0.017	--
Toxaphene	SOM02.3	8001-35-2	mg/kg	c	0.49	2.1	0.119	NS	NS	0.119	--	0.17	--
p,p-DDD	SOM02.3	72-54-8	mg/kg	c	2.3	9.6	0.01	0.021	DDT (and metabolites) value based on mammalian receptors (0.093 for	0.01	--	0.0033	--
p,p-DDE	SOM02.3	72-55-9	mg/kg	c	2	9.3	0.01	0.021	DDT (and metabolites) value based on mammalian receptors (0.093 for	0.01	--	0.0033	--
p,p-DDT	SOM02.3	50-29-3	mg/kg	c*	1.9	8.5	0.0035	0.021	DDT (and metabolites) value based on mammalian receptors (0.093 for avian)	0.0035	--	0.0033	--

TABLE B-1A. SCREENING CRITERIA FOR SOIL AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Soil Screening Level: EPA Regional Screening Level (1) c/nc	Residential	Industrial	Ecological Screening Level (2): Lowest RAIS Screening Value (3)	EPA Eco-SSL Lowest Value (4)	EPA Eco-SSL Additional Value (4)	Project Screening Level (5)	CRQL (6): Low Soil by SIM	Low Soil	Medium Soil
Polychlorinated Biphenyls (PCBs)													
Aroclor-1016	SOM02.3	12674-11-2	mg/kg	n	4.1	27	NS	NS	NS	4.1	--	0.033	--
Aroclor-1221	SOM02.3	11104-28-2	mg/kg	c	0.2	0.83	NS	NS	NS	0.2	--	0.033	--
Aroclor-1232	SOM02.3	11141-16-5	mg/kg	c	0.17	0.72	NS	NS	NS	0.17	--	0.033	--
Aroclor-1242	SOM02.3	53469-21-9	mg/kg	c	0.23	0.95	NS	NS	NS	0.23	--	0.033	--
Aroclor-1248	SOM02.3	12672-29-6	mg/kg	c	0.23	0.95	NS	NS	NS	0.23	--	0.033	--
Aroclor-1254	SOM02.3	11097-69-1	mg/kg	n	0.24	0.97	40	NS	NS	0.24	--	0.033	--
Aroclor-1260	SOM02.3	11096-82-5	mg/kg	c	0.24	0.99	NS	NS	NS	0.24	--	0.033	--
Aroclor-1262	SOM02.3	37324-23-5	mg/kg	c	0.24	0.99	NS	NS	NS	0.24	--	0.033	--
Aroclor-1268	SOM02.3	11100-14-4	mg/kg	c	0.24	0.99	NS	NS	NS	0.24	--	0.033	--
TAL Metals ICP-MS													
Antimony	ISM02.3	7440-36-0	mg/kg	n	31	470	0.14	0.27	Based on mammalian (78 for soil invertebrates)	0.14	--	1	--
Arsenic	ISM02.3	7440-38-2	mg/kg	c*R	0.68	3	5.7	18	Based on terrestrial plants (43 for avian, 46 for mammalian)	0.68	--	0.5	--
Barium	ISM02.3	7440-39-3	mg/kg	n	15000	220000	1	330	Based on soil invertebrates (2,000 for mammalian)	1	--	5	--
Beryllium	ISM02.3	7440-41-7	mg/kg	n	160	2300	1.1	21	Based on mammalian (40 for soil invertebrates)	1.1	--	0.5	--
Cadmium	ISM02.3	7440-43-9	mg/kg	n	71	980	0.0022	0.36	Based on mammalian (0.77 for avian receptors, 32 for plants, 140 for soil invertebrates)	0.0022	--	0.5	--
Chromium	ISM02.3	7440-47-3	mg/kg	nm	120000	1800000	0.4	26	Chromium III based on avian (34 for mammalian)	0.4	--	1	--
Cobalt	ISM02.3	7440-48-4	mg/kg	n	23	350	0.14	13	Based on terrestrial plants (120 for avian and 230 for mammalian)	0.14	--	0.5	--
Copper	ISM02.3	7440-50-8	mg/kg	n	3100	47000	5.4	28	Based on avian receptors (49 for mammalian, 70 for plants, and 80 for soil invertebrates)	5.4	--	1	--
Lead	ISM02.3	7439-92-1	mg/kg	L	400	800	0.054	11	Based on avian receptors (56 for mammalian, 120 for plants, and 1,700 for soil invertebrates)	0.054	--	0.5	--
Manganese	ISM02.3	7439-96-5	mg/kg	n	1800	26000	100	220	Based on terrestrial plants (450 for soil invertebrates, 4,000 for mammalian, and 4,300 for avian)	100	--	0.5	--
Nickel	ISM02.3	7440-02-0	mg/kg	n	1500	22000	14	38	Based on terrestrial plants (130 for mammalian, 210 for avian, and 280 for soil invertebrates)	14	--	0.5	--
Selenium	ISM02.3	7782-49-2	mg/kg	n	390	5800	0.028	0.52	Based on terrestrial plants (0.63 for mammalian, 1.2 for avian, and 4.1 for soil invertebrates)	0.028	--	2.5	--
Silver	ISM02.3	7440-22-4	mg/kg	n	390	5800	2	4.2	Based on avian receptors (14 for mammalian and 560 for plants)	2	--	0.5	--
Thallium	ISM02.3	7440-28-0	mg/kg	n	0.78	12	0.057	NS	NS	0.057	--	0.5	--
Vanadium	ISM02.3	7440-62-2	mg/kg	n	390	5800	1.6	7.8	Based on avian receptors (280 for mammalian)	1.6	--	2.5	--
Zinc	ISM02.3	7440-66-6	mg/kg	n	23000	350000	6.6	46	Based on avian receptors (79 for mammalian, 120 for soil invertebrates, and 160 for plants)	6.6	--	1	--
TAL Metals ICP-AES													
Aluminum	ISM02.3	7429-90-5	mg/kg	n	77000	1100000	50	NS	Not enough information to provide an Eco-SSL, instead if pH<5.5 then aluminum may be of concern	50	--	20	--
Calcium	ISM02.3	7440-70-2	mg/kg	-	NS	NS	NS	NS	NS	NS	--	500	--
Iron	ISM02.3	7439-89-6	mg/kg	n	55000	820000	200	NS	A determination of the geochemical conditions (i.e., pH and Eh at a minimum) of the environmental setting, as well as the presence of iron floc and the toxic metals, is critical to the determination of the relative importance of iron at a site.	200	--	10	--
Magnesium	ISM02.3	7439-95-4	mg/kg	-	NS	NS	NS	NS	NS	NS	--	500	--
Potassium	ISM02.3	7440-09-7	mg/kg	nc	NS	NS	NS	NS	NS	NS	--	500	--
Sodium	ISM02.3	7440-23-5	mg/kg	-	NS	NS	NS	NS	NS	NS	--	500	--
Miscellaneous													
Cyanide	ISM02.3	57-12-5	mg/kg	n	2.7	12	NS	NS	NS	2.7	--	0.5	--
2,3,7,8-TCDD (TEQ)	CLP HRSM01.2	1746-01-6	mg/kg	c	0.0000048	0.000022	NS	NS	NS	0.0000048	--	--	0.000001
Mercury	ISM02.3	7439-97-6	mg/kg	ns	11	46	0.1	NS	NS	0.1	--	0.1	--

NOTES:

1. EPA Regional Screening Levels (RSLs) for residential and industrial use scenario for hazard index = 1.0 for non-carcinogens and a 10^{-6} cancer risk level for carcinogens (May 2016).
2. Ecological screening levels for soil are only applicable to surface or shallow subsurface soil.
3. The lowest ecological risk soil screening value from the Risk Assessment Information System (RAIS) database, found at https://rais.ornl.gov/tools/eco_search.php.
4. EPA Ecological Soil Screening Levels (SSLs). http://www.epa.gov/ecotox/ecossl
5. The project screening level was selected to satisfy the EPA requirements as the (1) the residential EPA RSL and (2) the lowest ecological risk soil screening value from the RAIS. For analytes with no SSL or RSL, the project screening level will be NS (not specified).
6. Contract-required Quantitation Limits (CRQL) for U.S. Environmental Protection Agency (EPA) Contract Laboratory Program (CLP)
7. The values for cis-1,3-dichloropropene and trans-1,3-dichloropropene for the EPA RSLs reflect the value reported for 1,3-dichloropropene from their respective sources.
8. The values of endosulfan I, endosulfan II, and endosulfan sulfate for the EPA RSLs reflect the value reported for Endosulfan from their respective sources.

mg/kg = Milligram(s) per kilogram
-- = Not provided
c = Carcinogenic; nc = Non-carcinogenic
NS = Not specified
CASRN = Chemical Abstracts Service Registry Number
SIM = Selective ion monitoring
DL = Detection limit
SW = EPA SW-846 Test Methods for Evaluating Solid Waste, Third Edition
Eco-SSL = Ecological Screening Level

TABLE B-1B. SCREENING CRITERIA FOR SOIL AND PRIVATE LABORATORY REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Soil Screening Levels							Project Screening Level [6]	Achievable Laboratory Limits [7]	
				EPA Regional Screening Levels[1]			Ecological Screening Levels[2]			ODEQ Risk-based Level for TPH [5]			
				c/nc	Residential	Industrial	Lowest RAIS Screening Value [3]	EPA Eco-SSL Lowest Value [4]	EPA Eco-SSL Additional Values [4]			RL	DL
Miscellaneous													
Hexavalent chromium	SW3060/7199A	18540-29-9	mg/kg	c	0.3	6.3	NS	130	Based on mammalian (no other values)	NS	0.3	0.4	0.14

NOTES:

1. U.S. Environmental Protection Agency (EPA) Regional Screening Levels (RSLs) for residential and industrial use scenario for hazard index = 1.0 for non-carcinogens and a 10-6 cancer risk level for carcinogens (May 2016).
2. Ecological screening levels for soil are only applicable to surface or shallow subsurface soil.
3. The lowest ecological risk soil screening value from the Risk Assessment Information System (RAIS) database, found at http://rais.ornl.gov/tools/eco_search.php.
4. EPA Ecological Soil Screening Levels. http://www.epa.gov/ecotox/ecossl/.
5. Oklahoma Department of Environmental Quality (ODEQ). 2012. *Risk-Based Levels for Total Petroleum Hydrocarbons (TPH)* . Land Protection Division. October. https://www.deq.state.ok.us/lpdnew/VCPIndex.htm
6. The project screening level was selected to satisfy the requirements of the EPA as the (1) the residential EPA RSL and (2) the lowest ecological risk soil screening value from the RAIS. For analytes with no SSL or RSL, the project screening level will be NS (not specified).
7. Achievable laboratory limits are for Eurofins Lancaster Laboratories Environmental, LLC., Lancaster, Pennsylvania.

mg/kg = Milligram(s) per kilogram

c = Carcinogenic

CASRN = Chemical Abstracts Service Registry Number

DL = Detection limit

Eco-SSL = Ecological Screening Level

NS = Not specified

RL = Reporting limit

SW = EPA SW-846 Test Methods for Evaluating Solid Waste, Third Edition

TABLE B-2A. SCREENING CRITERIA FOR SEDIMENT AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Sediment Screening Levels			Project Screening Level [4]	CRQLs [5]		
				TCEQ Ecological Screening Values[1]	Protection of Benthic Invertebrates Screening Level [2]	Human Health Sediment Bioaccumulation Screening Level [3]		Low Soil by SIM	Low Soil	Medium Soil
Volatile Organic Compounds										
1,1,1-Trichloroethane	SOM02.3	71-55-6	mg/kg	4.13	0.07	NS	0.07	--	0.005	0.25
1,1,2-Trichloro-1,2,2-trifluoroethane	SOM02.3	76-13-1	mg/kg	2.78	NS	NS	3	--	0.005	0.25
1,1,2,2-Tetrachloroethane	SOM02.3	79-34-5	mg/kg	0.63	NS	NS	0.63	--	0.005	0.25
1,1,2-Trichloroethane	SOM02.3	79-00-5	mg/kg	0.98	0.4	NS	0.4	--	0.005	0.25
1,1-Dichloroethane	SOM02.3	75-34-3	mg/kg	2.32	0.02	NS	0.02	--	0.005	0.25
1,1-Dichloroethene	SOM02.3	75-35-4	mg/kg	1.87	0.1	NS	0.1	--	0.005	0.25
1,2,3-Trichlorobenzene	SOM02.3	87-61-6	mg/kg	NS	0.011	NS	0.011	--	0.005	0.25
1,2,4-Trichlorobenzene	SOM02.3	120-82-1	mg/kg	0.88	0.011	NS	0.011	--	0.005	0.25
1,2-Dibromo-3-chloropropane	SOM02.3	96-12-8	mg/kg	NS	NS	NS	NS	--	0.005	0.25
1,2-Dibromoethane (EDB)	SOM02.3	106-93-4	mg/kg	NS	NS	NS	NS	--	0.005	0.25
1,2-Dibromoethane (EDB)	SW8011	106-93-4	mg/kg	NS	NS	NS	NS	--	--	--
1,2-Dichlorobenzene	SOM02.3	95-50-1	mg/kg	0.83	0.03	NS	0.03	--	0.005	0.25
1,2-Dichloroethane	SOM02.3	107-06-2	mg/kg	4.79	0.02	NS	0.02	--	0.005	0.25
1,2-Dichloropropane	SOM02.3	78-87-5	mg/kg	2.20	0.002	NS	0.002	--	0.005	0.25
1,3-Dichlorobenzene	SOM02.3	541-73-1	mg/kg	0.19	0.03	NS	0.03	--	0.005	0.25
1,4-Dichlorobenzene	SOM02.3	106-46-7	mg/kg	0.77	0.03	NS	0.03	--	0.005	0.25
2-Butanone (Methyl ethyl ketone)	SOM02.3	78-93-3	mg/kg	25.71	35	NS	26	--	0.01	0.5
2-Hexanone	SOM02.3	591-78-6	mg/kg	4.70	NS	NS	4.7	--	0.01	0.5
4-Methyl-2-pentanone (Methyl-isobutyl ketone)	SOM02.3	108-10-1	mg/kg	19.43	NS	NS	19	--	0.01	0.5
Acetone	SOM02.3	67-64-1	mg/kg	60.03	NS	NS	60	--	0.01	0.5
Benzene	SOM02.3	71-43-2	mg/kg	0.16	0.01	NS	0.01	--	0.005	0.25
Bromochloromethane	SOM02.3	74-97-5	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Bromodichloromethane	SOM02.3	75-27-4	mg/kg	2.46	NS	NS	2.46	--	0.005	0.25
Bromoform	SOM02.3	75-25-2	mg/kg	0.22	75	NS	0.22	--	0.005	0.25
Bromomethane	SOM02.3	74-83-9	mg/kg	0.08	NS	NS	0.08	--	0.005	0.25
Carbon Disulfide	SOM02.3	75-15-0	mg/kg	0.12	NS	NS	0.12	--	0.005	0.25
Carbon Tetrachloride	SOM02.3	56-23-5	mg/kg	0.02	0.17	NS	0.02	--	0.005	0.25
Chlorobenzene	SOM02.3	108-90-7	mg/kg	0.17	0.03	NS	0.03	--	0.005	0.25
Chloroethane	SOM02.3	75-00-3	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Chloroform	SOM02.3	67-66-3	mg/kg	0.94	0.02	NS	0.02	--	0.005	0.25
Chloromethane	SOM02.3	74-87-3	mg/kg	17.80	NS	NS	18	--	0.005	0.25
cis-1,2-Dichloroethene	SOM02.3	156-59-2	mg/kg	NS	0.2	NS	0.2	--	0.005	0.25
cis-1,3-Dichloropropene	SOM02.3	10061-01-5	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Cyclohexane	SOM02.3	110-82-7	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Dibromochloromethane	SOM02.3	124-48-1	mg/kg	0.16	NS	NS	0.16	--	0.005	0.25
Dichlorodifluoromethane	SOM02.3	75-71-8	mg/kg	3.68	NS	NS	4	--	0.005	0.25
Ethylbenzene	SOM02.3	100-41-4	mg/kg	2.86	0.03	NS	0.03	--	0.005	0.25
Isopropylbenzene (Cumene)	SOM02.3	98-82-8	mg/kg	8.99	NS	NS	9	--	0.005	0.25
Methyl Acetate	SOM02.3	79-20-9	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Methylcyclohexane	SOM02.3	108-87-2	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Methyl tert Butyl Ether	SOM02.3	1634-04-4	mg/kg	NS	100	NS	100	--	0.005	0.25
Methylene Chloride	SOM02.3	75-09-2	mg/kg	7.75	0.018	NS	0.018	--	0.005	0.25
Styrene	SOM02.3	100-42-5	mg/kg	10.24	0.2	NS	0.2	--	0.005	0.25
Tetrachloroethene	SOM02.3	127-18-4	mg/kg	1.69	0.002	NS	0.002	--	0.005	0.25
Toluene	SOM02.3	108-88-3	mg/kg	2.88	0.01	NS	0.01	--	0.005	0.25
trans-1,2-Dichloroethene	SOM02.3	156-60-5	mg/kg	23.95	0.2	NS	0.2	--	0.005	0.25
trans-1,3-Dichloropropene	SOM02.3	10061-02-6	mg/kg	NS	NS	NS	NS	--	0.005	0.25
Trichloroethene	SOM02.3	79-01-6	mg/kg	0.84	0.0078	NS	0.0078	--	0.005	0.25
Trichlorofluoromethane	SOM02.3	75-69-4	mg/kg	1.69	NS	NS	1.69	--	0.005	0.25
Vinyl Chloride	SOM02.3	75-01-4	mg/kg	1.96	0.01	NS	0.01	--	0.005	0.25
m,p-Xylene	SOM02.3	179601-23-1	mg/kg	NS	0.11	NS	0.11	--	0.005	0.25
o-Xylene	SOM02.3	95-47-6	mg/kg	NS	0.089	NS	0.089	--	0.005	0.25
Semivolatile Organic Compounds										
1,1'-Biphenyl	SOM02.3	92-52-4	mg/kg	NS	NS	NS	NS	--	0.17	5
1,2,4,5-Tetrachlorobenzene	SOM02.3	95-94-3	mg/kg	NS	0.01	NS	0.01	--	0.17	5
1,4-Dioxane	SOM02.3	123-91-1	mg/kg	NS	NS	NS	NS	--	0.067	2
2,2'-Oxybis (1-chloropropane)	SOM02.3	108-60-1	mg/kg	NS	NS	NS	NS	--	0.33	10
2,3,4,6-Tetrachlorophenol	SOM02.3	58-90-2	mg/kg	NS	0.01	NS	0.01	--	0.17	5
2,4,5-Trichlorophenol	SOM02.3	95-95-4	mg/kg	NS	0.01	NS	0.01	--	0.17	5
2,4,6-Trichlorophenol	SOM02.3	88-06-2	mg/kg	NS	0.01	NS	0.01	--	0.17	5
2,4-Dichlorophenol	SOM02.3	120-83-2	mg/kg	NS	0.01	NS	0.01	--	0.17	5
2,4-Dimethylphenol	SOM02.3	105-67-9	mg/kg	NS	NS	NS	NS	--	0.17	5
2,4-Dinitrophenol	SOM02.3	51-28-5	mg/kg	NS	NS	NS	NS	--	0.33	10
2,4-Dinitrotoluene	SOM02.3	121-14-2	mg/kg	NS	NS	NS	NS	--	0.17	5
2,6-Dinitrotoluene	SOM02.3	606-20-2	mg/kg	NS	NS	NS	NS	--	0.17	5
2-Chloronaphthalene	SOM02.3	91-58-7	mg/kg	NS	0.25	NS	0.25	--	0.17	5
2-Chlorophenol	SOM02.3	95-57-8	mg/kg	NS	0.055	NS	0.055	--	0.17	5
2-Methylnaphthalene	SOM02.3	91-57-6	mg/kg	NS	NS	NS	NS	0.0033	0.17	5
2-Methylphenol	SOM02.3	95-48-7	mg/kg	NS	0.5	NS	0.5	--	0.33	10
2-Nitroaniline	SOM02.3	88-74-4	mg/kg	NS	NS	NS	NS	--	0.17	5
2-Nitrophenol	SOM02.3	88-75-5	mg/kg	NS	NS	NS	NS	--	0.17	5
3,3'-Dichlorobenzidine	SOM02.3	91-94-1	mg/kg	NS	NS	NS	NS	--	0.33	10
3-Nitroaniline	SOM02.3	99-09-2	mg/kg	NS	NS	NS	NS	--	0.33	10
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	SOM02.3	534-52-1	mg/kg	NS	NS	NS	NS	--	0.33	10
4-Bromophenyl-phenylether	SOM02.3	101-55-3	mg/kg	NS	NS	NS	NS	--	0.17	5
4-Chloro-3-methylphenol	SOM02.3	59-50-7	mg/kg	NS	NS	NS	NS	--	0.17	5
4-Chloroaniline	SOM02.3	106-47-8	mg/kg	NS	0.005	NS	0.005	--	0.33	10
4-Chlorophenyl-phenylether	SOM02.3	7005-72-3	mg/kg	NS	NS	NS	NS	--	0.17	5
4-Methylphenol	SOM02.3	106-44-5	mg/kg	NS	NS	NS	NS	--	0.33	10
4-Nitroaniline	SOM02.3	100-01-6	mg/kg	NS	NS	NS	NS	--	0.33	10
4-Nitrophenol	SOM02.3	100-02-7	mg/kg	NS	NS	NS	NS	--	0.33	10
Acenaphthene	SOM02.3	83-32-9	mg/kg	0.007	0.00671	NS	0.0067	0.0033	0.17	5
Acetophenone	SOM02.3	98-86-2	mg/kg	NS	NS	NS	NS	--	0.33	10
Acenaphthylene	SOM02.3	208-96-8	mg/kg	0.006	0.00587	NS	0.00587	0.0033	0.17	5
Anthracene	SOM02.3	120-12-7	mg/kg	0.057	0.0572	NS	0.0572	0.0033	0.17	5
Atrazine	SOM02.3	1912-24-9	mg/kg	0.000	0.0002	NS	0.0002	--	0.33	10
Benzaldehyde	SOM02.3	100-52-7	mg/kg	NS	NS	NS	NS	--	0.33	10
Benzo(a)anthracene	SOM02.3	56-55-3	mg/kg	0.108	0.0317	NS	0.0317	0.0033	0.17	5
Benzo(a)pyrene	SOM02.3	50-32-8	mg/kg	0.150	0.0319	NS	0.0319	0.0033	0.17	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	mg/kg	NS	NS	NS	NS	0.0033	0.17	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	mg/kg	NS	0.17	NS	0.17	0.0033	0.17	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	mg/kg	NS	0.0272	NS	0.0272	0.0033	0.17	5
bis(2-Chloroethoxy)methane	SOM02.3	111-91-1	mg/kg	NS	NS	NS	NS	--	0.17	5
bis(2-Chloroethyl)ether	SOM02.3	111-44-4	mg/kg	NS	NS	NS	NS	--	0.33	10
bis(2-Ethylhexyl)phthalate	SOM02.3	117-81-7	mg/kg	NS	0.1	NS	0.1	--	0.17	5
Butylbenzylphthalate	SOM02.3	85-68-7	mg/kg	NS	0.1	NS	0.1	--	0.17	5
Caprolactam	SOM02.3	105-60-2	mg/kg	NS	NS	NS	NS	--	0.33	10

TABLE B-2A. SCREENING CRITERIA FOR SEDIMENT AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Sediment Screening Levels			Project Screening Level [4]	CRQLs [5]		
				TCEQ Ecological Screening Values[1]	Protection of Benthic Invertebrates Screening Level [2]	Human Health Sediment Bioaccumulation Screening Level [3]		Low Soil by SIM	Low Soil	Medium Soil
Carbazole	SOM02.3	86-74-8	mg/kg	NS	NS	NS	NS	--	0.33	10
Chrysene	SOM02.3	218-01-9	mg/kg	0.166	0.0571	NS	0.0571	0.0033	0.17	5
Di-n-butylphthalate	SOM02.3	84-74-2	mg/kg	NS	0.11	NS	0.11	--	0.17	5
Di-n-octylphthalate	SOM02.3	117-84-0	mg/kg	NS	0.1	NS	0.1	--	0.33	10
Dibenz(a,h)anthracene	SOM02.3	53-70-3	mg/kg	0.033	0.00622	NS	0.00622	0.0033	0.17	5
Dibenzofuran	SOM02.3	132-64-9	mg/kg	NS	5.1	NS	5.1	--	0.17	5
Diethylphthalate	SOM02.3	84-66-2	mg/kg	0.630	0.53	NS	0.53	--	0.17	5
Dimethylphthalate	SOM02.3	131-11-3	mg/kg	NS	1	NS	1	--	0.17	5
Fluoranthene	SOM02.3	206-44-0	mg/kg	0.423	0.111	62	0.111	0.0033	0.33	10
Fluorene	SOM02.3	86-73-7	mg/kg	0.077	0.0774	NS	0.0774	0.0033	0.17	5
Hexachlorobenzene	SOM02.3	118-74-1	mg/kg	0.020	0.0014	0.0023	0.0014	--	0.17	5
Hexachlorobutadiene	SOM02.3	87-68-3	mg/kg	0.055	NS	NS	0.055	--	0.17	5
Hexachlorocyclopentadiene	SOM02.3	77-47-4	mg/kg	NS	NS	NS	NS	--	0.33	10
Hexachloroethane	--	67-72-1	mg/kg	0.230	NS	NS	0.23	--	0.17	--
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	mg/kg	NS	0.0173	NS	0.0173	0.0033	0.17	5
Isophorone	SOM02.3	78-59-1	mg/kg	NS	NS	NS	NS	--	0.17	5
N-Nitroso-di-n-propylamine	SOM02.3	621-64-7	mg/kg	NS	NS	NS	NS	--	0.17	5
N-Nitrosodiphenylamine	SOM02.3	86-30-6	mg/kg	NS	NS	NS	NS	--	0.17	5
Naphthalene	SOM02.3	91-20-3	mg/kg	0.176	0.176	NS	0.176	0.0033	0.17	5
Nitrobenzene	SOM02.3	98-95-3	mg/kg	0.510	NS	NS	0.51	--	0.17	5
Pentachlorophenol	SOM02.3	87-86-5	mg/kg	NS	0.01	0.03	0.01	0.0067	0.33	10
Phenanthrene	SOM02.3	85-01-8	mg/kg	0.204	0.0419	NS	0.0419	0.0033	0.17	5
Phenol	SOM02.3	108-95-2	mg/kg	NS	0.048	NS	0.048	--	0.33	10
Pyrene	SOM02.3	129-00-0	mg/kg	0.195	0.053	47	0.053	0.0033	0.17	5
Polycyclic Aromatic Hydrocarbons										
Acenaphthene	SOM02.3	83-32-9	mg/kg	0.007	0.00671	NS	0.0067	0.0033	0.17	5
Acenaphthylene	SOM02.3	208-96-8	mg/kg	0.006	0.00587	NS	0.00587	0.0033	0.17	5
Anthracene	SOM02.3	120-12-7	mg/kg	0.057	0.0572	NS	0.0572	0.0033	0.17	5
Benzo(a)anthracene	SOM02.3	56-55-3	mg/kg	0.108	0.0317	NS	0.0317	0.0033	0.17	5
Benzo(a)pyrene	SOM02.3	50-32-8	mg/kg	0.150	0.0319	NS	0.0319	0.0033	0.17	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	mg/kg	NS	NS	NS	NS	0.0033	0.17	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	mg/kg	NS	0.17	NS	0.17	0.0033	0.17	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	mg/kg	NS	0.0272	NS	0.0272	0.0033	0.17	5
Chrysene	SOM02.3	218-01-9	mg/kg	0.166	0.0571	NS	0.0571	0.0033	0.17	5
Dibenz(a,h)anthracene	SOM02.3	53-70-3	mg/kg	0.033	0.00622	NS	0.00622	0.0033	0.17	5
Fluoranthene	SOM02.3	206-44-0	mg/kg	0.423	0.111	62	0.111	0.0033	0.33	10
Fluorene	SOM02.3	86-73-7	mg/kg	0.077	0.0774	NS	0.0774	0.0033	0.17	5
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	mg/kg	NS	0.0173	NS	0.0173	0.0033	0.17	5
Naphthalene	SOM02.3	91-20-3	mg/kg	0.176	0.176	NS	0.176	0.0033	0.17	5
Phenanthrene	SOM02.3	85-01-8	mg/kg	0.204	0.0419	NS	0.0419	0.0033	0.17	5
Pyrene	SOM02.3	129-00-0	mg/kg	0.195	0.053	47	0.053	0.0033	0.17	5
2-Methylnaphthalene	SOM02.3	91-57-6	mg/kg	NS	NS	NS	NS	0.0033	0.17	5
Organochlorine Pesticides										
Aldrin	SOM02.3	309-00-2	mg/kg	0.002	0.00006	NS	0.00006	--	0.0017	--
Alpha BHC	SOM02.3	319-84-6	mg/kg	0.006	0.003	NS	0.003	--	0.0017	--
Alpha Chlordane	SOM02.3	5103-71-9	mg/kg	NS	0.00324	0.000046	0.000046	--	0.0017	--
Beta BHC	SOM02.3	319-85-7	mg/kg	0.005	0.005	NS	0.005	--	0.0017	--
Delta BHC	SOM02.3	319-86-8	mg/kg	NS	0.01	NS	0.01	--	0.0017	--
Dieldrin	SOM02.3	60-57-1	mg/kg	0.0019	0.0019	0.000001	0.000001	--	0.0033	--
Endosulfan I	SOM02.3	959-98-8	mg/kg	NS	0.00001	NS	0.00001	--	0.0017	--
Endosulfan II	SOM02.3	33213-65-9	mg/kg	NS	0.00001	NS	0.00001	--	0.0033	--
Endosulfan Sulfate	SOM02.3	1031-07-8	mg/kg	NS	NS	NS	NS	--	0.0033	--
Endrin	SOM02.3	72-20-8	mg/kg	0.00222	0.00222	NS	0.00222	--	0.0033	--
Endrin Aldehyde	SOM02.3	7421-93-4	mg/kg	NS	NS	NS	NS	--	0.0033	--
Endrin Ketone	SOM02.3	53494-70-5	mg/kg	NS	NS	NS	NS	--	0.0033	--
Gamma BHC - Lindane	SOM02.3	58-89-9	mg/kg	0.00237	0.00094	NS	0.00094	--	0.0017	--
Gamma Chlordane	SOM02.3	5103-74-2	mg/kg	NS	0.00324	0.000046	0.000046	--	0.0017	--
Heptachlor	SOM02.3	76-44-8	mg/kg	NS	0.0007	NS	0.0007	--	0.0017	--
Heptachlor Epoxide	SOM02.3	1024-57-3	mg/kg	0.00247	0.0006	NS	0.0006	--	0.0017	--
Methoxychlor	SOM02.3	72-43-5	mg/kg	NS	0.019	NS	0.019	--	0.017	--
Toxaphene	SOM02.3	8001-35-2	mg/kg	0.0001	0.0001	NS	0.0001	--	0.17	--
p,p-DDD	SOM02.3	72-54-8	mg/kg	0.00488	0.00354	0.00004	0.00004	--	0.0033	--
p,p-DDE	SOM02.3	72-55-9	mg/kg	0.00316	0.00142	0.00004	0.00004	--	0.0033	--
p,p-DDT	SOM02.3	50-29-3	mg/kg	0.00416	0.00119	0.00004	0.00004	--	0.0033	--
Polychlorinated Biphenyls										
Aroclor-1016	SOM02.3	12674-11-2	mg/kg	0.007	NS	NS	0.007	--	0.033	--
Aroclor-1221	SOM02.3	11104-28-2	mg/kg	NS	NS	NS	NS	--	0.033	--
Aroclor-1232	SOM02.3	11141-16-5	mg/kg	NS	NS	NS	NS	--	0.033	--
Aroclor-1242	SOM02.3	53469-21-9	mg/kg	NS	NS	NS	NS	--	0.033	--
Aroclor-1248	SOM02.3	12672-29-6	mg/kg	0.03	NS	NS	0.03	--	0.033	--
Aroclor-1254	SOM02.3	11097-69-1	mg/kg	NS	0.06	NS	0.06	--	0.033	--
Aroclor-1260	SOM02.3	11096-82-5	mg/kg	0.005	NS	NS	0.005	--	0.033	--
Aroclor-1262	SOM02.3	37324-23-5	mg/kg	NS	NS	NS	NS	--	0.033	--
Aroclor-1268	SOM02.3	11100-14-4	mg/kg	NS	NS	NS	NS	--	0.033	--
Total PCBs	--	1336-36-3	mg/kg	0.0598	0.0341	0.000048	0.000048	--	--	--
Nitroaromatics/ Nitroamines										
1,3,5-Trinitrobenzene	SW8330B	99-35-4	mg/kg	NS	NS	NS	NS	--	--	--
1,3-Dinitrobenzene	SW8330B	99-65-0	mg/kg	NS	NS	NS	NS	--	--	--
2,4,6-Trinitrotoluene	SW8330B	118-96-7	mg/kg	NS	NS	NS	NS	--	--	--
2,4-Dinitrotoluene	SW8330B	121-14-2	mg/kg	NS	NS	NS	NS	--	0.17	5
2,6-Dinitrotoluene	SW8330B	606-20-2	mg/kg	NS	NS	NS	NS	--	0.17	5
2-Amino-4,6-Dinitrotoluene	SW8330B	35572-78-2	mg/kg	NS	NS	NS	NS	--	--	--
2-Nitrotoluene (o-Nitrotoluene)	SW8330B	88-72-2	mg/kg	NS	NS	NS	NS	--	--	--
3,5-Dinitroaniline	SW8330B	618-87-1	mg/kg	NS	NS	NS	NS	--	--	--
3-Nitrotoluene (m-Nitrotoluene)	SW8330B	99-08-1	mg/kg	NS	NS	NS	NS	--	--	--
4-Amino-2,6-Dinitrotoluene	SW8330B	19406-51-0	mg/kg	NS	NS	NS	NS	--	--	--
4-Nitrotoluene (p-Nitrotoluene)	SW8330B	99-99-0	mg/kg	NS	NS	NS	NS	--	--	--
Octahydro-1,3,5,7-tetratnitro-1,3,5,7-tetrazocine (HI	SW8330B	2691-41-0	mg/kg	NS	NS	NS	NS	--	--	--
Nitrobenzene	SW8330B	98-95-3	mg/kg	0.51	NS	NS	0.51	--	--	--
Nitroglycerin	SW8330B	55-63-0	mg/kg	NS	NS	NS	NS	--	--	--
Pentaerythritol tetranitrate (PETN)	SW8330B	78-11-5	mg/kg	NS	NS	NS	NS	--	--	--
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	SW8330B	121-82-4	mg/kg	NS	NS	NS	NS	--	--	--
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	SW8330B	479-45-8	mg/kg	NS	NS	NS	NS	--	--	--

TABLE B-2A. SCREENING CRITERIA FOR SEDIMENT AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Sediment Screening Levels			Project Screening Level (4)	CRQLs (5)		
				TCEQ Ecological Screening Values(1)	Protection of Benthic Invertebrates Screening Level (2)	Human Health Sediment Bioaccumulation Screening Level (3)		Low Soil by SIM	Low Soil	Medium Soil
Hydrazines										
1,1-Dimethylhydrazine	SW8315A	57-14-7	mg/kg	NS	NS	NS	NS	--	--	--
Hydrazine	SW8315A	302-01-2	mg/kg	NS	NS	NS	NS	--	--	--
Methylhydrazine	SW8315A	60-34-4	mg/kg	NS	NS	NS	NS	--	--	--
TAL Metals ICP-MS										
Antimony	ISM02.3	7440-36-0	mg/kg	2	3	NS	2	--	1	--
Arsenic	ISM02.3	7440-38-2	mg/kg	9.79	5.9	7	5.9	--	0.5	--
Barium	ISM02.3	7440-39-3	mg/kg	NS	NS	NS	NS	--	5	--
Beryllium	ISM02.3	7440-41-7	mg/kg	NS	NS	NS	NS	--	0.5	--
Cadmium	ISM02.3	7440-43-9	mg/kg	0.99	0.596	1	0.596	--	0.5	--
Chromium	ISM02.3	7440-47-3	mg/kg	43.4	37.3	NS	37.3	--	1	--
Cobalt	ISM02.3	7440-48-4	mg/kg	50	50	NS	50	--	0.5	--
Copper	ISM02.3	7440-50-8	mg/kg	31.6	31.6	NS	31.6	--	1	--
Lead	ISM02.3	7439-92-1	mg/kg	35.8	35	17	17	--	0.5	--
Manganese	ISM02.3	7439-96-5	mg/kg	460	460	NS	460	--	0.5	--
Nickel	ISM02.3	7440-02-0	mg/kg	22.7	18	NS	18	--	0.5	--
Selenium	ISM02.3	7782-49-2	mg/kg	NS	NS	2	2	--	2.5	--
Silver	ISM02.3	7440-22-4	mg/kg	1	0.5	NS	0.5	--	0.5	--
Thallium	ISM02.3	7440-28-0	mg/kg	NS	NS	NS	NS	--	0.5	--
Vanadium	ISM02.3	7440-62-2	mg/kg	NS	NS	NS	NS	--	2.5	--
Zinc	ISM02.3	7440-66-6	mg/kg	121	121	NS	121	--	1	--
TAL Metals ICP-AES										
Aluminum	ISM02.3	7429-90-5	mg/kg	NS	25,500	NS	25,500	--	20	--
Calcium	ISM02.3	7440-70-2	mg/kg	NS	NS	NS	NS	--	500	--
Iron	ISM02.3	7439-89-6	mg/kg	20000	20,000	NS	20,000	--	10	--
Magnesium	ISM02.3	7439-95-4	mg/kg	NS	NS	NS	NS	--	500	--
Potassium	ISM02.3	7440-09-7	mg/kg	NS	NS	NS	NS	--	500	--
Sodium	ISM02.3	7440-23-5	mg/kg	NS	NS	NS	NS	--	500	--
Miscellaneous										
Asbestos	USEPA/600/R-93/116	1332-21-4	fibers	NS	NS	NS	NS	--	--	--
Chloride	E300.0	16887-00-6	mg/kg	NS	NS	NS	NS	--	--	--
Cyanide	ISM02.3	57-12-5	mg/kg	NS	NS	NS	NS	--	0.5	--
Mercury	ISM02.3	7439-97-6	mg/kg	0.18	0.174	0.07	0.07	--	0.1	--
Nitrate nitrogen	E300.0	14797-55-8	mg/kg	850000	NS	NS	850000	--	--	--
Nitrate-Nitrite nitrogen	E300.0	NS	mg/kg	NS	NS	NS	NS	--	--	--
Nitrite nitrogen	E300.0	14797-65-0	mg/kg	53000	NS	NS	53000	--	--	--
Perchlorate	SW6850	14797-73-0	mg/kg	180	NS	NS	180	--	--	--
pH	SW9045C	NS	S.U.	NS	NS	NS	NS	--	--	--
Sulfate	E300.0	18785-72-3	mg/kg	NS	NS	NS	NS	--	--	--
Total Phosphorous as Phosphate	E365.1	98059-61-1	mg/kg	NS	NS	NS	NS	--	--	--

NOTES:

1. Ecological Screening Values for Freshwater Sediment from TCEQ's *Draft Conducting Ecological Risk Assessments at Remediation Sites in Texas* . January 2014. https://www.tceq.texas.gov/assets/public/remediation/trrp/rg263-draft.pdf
2. Benthic protection based on the NOAA SQuIRTs values listed in Buchman (NOAA 2008), consensus-based unless not available, otherwise the lowest of listed screening values are presente
3. State of Oregon Department of Environmental Quality, *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (2007), Table A-1a. Used for chemicals bioaccumulating into fish with subsequent human ingestion. Based on subsistence/tribal ingestion rate.
4. The minimum value was selected as the project screening level
5. Contract-required Quantitation Limits (CRQL) for U.S. Environmental Protection Agency (EPA) Contract Laboratory Program (CLP)

mg/kg = Milligram(s) per kilogram
NS = Not specified
SL = Screening Level
CASRN = Chemical Abstracts Service Registry Numbe
PCLs = Protective Concentration Levels
-- = Not provided
SIM = Selective ion monitoring

TABLE B-2B. SCREENING CRITERIA FOR SEDIMENT AND PRIVATE LABORATORY REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	Sediment Screening Levels			Project Screening Level (4)	Achievable Laboratory Limits (5)	
				TCEQ Ecological Screening Values(1)	Protection of Benthic Invertebrates Screening Level (2)	Human Health Sediment Bioaccumulation Screening Level (3)		RL	DL
Miscellaneous									
AVS/SEM	EPA 821/R-91-100 SW 6010C/9034	NS	µmol/g	NS	NS	NS	NS	--	--
Hexavalent chromium	SW3060/7199A	18540-29-9	mg/kg	NS	NS	NS	NS	0.4	0.14
Grain size	ASTM D422	NS	NS	NS	NS	NS	NS	--	--
pH	SW9045C	NS	S.U.	NS	NS	NS	NS	--	--
Total organic carbon	SM 5310B	NS	mg/kg	NS	NS	NS	NS	--	--

NOTES:

1. Ecological Screening Values for Freshwater Sediment from TCEQ's Draft Conducting Ecological Risk Assessments at Remediation Sites in Texas . January 2014. https://www.tceq.texas.gov/assets/public/remediation/trrp/rg263-draft.pdf
2. Benthic protection based on the NOAA SQuIRTs values listed in Buchman (2008), consensus-based unless not available, otherwise the lowest of listed screening values are presented.
3. State of Oregon Department of Environmental Quality, *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (2007), Table A-1a. Used for chemicals bioaccumulating into fish with subsequent human ingestion.
4. The minimum value was selected as the project screening level
5. Achievable laboratory limits are for Eurofins Lancaster Laboratories Environmental, LLC., Lancaster, Pennsylvania.

mg/kg = Milligram(s) per kilogram
CASRN = Chemical Abstracts Service Registry Number
DL = Detection limit
NS = Not specified
PCLs = Protective Concentration Levels
RL = Reporting limit
SL = Screening Level
S.U. = Standard Unit
µmol/g = micromole per gram

TABLE B-3A. SCREENING CRITERIA FOR GROUND WATER AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	EPA MCL[1]	EPA Tapwater RSL [2]	OWRB Interim WQS[3] for Public & Private Water Supply (Raw Water)	Project Screening Level[4]	CRQLs[5]		
									Low Water by SIM	Trace Water	Low Water
Volatile Organic Compounds											
1,1,1-Trichloroethane	SOM02.3	71-55-6	µg/L	nc	200	8000	NS	200	--	0.50	5
1,1,2-Trichloro-1,2,2-trifluoroethane	SOM02.3	76-13-1	µg/L	-	NS	55000	NS	55000	--	0.50	5
1,1,2,2-Tetrachloroethane	SOM02.3	79-34-5	µg/L	c	NS	0.076	NS	0.076	--	0.50	5
1,1,2-Trichloroethane	SOM02.3	79-00-5	µg/L	c	5	0.28	NS	5	--	0.50	5
1,1-Dichloroethane	SOM02.3	75-34-3	µg/L	c	NS	2.8	NS	2.8	--	0.50	5
1,1-Dichloroethene	SOM02.3	75-35-4	µg/L	nc	7	280	NS	7	--	0.50	5
1,2,3-Trichlorobenzene	SOM02.3	87-61-6	µg/L	nc	NS	7	NS	7	--	0.50	5
1,2,4-Trichlorobenzene	SOM02.3	120-82-1	µg/L	c	70	1.2	NS	70	--	0.50	5
1,2-Dibromo-3-chloropropane	SOM02.3	96-12-8	µg/L	c	0.2	0.00033	NS	0.2	--	0.50	5
1,2-Dibromoethane (EDB)	SOM02.3	106-93-4	µg/L	c	0.05	0.0075	NS	0.05	--	0.50	5
1,2-Dichlorobenzene	SOM02.3	95-50-1	µg/L	nc	600	300	NS	600	--	0.50	5
1,2-Dichloroethane	SOM02.3	107-06-2	µg/L	c	5	0.17	NS	5	--	0.50	5
1,2-Dichloropropane	SOM02.3	78-87-5	µg/L	c	5	0.44	NS	5	--	0.50	5
1,3-Dichlorobenzene	SOM02.3	541-73-1	µg/L	-	600	300	NS	600	--	0.50	5
1,4-Dichlorobenzene	SOM02.3	106-46-7	µg/L	c	75	0.48	NS	75	--	0.50	5
2-Butanone (Methyl Ethyl Ketone)	SOM02.3	78-93-3	µg/L	nc	NS	5600	NS	5,600	--	5	10
2-Hexanone	SOM02.3	591-78-6	µg/L	nc	NS	38	NS	38	--	5	10
4-Methyl-2-pentanone (Methyl isobutyl ketone)	SOM02.3	108-10-1	µg/L	nc	NS	6300	NS	6,300	--	5	10
Acetone	SOM02.3	67-64-1	µg/L	nc	NS	14000	NS	14,000	--	5	10
Benzene	SOM02.3	71-43-2	µg/L	c	5	0.46	NS	5	--	0.50	5
Bromochloromethane	SOM02.3	74-97-5	µg/L	nc	NS	83	NS	83	--	0.50	5
Bromodichloromethane[6]	SOM02.3	75-27-4	µg/L	c	80	0.13	NS	80	--	0.50	5
Bromoform[6]	SOM02.3	75-25-2	µg/L	c	80	3.3	NS	80	--	0.50	5
Bromomethane	SOM02.3	74-83-9	µg/L	nc	NS	7.5	NS	7.5	--	0.50	5
Carbon Disulfide	SOM02.3	75-15-0	µg/L	nc	NS	810	NS	810	--	0.50	5
Carbon Tetrachloride	SOM02.3	56-23-5	µg/L	c	5	0.46	NS	5	--	0.50	5
Chlorobenzene	SOM02.3	108-90-7	µg/L	nc	100	78	NS	100	--	0.50	5
Chloroethane	SOM02.3	75-00-3	µg/L	nc	NS	21000	NS	21,000	--	0.50	5
Chloroform[6]	SOM02.3	67-66-3	µg/L	c	80	0.22	NS	80	--	0.50	5
Chloromethane	SOM02.3	74-87-3	µg/L	nc	NS	190	NS	190	--	0.50	5
cis-1,2-Dichloroethene	SOM02.3	156-59-2	µg/L	nc	70	36	NS	70	--	0.50	5
cis-1,3-Dichloropropene	SOM02.3	10061-01-5	µg/L	c	NS	0.47	NS	0.47	--	0.50	5
Cyclohexane	SOM02.3	110-82-7	µg/L	-	NS	13000	NS	13,000	--	0.50	5
Dibromochloromethane	SOM02.3	124-48-1	µg/L	c	80	0.87	NS	80	--	0.50	5
Dichlorodifluoromethane	SOM02.3	75-71-8	µg/L	nc	NS	200	NS	200	--	0.50	5
Ethylbenzene	SOM02.3	100-41-4	µg/L	c	700	1.5	NS	700	--	0.50	5
Isopropylbenzene (Cumene)	SOM02.3	98-82-8	µg/L	-	NS	450	NS	450	--	0.50	5
Methyl Acetate	SOM02.3	79-20-9	µg/L	-	NS	20000	NS	20,000	--	0.50	5
Methylcyclohexane	SOM02.3	108-87-2	µg/L	-	NS	13000	NS	13000	--	0.50	5
Methyl tert-Butyl Ether	SOM02.3	1634-04-4	µg/L	c	NS	14	NS	14	--	0.50	5
Methylene Chloride	SOM02.3	75-09-2	µg/L	c	5	11	NS	5	--	0.50	5
Styrene	SOM02.3	100-42-5	µg/L	nc	100	1200	NS	100	--	0.50	5
Tetrachloroethene	SOM02.3	127-18-4	µg/L	c	5	11	NS	5	--	0.50	5
Toluene	SOM02.3	108-88-3	µg/L	nc	1000	1100	NS	1,000	--	0.50	5
trans-1,2-Dichloroethene	SOM02.3	156-60-5	µg/L	nc	100	360	NS	100	--	0.50	5
trans-1,3-Dichloropropene	SOM02.3	10061-02-6	µg/L	c	NS	0.47	NS	0.47	--	0.50	5
Trichloroethene	SOM02.3	79-01-6	µg/L	c	5	0.49	NS	5	--	0.50	5
Trichlorofluoromethane	SOM02.3	75-69-4	µg/L	nc	NS	5200	NS	5,200	--	0.50	5
Vinyl Chloride	SOM02.3	75-01-4	µg/L	c	2	0.019	NS	2	--	0.50	5
m,p-Xylene	SOM02.3	179601-23-1	µg/L	nc	10000	190	NS	10,000	--	0.50	5
o-Xylene	SOM02.3	95-47-6	µg/L	nc	NS	190	NS	190	--	0.50	5
Semivolatile Organic Compounds											
1,1'-Biphenyl	SOM02.3	92-52-4	µg/L	nc	NS	0.83	NS	0.83	--	--	5
1,2,4,5-Tetrachlorobenzene	SOM02.3	95-94-3	µg/L	nc	NS	1.7	NS	1.7	--	--	5
1,4-Dioxane	SOM02.3	123-91-1	µg/L	c	NS	0.46	NS	0.46	--	--	2
2,2'-Oxybis (1-chloropropane)	SOM02.3	108-60-1	µg/L	nc	NS	710	NS	710	--	--	10
2,3,4,6-Tetrachlorophenol	SOM02.3	58-90-2	µg/L	nc	NS	240	NS	240	--	--	5
2,4,5-Trichlorophenol	SOM02.3	95-95-4	µg/L	nc	NS	1200	NS	1,200	--	--	5
2,4,6-Trichlorophenol	SOM02.3	88-06-2	µg/L	c	NS	4.1	NS	4.1	--	--	5
2,4-Dichlorophenol	SOM02.3	120-83-2	µg/L	nc	NS	46	NS	46	--	--	5
2,4-Dimethylphenol	SOM02.3	105-67-9	µg/L	nc	NS	360	NS	360	--	--	5
2,4-Dinitrophenol	SOM02.3	51-28-5	µg/L	nc	NS	39	NS	39	--	--	10
2,4-Dinitrotoluene	SOM02.3	121-14-2	µg/L	c	NS	0.24	NS	0.24	--	--	5
2,6-Dinitrotoluene	SOM02.3	606-20-2	µg/L	c	NS	0.049	NS	0.049	--	--	5
2-Chloronaphthalene	SOM02.3	91-58-7	µg/L	nc	NS	750	NS	750	--	--	5
2-Chlorophenol	SOM02.3	95-57-8	µg/L	nc	NS	91	NS	91	--	--	5
2-Methylnaphthalene	SOM02.3	91-57-6	µg/L	nc	NS	36	NS	36	0.1	--	5
2-Methylphenol	SOM02.3	95-48-7	µg/L	nc	NS	930	NS	930	--	--	10
2-Nitroaniline	SOM02.3	88-74-4	µg/L	nc	NS	190	NS	190	--	--	5
2-Nitrophenol	SOM02.3	88-75-5	µg/L	c	NS	NS	NS	NS	--	--	5
3,3'-Dichlorobenzidine	SOM02.3	91-94-1	µg/L	c	NS	0.13	NS	0.13	--	--	5
3-Methylphenol	SOM02.3	108-39-4	µg/L	nc	NS	930	NS	930	--	--	5
3-Nitroaniline	SOM02.3	99-09-2	µg/L	nc	NS	NS	NS	NS	--	--	10
4,6-Dinitro-2-methylphenol	SOM02.3	534-52-1	µg/L	nc	NS	1.5	NS	1.5	--	--	10
4-Bromophenyl-phenylether	SOM02.3	101-55-3	µg/L	-	NS	NS	NS	NS	--	--	5
4-Chloro-3-methylphenol	SOM02.3	59-50-7	µg/L	nc	NS	1400	NS	1,400	--	--	5
4-Chloroaniline	SOM02.3	106-47-8	µg/L	c	NS	0.37	NS	0.37	--	--	10
4-Chlorophenyl-phenylether	SOM02.3	7005-72-3	µg/L	-	NS	NS	NS	NS	0.1	--	5
4-Methylphenol	SOM02.3	106-44-5	µg/L	nc	NS	1900	NS	1,900	--	--	10
4-Nitroaniline	SOM02.3	100-01-6	µg/L	c	NS	3.8	NS	3.8	--	--	10
4-Nitrophenol	SOM02.3	100-02-7	µg/L	c	NS	NS	NS	NS	--	--	10
Acenaphthene	SOM02.3	83-32-9	µg/L	nc	NS	530	NS	530	0.1	--	5
Acetophenone	SOM02.3	98-86-2	µg/L	nc	NS	1900	NS	1,900	--	--	10
Acenaphthylene	SOM02.3	208-96-8	µg/L	-	NS	530	NS	530	0.1	--	5
Anthracene	SOM02.3	120-12-7	µg/L	nc	NS	1800	NS	1,800	0.1	--	5
Atrazine	SOM02.3	1912-24-9	µg/L	c	3	0.3	NS	3	--	--	10
Benzaldehyde	SOM02.3	100-52-7	µg/L	nc	NS	1900	NS	1,900	--	--	10
Benzo(a)anthracene	SOM02.3	56-55-3	µg/L	c	NS	0.012	NS	0.012	0.1	--	5
Benzo(a)pyrene	SOM02.3	50-32-8	µg/L	c	0.2	0.0034	NS	0.2	0.1	--	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	µg/L	c	NS	0.034	NS	0.034	0.1	--	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	µg/L	nc	NS	120	NS	120	0.1	--	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	µg/L	c	NS	0.34	NS	0.34	0.1	--	5
bis(2-Chloroethoxy)methane	SOM02.3	111-91-1	µg/L	nc	NS	59	NS	59	--	--	5
bis(2-Chloroethyl)ether	SOM02.3	111-44-4	µg/L	c	NS	0.014	NS	0.014	--	--	10
bis(2-Ethylhexyl)phthalate	SOM02.3	117-81-7	µg/L	c	6	5.6	NS	6	--	--	5
Butylbenzylphthalate	SOM02.3	85-68-7	µg/L	c	NS	16	150	16	--	--	5

TABLE B-3A. SCREENING CRITERIA FOR GROUND WATER AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	EPA MCL[1]	EPA Tapwater RSL [2]	OWRB Interim WQS[3] for Public & Private Water Supply (Raw Water)	Project Screening Level[4]	CRQLs[5]		
									Low Water by SIM	Trace Water	Low Water
Caprolactam	SOM02.3	105-60-2	µg/L	nc	NS	9900	NS	9,900	--	--	10
Carbazole	SOM02.3	86-74-8	µg/L	-	NS	NS	NS	NS	--	--	10
Chrysene	SOM02.3	218-01-9	µg/L	c	NS	3.4	NS	3.4	0.1	--	5
Di-n-butylphthalate	SOM02.3	84-74-2	µg/L	nc	NS	900	NS	900	--	--	5
Di-n-octylphthalate	SOM02.3	117-84-0	µg/L	nc	NS	200	NS	200	--	--	10
Dibenz(a,h)anthracene	SOM02.3	53-70-3	µg/L	c	NS	0.0034	NS	0.0034	0.1	--	5
Dibenzofuran	SOM02.3	132-64-9	µg/L	nc	NS	7.9	NS	7.9	--	--	5
Diethylphthalate	SOM02.3	84-66-2	µg/L	nc	NS	15000	NS	15,000	--	--	5
Dimethylphthalate	SOM02.3	131-11-3	µg/L	-	NS	NS	NS	NS	--	--	5
Fluoranthene	SOM02.3	206-44-0	µg/L	nc	NS	800	NS	800	0.1	--	10
Fluorene	SOM02.3	86-73-7	µg/L	nc	NS	290	NS	290	0.1	--	5
Hexachlorobenzene	SOM02.3	118-74-1	µg/L	c	1	0.0098	NS	1	--	--	5
Hexachlorobutadiene	SOM02.3	87-68-3	µg/L	c	NS	0.14	NS	0.14	--	--	5
Hexachlorocyclopentadiene	SOM02.3	77-47-4	µg/L	nc	50	0.41	NS	50	--	--	10
Hexachloroethane	SOM02.3	67-72-1	µg/L	c	NS	0.33	NS	0.33	--	--	5
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	µg/L	c	NS	0.034	NS	0.034	0.1	--	5
Isophorone	SOM02.3	78-59-1	µg/L	c	NS	78	NS	78	--	--	5
N-Nitrosodimethylamine	SOM02.3	62-75-9	µg/L	c	NS	0.00011	NS	0.00011	--	--	5
N-Nitroso-di-n-propylamine	--	621-64-7	µg/L	c	NS	0.011	NS	0.011	--	--	--
Naphthalene	SOM02.3	91-20-3	µg/L	c	NS	0.17	NS	0.17	--	--	5
Nitrobenzene	SOM02.3	98-95-3	µg/L	c	NS	0.14	NS	0.14	0.1	--	5
Pentachlorophenol	SOM02.3	87-86-5	µg/L	c	1	0.041	NS	1	0.2	--	10
Phenanthrene	SOM02.3	85-01-8	µg/L	nc	NS	120	NS	120	0.1	--	5
Phenol	SOM02.3	108-95-2	µg/L	nc	NS	5800	NS	5,800	NS	--	10
Pyrene	SOM02.3	129-00-0	µg/L	nc	NS	120	NS	120	0.1	--	5
Polycyclic Aromatic Hydrocarbons											
Acenaphthene	SOM02.3	83-32-9	µg/L	nc	NS	530	NS	530	0.1	--	5
Acenaphthylene	SOM02.3	208-96-8	µg/L	-	NS	530	NS	530.00	0.1	--	5
Anthracene	SOM02.3	120-12-7	µg/L	nc	NS	1800	NS	1,800	0.1	--	5
Benzo(a)anthracene	SOM02.3	56-55-3	µg/L	c	NS	0.012	NS	0.012	0.1	--	5
Benzo(a)pyrene	SOM02.3	50-32-8	µg/L	c	0.2	0.0034	NS	0.2	0.1	--	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	µg/L	c	NS	0.034	NS	0.034	0.1	--	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	µg/L	nc	NS	120	NS	120.00	0.1	--	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	µg/L	c	NS	0.34	NS	0.34	0.1	--	5
Chrysene	SOM02.3	218-01-9	µg/L	c	NS	3.4	NS	3.4	0.1	--	5
Dibenz(a,h)anthracene	SOM02.3	53-70-3	µg/L	c	NS	0.0034	NS	0.0034	0.1	--	5
Fluoranthene	SOM02.3	206-44-0	µg/L	nc	NS	800	NS	800	0.1	--	10
Fluorene	SOM02.3	86-73-7	µg/L	nc	NS	290	NS	290	0.1	--	5
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	µg/L	c	NS	0.034	NS	0.034	0.1	--	5
Naphthalene	SOM02.3	91-20-3	µg/L	c	NS	0.17	NS	0.17	0.1	--	5
Phenanthrene	SOM02.3	85-01-8	µg/L	nc	NS	120	NS	120.00	0.1	--	5
Pyrene	SOM02.3	129-00-0	µg/L	nc	NS	120	NS	120	0.1	--	5
2-Methylnaphthalene	SOM02.3	91-57-6	µg/L	nc	NS	36	NS	36	0.1	--	5
Organochlorine Pesticides											
Aldrin	SOM02.3	309-00-2	µg/L	c	NS	0.00092	NS	0.00092	--	--	0.05
Alpha BHC (Hexachlorocyclohexane)	SOM02.3	319-84-6	µg/L	c	NS	0.0072	NS	0.0072	--	--	0.05
Alpha Chlordane	SOM02.3	5103-71-9	µg/L	c	2	0.045	NS	2	--	--	0.05
Beta BHC	SOM02.3	319-85-7	µg/L	c	NS	0.025	NS	0.025	--	--	0.05
Delta BHC	SOM02.3	319-86-8	µg/L	c	NS	0.0072	NS	0.0072	--	--	0.05
Dieldrin	SOM02.3	60-57-1	µg/L	c	NS	0.0018	NS	0.0018	--	--	0.1
Endosulfan I	SOM02.3	959-98-8	µg/L	nc	NS	100	NS	100	--	--	0.05
Endosulfan II	SOM02.3	33213-65-9	µg/L	nc	NS	100	NS	100	--	--	0.1
Endosulfan Sulfate	SOM02.3	1031-07-8	µg/L	nc	NS	100	NS	100	--	--	0.1
Endrin	SOM02.3	72-20-8	µg/L	nc	2	2.3	0.2	2	--	--	0.1
Endrin Aldehyde	SOM02.3	7421-93-4	µg/L	nc	2	2.3	NS	2	--	--	0.1
Endrin Ketone	SOM02.3	53494-70-5	µg/L	nc	2	2.3	NS	2	--	--	0.1
Gamma BHC (Lindane)	SOM02.3	58-89-9	µg/L	c	0.2	0.042	4	0.2	--	--	0.05
Gamma Chlordane	SOM02.3	5103-74-2	µg/L	c	2	0.045	NS	2	--	--	0.05
Heptachlor	SOM02.3	76-44-8	µg/L	c	0.4	0.0014	NS	0.4	--	--	0.05
Heptachlor Epoxide	SOM02.3	1024-57-3	µg/L	c	0.2	0.0014	NS	0.2	--	--	0.05
Methoxychlor	SOM02.3	72-43-5	µg/L	nc	40	37	100	40	--	--	0.5
Toxaphene	SOM02.3	8001-35-2	µg/L	c	3	0.071	5	3	--	--	5
p,p-DDD	SOM02.3	72-54-8	µg/L	c	NS	0.032	NS	0.032	--	--	0.1
p,p-DDE	SOM02.3	72-55-9	µg/L	c	NS	0.046	NS	0.046	--	--	0.1
p,p-DDT	SOM02.3	50-29-3	µg/L	c	NS	0.23	NS	0.23	--	--	0.1
Polychlorinated Biphenyls											
Aroclor-1016	SOM02.3	12674-11-2	µg/L	c	NS	0.22	NS	0.22	--	--	1
Aroclor-1221	SOM02.3	11104-28-2	µg/L	c	NS	0.0047	NS	0.0047	--	--	1
Aroclor-1232	SOM02.3	11141-16-5	µg/L	c	NS	0.0047	NS	0.0047	--	--	1
Aroclor-1242	SOM02.3	53469-21-9	µg/L	c	NS	0.0078	NS	0.0078	--	--	1
Aroclor-1248	SOM02.3	12672-29-6	µg/L	c	NS	0.0078	NS	0.0078	--	--	1
Aroclor-1254	SOM02.3	11097-69-1	µg/L	c	NS	0.0078	NS	0.0078	--	--	1
Aroclor-1260	SOM02.3	11096-82-5	µg/L	c	NS	0.0078	NS	0.0078	--	--	1
Aroclor-1262	SOM02.3	37324-23-5	µg/L	-	NS	0.0078	NS	0.0078	--	--	1
Aroclor-1268	SOM02.3	11100-14-4	µg/L	-	NS	0.0078	NS	0.0078	--	--	1
Total PCBs	--	1336-36-3	µg/L	c	NS	NS	NS	NS	--	--	--
Nitroaromatic/Nitramine Explosive Compounds											
1,3,5-Trinitrobenzene	SW8330B	99-35-4	µg/L	nc	NS	590	NS	590			
1,3-Dinitrobenzene	SW8330B	99-65-0	µg/L	nc	NS	2	NS	2			
2,4,6-Trinitrotoluene	SW8330B	118-96-7	µg/L	c	NS	2.5	NS	2.5			
2,4-Dinitrotoluene	SW8330B	121-14-2	µg/L	c	NS	0.24	NS	0.24			
2,6-Dinitrotoluene	SW8330B	606-20-2	µg/L	c	NS	0.049	NS	0.049			
2-Amino-4,6-Dinitrotoluene	SW8330B	35572-78-2	µg/L	nc	NS	39	NS	39			
2-Nitrotoluene	SW8330B	88-72-2	µg/L	c	NS	0.31	NS	0.31			
3,5-Dinitroaniline	SW8330B	618-87-1	µg/L	-	NS	NS	NS	NS			
3-Nitrotoluene	SW8330B	99-08-1	µg/L	nc	NS	1.7	NS	1.7			
4-Amino-2,6-Dinitrotoluene	SW8330B	19406-51-0	µg/L	nc	NS	39	NS	39			
4-Nitrotoluene	SW8330B	99-99-0	µg/L	c	NS	4.3	NS	4.3			
HMX	SW8330B	2691-41-0	µg/L	nc	NS	1000	NS	1000			
Nitrobenzene	SW8330B	98-95-3	µg/L	c	NS	0.14	NS	0.14			
Nitroglycerin	SW8330B	55-63-0	µg/L	nc	NS	2	NS	2			
PETN	SW8330B	78-11-5	µg/L	c	NS	19	NS	19			
RDX	SW8330B	121-82-4	µg/L	c	NS	0.7	NS	0.7			
Tetryl	SW8330B	479-45-8	µg/L	nc	NS	39	NS	39			

TABLE B-3A. SCREENING CRITERIA FOR GROUND WATER AND CLP REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	EPA MCL[1]	EPA Tapwater RSL [2]	OWRB Interim WQS[3] for Public & Private Water Supply (Raw Water)	Project Screening Level[4]	CRQLs[5]		
									Low Water by SIM	Trace Water	Low Water
Hydrazines											
1,1-Dimethylhydrazine	SW8315A	57-14-7	µg/L	nc	NS	0.0042	NS	0.0042			
Hydrazine	SW8315A	302-01-2	µg/L	c	NS	0.0011	NS	0.0011			
Methylhydrazine	SW8315A	60-34-4	µg/L	c	NS	0.0056	NS	0.0056			
ICP-MS Metals[7]											
Aluminum	ISM02.3	7429-90-5	µg/L	nc	NS	20000	NS	20000	--	--	20
Antimony	ISM02.3	7440-36-0	µg/L	nc	6	7.8	NS	6	--	--	2
Arsenic	ISM02.3	7440-38-2	µg/L	c	10	0.052	40	10	--	--	1
Barium	ISM02.3	7440-39-3	µg/L	nc	2000	3800	1,000	2,000	--	--	10
Beryllium	ISM02.3	7440-41-7	µg/L	nc	4	25	NS	4	--	--	1
Cadmium	ISM02.3	7440-43-9	µg/L	nc	NS	NS	20	20	--	--	1
Calcium	ISM02.3	7440-70-2	µg/L	-	NS	NS	NS	NS	--	--	500
Chromium[8]	ISM02.3	7440-47-3	µg/L	nc	100	22000	50	100	--	--	2
Cobalt	ISM02.3	7440-48-4	µg/L	nc	NS	6	NS	6	--	--	1
Copper	ISM02.3	7440-50-8	µg/L	nc	1300	800	1,000	1,300	--	--	2
Iron	ISM02.3	7439-89-6	µg/L	nc	NS	14000	NS	14,000	--	--	200
Lead	ISM02.3	7439-92-1	µg/L	-	15	15	100	15	--	--	1
Magnesium	ISM02.3	7439-95-4	µg/L	-	NS	NS	NS	NS	--	--	500
Manganese	ISM02.3	7439-96-5	µg/L	nc	NS	430	NS	430	--	--	1
Nickel	ISM02.3	7440-02-0	µg/L	nc	NS	390	NS	390	--	--	1
Potassium	ISM02.3	7440-09-7	µg/L	-	NS	NS	NS	NS	--	--	500
Selenium	ISM02.3	7782-49-2	µg/L	nc	50	100	10	50	--	--	5
Silver	ISM02.3	7440-22-4	µg/L	nc	NS	94	50	50	--	--	1
Sodium	ISM02.3	7440-23-5	µg/L	-	NS	NS	50	50	--	--	500
Thallium	ISM02.3	7440-28-0	µg/L	nc	2	0.2	NS	2	--	--	1
Vanadium	ISM02.3	7440-62-2	µg/L	nc	NS	86	NS	86	--	--	5
Zinc	ISM02.3	7440-66-6	µg/L	nc	NS	6000	5,000	5,000	--	--	2
ICP-AES Metals[7]											
Aluminum	ISM02.3	7429-90-5	µg/L	nc	NS	20000	NS	20,000	--	--	200
Antimony	ISM02.3	7440-36-0	µg/L	nc	6	7.8	NS	6	--	--	60
Arsenic	ISM02.3	7440-38-2	µg/L	c	10	0.052	40	10	--	--	10
Barium	ISM02.3	7440-39-3	µg/L	nc	2000	3800	1,000	2,000	--	--	200
Beryllium	ISM02.3	7440-41-7	µg/L	nc	4	25	NS	4	--	--	5
Boron	--	7440-42-8	µg/L	nc	NS	4000	NS	4,000	--	--	--
Cadmium	ISM02.3	7440-43-9	µg/L	nc	NS	NS	20	20	--	--	5
Calcium	ISM02.3	7440-70-2	µg/L	-	NS	NS	NS	NS	--	--	5,000
Chromium[8]	ISM02.3	7440-47-3	µg/L	nc	100	22000	50	100	--	--	10
Cobalt	ISM02.3	7440-48-4	µg/L	nc	NS	6	NS	6	--	--	50
Copper	ISM02.3	7440-50-8	µg/L	nc	1300	800	1000	1300	--	--	25
Iron	ISM02.3	7439-89-6	µg/L	nc	NS	14000	NS	14,000	--	--	100
Lead	ISM02.3	7439-92-1	µg/L	-	15	15	100	15	--	--	10
Magnesium	ISM02.3	7439-95-4	µg/L	-	NS	NS	NS	NS	--	--	5,000
Manganese	ISM02.3	7439-96-5	µg/L	nc	NS	430	NS	430	--	--	15
Nickel	ISM02.3	7440-02-0	µg/L	nc	NS	390	NS	390	--	--	40
Potassium	ISM02.3	7440-09-7	µg/L	-	NS	NS	NS	NS	--	--	5,000
Selenium	ISM02.3	7782-49-2	µg/L	nc	50	100	10	50	--	--	35
Silicon	ISM02.3	7440-21-3	µg/L	-	NS	NS	NS	NS	--	--	NS
Silver	ISM02.3	7440-22-4	µg/L	nc	NS	94	50	50	--	--	10
Sodium	ISM02.3	7440-23-5	µg/L	-	NS	NS	NS	NS	--	--	5,000
Thallium	ISM02.3	7440-28-0	µg/L	nc	2	0.2	NS	2	--	--	25
Vanadium	ISM02.3	7440-62-2	µg/L	nc	NS	86	NS	86	--	--	50
Zinc	ISM02.3	7440-66-6	µg/L	nc	NS	6000	5,000	5,000	--	--	60
Miscellaneous											
Cyanide	ISM02.3	57-12-5	µg/L	nc	200	1.5	200	200	--	--	10
Hexavalent Chromium (EPA Region 6 Lab)	EPA 218.6	18540-29-9	µg/L	c	NS	0.035	NS	0.035	--	--	--
Mercury	ISM02.3	7439-97-6	µg/L	nc	2	0.63	2	2	--	--	0.2

NOTES:

1. U.S. Environmental Protection Agency (EPA) National Primary Drinking Water Regulations, Maximum Contaminant Levels (MCLs), May 2009.
2. EPA Region 6 Regional Screening Levels (RSLs) for Tapwater (May 2016) for hazard index = 1.0 for non-carcinogens and a 10-6 cancer risk level for carcinogens.
3. Oklahoma Water Resources Board (OWRB) Interim Water Quality Standards (WQSs) (https://www.owrb.ok.gov/quality/standards/standards.php) (OWRB 2013)
4. The project screening level was selected to satisfy EPA requirements. The EPA MCL will be used; if no EPA MCL standard exists for an analyte, then the project screening level is the lower of the EPA Tapwater RSL or OWRB Interim WQS, if achievable.
5. Contract-required Quantitation Limits (CRQLs) for EPA Contract Laboratory Program (CLP)
6. EPA RSL for tapwater is for total trihalomethanes.
7. EPA MCL and tapwater RSL apply to total metals.

µg/L = Microgram(s) per liter
mg/L = Milligram(s) per liter
-- = Not provided
c = Carcinogenic; nc = Non-carcinogenic
CASRN = Chemical Abstracts Service Registry Number
DL = Detection limit
ICP-AES = Inductively-coupled plasma and atomic emission spectroscopy
ICPMS = Inductively-coupled plasma and mass spectrometry
NS = Not specified
PCB = Polychlorinated biphenyl
SIM = Selective ion monitoring
S.U. = Standard Unit
TPH = Total petroleum hydrocarbon

TABLE B-3B. SCREENING CRITERIA FOR GROUND WATER AND PRIVATE LABORATORY REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	EPA MCL (1)	EPA Tapwater RSL (2)	OWRB Interim WQS (3)	Project Screening Level (4)	Achievable Laboratory Limits (5)	
									RL	DL
Miscellaneous										
Hexavalent Chromium	SW7199	18540-29-9	mg/L	c	NS	0.000035	NS	0.000035	0.01	0.005

NOTES:

1. U.S. Environmental Protection Agency (EPA) National Primary Drinking Water Regulations, Maximum Contaminant Levels (MCLs), May 2009.

2. EPA Region 6 Regional Screening Levels (RSLs) for Tapwater (November 2015) for hazard index = 1.0 for non-carcinogens and a 10-6 cancer risk level for carcinogens.

3. Oklahoma Water Resources Board (OWRB) Interim Water Quality Standards (WQSs) (https://www.owrb.ok.gov/quality/standards/standards.php) (OWRB 2013)

4. The project screening level was selected to satisfy the requirements of the EPA. The EPA MCL will be used; if no EPA MCL standard exists for any analyte, then the project screening level is lower of the EPA Tapwater RSL or OWRB Interim WQS, if achievable.

5. Achievable laboratory limits are for Eurofins Lancaster Laboratories Environmental, LLC.

µg/L = Microgram(s) per liter
mg/L = Milligram(s) per liter
c = Carcinogenic; nc = Non-carcinogenic
CASRN = Chemical Abstracts Service Registry Number
DL = Detection limit
ICP-AES = Inductively-coupled plasma and atomic emission spectroscopy
ICP-MS = Inductively-coupled plasma and mass spectrometry
-- = Not provided
NS = Not specified
PCB = Polychlorinated biphenyl
RL = Reporting limit
SIM = Selective ion monitoring
S.U. = Standard Unit

TABLE B-4A. SCREENING CRITERIA FOR SURFACE WATER AND CONTRACT LABORATORY PROGRAM REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	National Recommended Water Quality Criteria [1]			OWRB Interim Water Quality Standards [2]				Project Screening Level [3]	CRQLs [4]		
					Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Human Health for Consumption Organism Only	Fish & Wildlife Propagation Acute	Fish & Wildlife Propagation Chronic	Fish Consumption (+ Other Organisms) & Water	Fish Consumption (+ Other Organisms)		Low Water by SIM	Trace Water	Low Water
Volatile Organic Compounds															
1,1,1-Trichloroethane	SOM02.3	71-55-6	µg/L	nc	NS	NS	200	NS	NS	3094	173100	200	--	0.50	5
1,1,2-Trichloro-1,2,2-trifluoroethane	SOM02.3	76-13-1	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
1,1,2,2-Tetrachloroethane	SOM02.3	79-34-5	µg/L	c	NS	NS	0.17	NS	NS	NS	NS	0.17	--	0.50	5
1,1,2-Trichloroethane	SOM02.3	79-00-5	µg/L	c	NS	NS	0.59	NS	NS	NS	NS	0.59	--	0.50	5
1,1-Dichloroethane	SOM02.3	75-34-3	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
1,1-Dichloroethene	SOM02.3	75-35-4	µg/L	nc	NS	NS	330	NS	NS	NS	NS	330	--	0.50	5
1,2,3-Trichlorobenzene	SOM02.3	87-61-6	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
1,2,4-Trichlorobenzene	SOM02.3	120-82-1	µg/L	c	NS	NS	35	NS	NS	NS	NS	35	--	0.50	5
1,2-Dibromo-3-chloropropane	SOM02.3	96-12-8	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
1,2-Dibromoethane (EDB)	SOM02.3	106-93-4	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
1,2-Dichlorobenzene	SOM02.3	95-50-1	µg/L	nc	NS	NS	420	NS	NS	NS	NS	420	--	0.50	5
1,2-Dichloroethane	SOM02.3	107-06-2	µg/L	c	NS	NS	0.38	NS	NS	NS	NS	0.38	--	0.50	5
1,2-Dichloropropane	SOM02.3	78-87-5	µg/L	c	NS	NS	0.5	NS	NS	NS	NS	0.5	--	0.50	5
1,3-Dichlorobenzene	SOM02.3	541-73-1	µg/L	-	NS	NS	320	NS	NS	NS	NS	320	--	0.50	5
1,4-Dichlorobenzene	SOM02.3	106-46-7	µg/L	c	NS	NS	63	NS	NS	NS	NS	63	--	0.50	5
2-Butanone (Methyl Ethyl Ketone)	SOM02.3	78-93-3	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	5	10
2-Hexanone	SOM02.3	591-78-6	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	5	10
4-Methyl-2-pentanone (Methyl isobutyl ketone)	SOM02.3	108-10-1	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	5	10
Acetone	SOM02.3	67-64-1	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	5	10
Benzene	SOM02.3	71-43-2	µg/L	c	NS	NS	2.2	NS	2,200	22	510	2.2	--	0.50	5
Bromochloromethane	SOM02.3	74-97-5	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Bromodichloromethane	SOM02.3	75-27-4	µg/L	c	NS	NS	0.55	NS	NS	5.5	170	0.55	--	0.50	5
Bromoform	SOM02.3	75-25-2	µg/L	c	NS	NS	4.3	NS	NS	NS	NS	4.3	--	0.50	5
Bromomethane	SOM02.3	74-83-9	µg/L	nc	NS	NS	47	NS	NS	NS	NS	47	--	0.50	5
Carbon Disulfide	SOM02.3	75-15-0	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Carbon Tetrachloride	SOM02.3	56-23-5	µg/L	c	NS	NS	0.23	NS	NS	2.3	16	0.23	--	0.50	5
Chlorobenzene	SOM02.3	108-90-7	µg/L	nc	NS	NS	100	NS	NS	NS	NS	100	--	0.50	5
Chloroethane	SOM02.3	75-00-3	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Chloroform	SOM02.3	67-66-3	µg/L	c	NS	NS	5.7	NS	NS	56.69	4,708	5.7	--	0.50	5
Chloromethane	SOM02.3	74-87-3	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
cis-1,2-Dichloroethene	SOM02.3	156-59-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
cis-1,3-Dichloropropene	SOM02.3	10061-01-5	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Cyclohexane	SOM02.3	110-82-7	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Dibromochloromethane	SOM02.3	124-48-1	µg/L	c	NS	NS	0.4	NS	NS	NS	NS	0.4	--	0.50	5
Dichlorodifluoromethane	SOM02.3	75-71-8	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Ethylbenzene	SOM02.3	100-41-4	µg/L	c	NS	NS	530	NS	NS	530	2,100	530	--	0.50	5
Isopropylbenzene (Cumene)	SOM02.3	98-82-8	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Methyl Acetate	SOM02.3	79-20-9	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Methylcyclohexane	SOM02.3	108-87-2	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Methyl tert-Butyl Ether	SOM02.3	1634-04-4	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Methylene Chloride	SOM02.3	75-09-2	µg/L	c	NS	NS	4.6	NS	NS	NS	NS	4.6	--	0.50	5
Styrene	SOM02.3	100-42-5	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Tetrachloroethene	SOM02.3	127-18-4	µg/L	c	NS	NS	0.69	5,280	NS	6.9	33	0.69	--	0.50	5
Toluene	SOM02.3	108-88-3	µg/L	nc	NS	NS	1000	NS	875	1,300	15,000	875	--	0.50	5
trans-1,2-Dichloroethene	SOM02.3	156-60-5	µg/L	nc	NS	NS	100	NS	NS	NS	NS	100	--	0.50	5
trans-1,3-Dichloropropene	SOM02.3	10061-02-6	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Trichloroethene	SOM02.3	79-01-6	µg/L	c	NS	NS	2.5	NS	NS	3,094	173,100	3	--	0.50	5
Trichlorofluoromethane	SOM02.3	75-69-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Vinyl Chloride	SOM02.3	75-01-4	µg/L	c	NS	NS	0.025	NS	NS	NS	NS	0.025	--	0.50	5
m,p-Xylene	SOM02.3	179601-23-1	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
o-Xylene	SOM02.3	95-47-6	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	0.50	5
Semivolatile Organic Compound															
1,1'-Biphenyl	SOM02.3	92-52-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
1,2,4,5-Tetrachlorobenzene	SOM02.3	95-94-3	µg/L	nc	NS	NS	0.97	NS	NS	NS	NS	0.97	--	--	5
1,4-Dioxane	SOM02.3	123-91-1	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	2
2,2'-Oxybis (1-chloropropane)	SOM02.3	108-60-1	µg/L	nc	NS	NS	1400	NS	NS	NS	NS	1400	--	--	10
2,3,4,6-Tetrachlorophenol	SOM02.3	58-90-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
2,4,5-Trichlorophenol	SOM02.3	95-95-4	µg/L	nc	NS	NS	1800	NS	NS	NS	NS	1800	--	--	5
2,4,6-Trichlorophenol	SOM02.3	88-06-2	µg/L	c	NS	NS	1.4	NS	NS	NS	NS	1.4	--	--	5
2,4-Dichlorophenol	SOM02.3	120-83-2	µg/L	nc	NS	NS	77	NS	NS	NS	NS	77	--	--	5
2,4-Dimethylphenol	SOM02.3	105-67-9	µg/L	nc	NS	NS	380	NS	NS	NS	NS	380	--	--	5
2,4-Dinitrophenol	SOM02.3	51-28-5	µg/L	nc	NS	NS	69	NS	NS	NS	NS	69	--	--	10
2,4-Dinitrotoluene	SOM02.3	121-14-2	µg/L	c	NS	NS	0.11	NS	NS	NS	NS	0.11	--	--	5
2,6-Dinitrotoluene	SOM02.3	606-20-2	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
2-Chloronaphthalene	SOM02.3	91-58-7	µg/L	nc	NS	NS	1000	NS	NS	NS	NS	1000	--	--	5
2-Chlorophenol	SOM02.3	95-57-8	µg/L	nc	NS	NS	81	NS	NS	NS	NS	81	--	--	5
2-Methylnaphthalene	SOM02.3	91-57-6	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
2-Methylphenol	SOM02.3	95-48-7	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
2-Nitroaniline	SOM02.3	88-74-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
2-Nitrophenol	SOM02.3	88-75-5	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
3,3'-Dichlorobenzidine	SOM02.3	91-94-1	µg/L	c	NS	NS	0.021	NS	NS	NS	NS	0.021	--	--	5
3-Methylphenol	SOM02.3	108-39-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
3-Nitroaniline	SOM02.3	99-09-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
4,6-Dinitro-2-methylphenol	SOM02.3	534-52-1	µg/L	nc	NS	NS	13	NS	NS	NS	NS	13	--	--	10
4-Bromophenyl-phenylether	SOM02.3	101-55-3	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
4-Chloro-3-methylphenol	SOM02.3	59-50-7	µg/L	nc	NS	NS	59507	NS	NS	NS	NS	59507	--	--	5
4-Chloroaniline	SOM02.3	106-47-8	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
4-Chlorophenyl-phenylether	SOM02.3	7005-72-3	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
4-Methylphenol	SOM02.3	106-44-5	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
4-Nitroaniline	SOM02.3	100-01-6	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
4-Nitrophenol	SOM02.3	100-02-7	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Acenaphthene	SOM02.3	83-32-9	µg/L	nc	NS	NS	670	NS	NS	NS	NS	670	0.1	--	5
Acetophenone	SOM02.3	98-86-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Acenaphthylene	SOM02.3	208-96-8	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Anthracene	SOM02.3	120-12-7	µg/L	nc	NS	NS	8300	NS	NS	NS	NS	8,300	0.1	--	5
Atrazine	SOM02.3	1912-24-9	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Benzaldehyde	SOM02.3	100-52-7	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Benzo(a)anthracene	SOM02.3	56-55-3	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Benzo(a)pyrene	SOM02.3	50-32-8	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
bis(2-Chloroethoxy)methane	SOM02.3	111-91-1	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
bis(2-Chloroethyl)ether	SOM02.3	111-44-4	µg/L	c	NS	NS	0.03	NS	NS	NS	NS	0.03	--	--	10
bis(2-Ethylhexyl)phthalate	SOM02.3	117-81-7	µg/L	c	NS	NS	1.2	NS	NS	12	22	1.2	--	--	5
Butylbenzylphthalate	SOM02.3	85-68-7	µg/L	c	NS	NS	1500	NS	NS	1,500	1,900	1,500	--	--	5
Caprolactam	SOM02.3	105-60-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Carbazole	SOM02.3	86-74-8	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Chrysene	SOM02.3	218-01-9	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Di-n-butylphthalate	SOM02.3	84-74-2	µg/L	nc	NS	NS	2000	NS	NS	2,000	4,500	2,000	--	--	5
Di-n-octylphthalate	SOM02.3	117-84-0	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	10
Dibenz(a,h)anthracene	SOM02.3	53-70-3	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Dibenzofuran	SOM02.3	132-64-9	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
Diethylphthalate	SOM02.3	84-66-2	µg/L	nc	NS	NS	17000	NS	NS	17,000	44,000	17,000	--	--	5
Dimethylphthalate	SOM02.3	131-11-3	µg/L	-	NS	NS	270000	NS	NS	270,000	1,100,000	270,000	--	--	5
Fluoranthene	SOM02.3	206-44-0	µg/L	nc	NS	NS	130	NS	NS	NS	NS	130	0.1	--	10
Fluorene	SOM02.3	86-73-7	µg/L	nc	NS	NS	1100	NS	NS	NS	NS	1,100	0.1	--	5
Hexachlorobenzene	SOM02.3	118-74-1	µg/L	c	NS	NS	0.00028	NS	NS	0.0028	0.0029	0.00028	--	--	5
Hexachlorobutadiene	SOM02.3	87-68-3	µg/L	c	NS	NS	0.44	NS	NS	NS	NS	0.44	--	--	5
Hexachlorocyclopentadiene	SOM02.3	77-47-4	µg/L	nc	NS	NS	40	NS	NS	NS	NS	40	--	--	10
Hexachloroethane	SOM02.3	67-72-1	µg/L	c	NS	NS	1.4	NS	NS	NS	NS	1.4	--	--	5
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Isophorone	SOM02.3	78-59-1	µg/L	c	NS	NS	35	NS	NS	NS	NS	35	--	--	5
N-Nitroso-di-n-propylamine	--	621-64-7	µg/L	c	NS	NS	0.005	NS	NS	NS	NS	0.005	--	--	--
N-Nitrosodiphenylamine	SOM02.3	86-30-6	µg/L	c	NS	NS	3.3	NS	NS	NS	NS	3.3	--	--	5
Naphthalene	SOM02.3	91-20-3	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
Nitrobenzene	SOM02.3	98-95-3	µg/L	c	NS	NS	17	NS	NS	NS	NS	17	0.1	--	5
Pentachlorophenol	SOM02.3	87-86-5	µg/L	c	19	15	0.27	see OWRB	see OWRB	2.7	30	0.27	0.2	--	10
Phenanthrene	SOM02.3	85-01-8	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Phenol	SOM02.3	108-95-2	µg/L	nc	NS	NS	10000	NS	NS	10,000	860,000	10,000	--	--	10
Pyrene	SOM02.3	129-00-0	µg/L	nc	NS	NS	830	NS	NS	NS	NS	830	0.1	--	5

TABLE B-4A. SCREENING CRITERIA FOR SURFACE WATER AND CONTRACT LABORATORY PROGRAM REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	National Recommended Water Quality Criteria [1]			OWRB Interim Water Quality Standards [2]				Project Screening Level [3]	CRQLs [4]		
					Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Human Health for Consumption Organism Only	Fish & Wildlife Propagation Acute	Fish & Wildlife Propagation Chronic	Fish Consumption (+ Other Organisms) & Water	Fish Consumption (+ Other Organisms)		Low Water by SIM	Trace Water	Low Water
Polycyclic Aromatic Hydrocarbons															
Acenaphthene	SOM02.3	83-32-9	µg/L	nc	NS	NS	670	NS	NS	NS	NS	670	0.1	--	5
Acenaphthylene	SOM02.3	208-96-8	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Anthracene	SOM02.3	120-12-7	µg/L	nc	NS	NS	8300	NS	NS	NS	NS	8,300	0.1	--	5
Benzo(a)anthracene	SOM02.3	56-55-3	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Benzo(a)pyrene	SOM02.3	50-32-8	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Benzo(b)fluoranthene	SOM02.3	205-99-2	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Benzo(g,h,i)perylene	SOM02.3	191-24-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Benzo(k)fluoranthene	SOM02.3	207-08-9	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Chrysene	SOM02.3	218-01-9	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Dibenz(a,h)anthracene	SOM02.3	53-70-3	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Fluoranthene	SOM02.3	206-44-0	µg/L	nc	NS	NS	130	NS	NS	NS	NS	130	0.1	--	10
Fluorene	SOM02.3	86-73-7	µg/L	nc	NS	NS	1100	NS	NS	NS	NS	1,100	0.1	--	5
Indeno(1,2,3-cd)pyrene	SOM02.3	193-39-5	µg/L	c	NS	NS	0.0038	NS	NS	NS	NS	0.0038	0.1	--	5
Naphthalene	SOM02.3	91-20-3	µg/L	c	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Phenanthrene	SOM02.3	85-01-8	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
Pyrene	SOM02.3	129-00-0	µg/L	nc	NS	NS	830	NS	NS	NS	NS	830	0.1	--	5
2-Methylnaphthalene	SOM02.3	91-57-6	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	0.1	--	5
ICP-MS Metals - Total															
Aluminum	ISM02.3	7429-90-5	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	20
Antimony	ISM02.3	7440-36-0	µg/L	nc	NS	NS	5.6	NS	NS	NS	NS	5.6	--	--	2
Arsenic	ISM02.3	7440-38-2	µg/L	c	340	150	0.018	360	190	NS	205	0.018	--	--	1
Barium	ISM02.3	7440-39-3	µg/L	nc	NS	NS	1000	NS	NS	NS	NS	1000	--	--	10
Beryllium	ISM02.3	7440-41-7	µg/L	nc	NS	NS	4	NS	NS	NS	NS	4	--	--	1
Cadmium	ISM02.3	7440-43-9	µg/L	nc	2	0.25	5	see OWRB	see OWRB	14.49	84.13	0.25	--	--	1
Calcium	ISM02.3	7440-70-2	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Chromium	ISM02.3	7440-47-3	µg/L	nc	16	11	100	NS	NS	166.3	3,365	11	--	--	2
Cobalt	ISM02.3	7440-48-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	1
Copper	ISM02.3	7440-50-8	µg/L	nc	13	9	1300	see OWRB	see OWRB	NS	NS	9	--	--	2
Iron	ISM02.3	7439-89-6	µg/L	nc	NS	1,000	NS	NS	NS	NS	NS	1,000	--	--	200
Lead	ISM02.3	7439-92-1	µg/L	-	65	2.5	NS	see OWRB	see OWRB	5	25	2.5	--	--	1
Magnesium	ISM02.3	7439-95-4	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Manganese	ISM02.3	7439-96-5	µg/L	nc	NS	NS	50	NS	NS	NS	NS	50	--	--	1
Nickel	ISM02.3	7440-02-0	µg/L	nc	470	52	610	see OWRB	see OWRB	607.2	4,583	52	--	--	1
Potassium	ISM02.3	7440-09-7	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Selenium	ISM02.3	7782-49-2	µg/L	nc	NS	4.6	50	20	5	NS	NS	4.6	--	--	5
Silver	ISM02.3	7440-22-4	µg/L	nc	3.2	NS	NS	see OWRB	NS	104.8	64,620	3.2	--	--	1
Sodium	ISM02.3	7440-23-5	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Thallium	ISM02.3	7440-28-0	µg/L	nc	NS	NS	0.24	1,400	NS	0.24	0.47	0.24	--	--	1
Vanadium	ISM02.3	7440-62-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
Zinc	ISM02.3	7440-66-6	µg/L	nc	120	120	7400	see OWRB	see OWRB	NS	NS	120	--	--	2
ICP-AES Metals - Total															
Aluminum	ISM02.3	7429-90-5	µg/L	nc	750	87	NS	NS	NS	NS	NS	87	--		20
Antimony	ISM02.3	7440-36-0	µg/L	nc	NS	NS	5.6	NS	NS	NS	NS	5.6	--	--	60
Arsenic	ISM02.3	7440-38-2	µg/L	c	340	150	0.018	360	190	NS	205	0.018	--	--	10
Barium	ISM02.3	7440-39-3	µg/L	nc	NS	NS	1000	NS	NS	NS	NS	1000	--	--	200
Beryllium	ISM02.3	7440-41-7	µg/L	nc	NS	NS	4	NS	NS	NS	NS	4	--	--	5
Cadmium	ISM02.3	7440-43-9	µg/L	nc	1.8	0.72	5	see OWRB	see OWRB	14.49	84.13	0.72	--	--	5
Calcium	ISM02.3	7440-70-2	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--		5,000
Chromium	ISM02.3	7440-47-3	µg/L	nc	16	11	100	NS	NS	166.3	3,365	11	--	--	10
Cobalt	ISM02.3	7440-48-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	50
Copper	ISM02.3	7440-50-8	µg/L	nc	13	9	1300	see OWRB	see OWRB	NS	NS	9	--	--	25
Iron	ISM02.3	7439-89-6	µg/L	nc	NS	1,000	NS	NS	NS	NS	NS	1,000	--		100
Lead	ISM02.3	7439-92-1	µg/L	-	65	2.5	NS	see OWRB	see OWRB	5	25	2.5	--	--	10
Magnesium	ISM02.3	7439-95-4	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--		5,000
Manganese	ISM02.3	7439-96-5	µg/L	nc	NS	NS	50	NS	NS	NS	NS	50	--	--	15
Nickel	ISM02.3	7440-02-0	µg/L	nc	470	52	610	see OWRB	see OWRB	607.2	4,583	52	--	--	40
Potassium	ISM02.3	7440-09-7	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--		5,000
Selenium	ISM02.3	7782-49-2	µg/L	nc	NS	5	50	20	5	NS	NS	5	--	--	35
Silver	ISM02.3	7440-22-4	µg/L	nc	3.2	NS	NS	see OWRB	NS	104.8	64,620	3.2	--	--	10
Sodium	ISM02.3	7440-23-5	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--		5,000
Thallium	ISM02.3	7440-28-0	µg/L	nc	NS	NS	0.24	1,400	NS	0.24	0.47	0.24	--	--	25
Vanadium	ISM02.3	7440-62-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	50
Zinc	ISM02.3	7440-66-6	µg/L	nc	120	120	7400	see OWRB	see OWRB	NS	NS	120	--	--	60
ICP-MS Metals - Dissolved															
Aluminum	ISM02.3	7429-90-5	µg/L	nc	750	87	NS	NS	NS	NS	NS	87	--	--	20
Antimony	ISM02.3	7440-36-0	µg/L	nc	NS	NS	5.6	NS	NS	NS	NS	5.6	--	--	2
Arsenic	ISM02.3	7440-38-2	µg/L	c	340	150	0.018	360	190	NS	205	0.018	--	--	1
Barium	ISM02.3	7440-39-3	µg/L	nc	NS	NS	1000	NS	NS	NS	NS	1000	--	--	10
Beryllium	ISM02.3	7440-41-7	µg/L	nc	NS	NS	4	NS	NS	NS	NS	4	--	--	1
Cadmium	ISM02.3	7440-43-9	µg/L	nc	2	0.25	5	see OWRB	see OWRB	14.49	84.13	0.25	--	--	1
Calcium	ISM02.3	7440-70-2	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Chromium	ISM02.3	7440-47-3	µg/L	nc	16	11	100	NS	NS	166.3	3,365	11	--	--	2
Cobalt	ISM02.3	7440-48-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	1
Copper	ISM02.3	7440-50-8	µg/L	nc	13	9	1300	see OWRB	see OWRB	NS	NS	9	--	--	2
Iron	ISM02.3	7439-89-6	µg/L	nc	NS	1,000	NS	NS	NS	NS	NS	1,000	--	--	200
Lead	ISM02.3	7439-92-1	µg/L	-	65	2.5	NS	see OWRB	see OWRB	5	25	2.5	--	--	1
Magnesium	ISM02.3	7439-95-4	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Manganese	ISM02.3	7439-96-5	µg/L	nc	NS	NS	50	NS	NS	NS	NS	50	--	--	1
Nickel	ISM02.3	7440-02-0	µg/L	nc	470	52	610	see OWRB	see OWRB	607.2	4,583	52	--	--	1
Potassium	ISM02.3	7440-09-7	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Selenium	ISM02.3	7782-49-2	µg/L	nc	NS	4.6	50	20	5	NS	NS	4.6	--	--	5
Silver	ISM02.3	7440-22-4	µg/L	nc	3.2	NS	NS	see OWRB	NS	104.8	64,620	3.2	--	--	1
Sodium	ISM02.3	7440-23-5	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	500
Thallium	ISM02.3	7440-28-0	µg/L	nc	NS	NS	0.24	1,400	NS	0.24	0.47	0.24	--	--	1
Vanadium	ISM02.3	7440-62-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5
Zinc	ISM02.3	7440-66-6	µg/L	nc	120	120	7400	see OWRB	see OWRB	NS	NS	120	--	--	2
ICP-AES Metals - Dissolved															
Aluminum	ISM02.3	7429-90-5	µg/L	nc	750	87	NS	NS	NS	NS	NS	87	--	--	20
Antimony	ISM02.3	7440-36-0	µg/L	nc	NS	NS	5.6	NS	NS	NS	NS	5.6	--	--	60
Arsenic	ISM02.3	7440-38-2	µg/L	c	340	150	0.018	360	190	NS	205	0.018	--	--	10
Barium	ISM02.3	7440-39-3	µg/L	nc	NS	NS	1000	NS	NS	NS	NS	1000	--	--	200
Beryllium	ISM02.3	7440-41-7	µg/L	nc	NS	NS	4	NS	NS	NS	NS	4	--	--	5
Cadmium	ISM02.3	7440-43-9	µg/L	nc	1.8	0.72	5	see OWRB	see OWRB	14.49	84.13	0.72	--	--	5
Calcium	ISM02.3	7440-70-2	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5,000
Chromium	ISM02.3	7440-47-3	µg/L	nc	16	11	100	NS	NS	166.3	3,365	11	--	--	10
Cobalt	ISM02.3	7440-48-4	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	50
Copper	ISM02.3	7440-50-8	µg/L	nc	13	9	1300	see OWRB	see OWRB	NS	NS	9	--	--	25
Iron	ISM02.3	7439-89-6	µg/L	nc	NS	1,000	NS	NS	NS	NS	NS	1,000	--	--	100
Lead	ISM02.3	7439-92-1	µg/L	-	65	2.5	NS	see OWRB	see OWRB	5	25	2.5	--	--	10
Magnesium	ISM02.3	7439-95-4	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5,000
Manganese	ISM02.3	7439-96-5	µg/L	nc	NS	NS	50	NS	NS	NS	NS	50	--	--	15
Nickel	ISM02.3	7440-02-0	µg/L	nc	470	52	610	see OWRB	see OWRB	607.2	4,583	52	--	--	40
Potassium	ISM02.3	7440-09-7	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5,000
Selenium	ISM02.3	7782-49-2	µg/L	nc	NS	5	50	20	5	NS	NS	5	--	--	35
Silver	ISM02.3	7440-22-4	µg/L	nc	3.2	NS	NS	see OWRB	NS	104.8	64,620	3.2	--	--	10
Sodium	ISM02.3	7440-23-5	µg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--	5,000
Thallium	ISM02.3	7440-28-0	µg/L	nc	NS	NS	0.24	1,400	NS	0.24	0.47	0.24	--	--	25
Vanadium	ISM02.3	7440-62-2	µg/L	nc	NS	NS	NS	NS	NS	NS	NS	NS	--	--	50
Zinc	ISM02.3	7440-66-6	µg/L	nc	120	120	7400	see OWRB	see OWRB	NS	NS	120	--	--	60
Miscellaneous															
Cyanide - Total	ISM02.3	57-12-5	mg/L	nc	0.022	0.0052	140	0.04593	0.01072	NS	NS	0.0052	--		0.001
Mercury (Total)	ISM02.3	7439-97-6	mg/L	nc	0.0017	0.00091	NS	0.0024	0.00132	0.00005	0.000051	0.00005	--		0.0002

NOTES:

1. EPA National Recommended Water Quality Criteria (accessed 18 June 2012 at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm).
2. Oklahoma Water Resources Board (OWRB) Interim Water Quality Standards (WQSs) (https://www.owrb.ok.gov/quality/standards/standards.php) (OWRB 2013) Equations are prescribed in Table 2 of this reference for metals whose toxicity varies with water quality.
3. Project screening levels reflect the lowest value for EPA or OWRB surface water quality criteria.
4. Contract-required Quantitation Limits (CRQL) for EPA Contract Laboratory Program (CLP)

µg/L = Microgram(s) per liter
AES = Atomic emission spectroscopy
c = Carcinogenic; nc = Non-carcinogenic
CASRN = Chemical Abstracts Service Registry Number
ICP = Inductively-coupled plasma
mg/L = Milligram(s) per liter
MS = Mass spectrometry
-- = Not provided
NS = Not specified
PCB = Polychlorinated biphenyl
SIM = Selective ion monitoring

TABLE B-4B. SCREENING CRITERIA FOR SURFACE WATER AND PRIVATE LABORATORY REFERENCE LIMITS

Analyte	Analytical Method	CASRN	Units	c/nc	National Recommended Water Quality Criteria [1]			OWRB Interim Water Quality Standards [2]				Project Screening Level [3]	Achievable Laboratory Limits [4]	
					Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Human Health for Consumption Organism Only	Fish & Wildlife Propagation Acute	Fish & Wildlife Propagation Chronic	Fish Consumption (+ Other Organisms) & Water	Fish Consumption (+ Other Organisms)		RL	DL
Miscellaneous														
Alkalinity -Bicarbonate/Carbonate	SM 2320B	NS	mg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	2	0.7
Hardness	EPA 130.2	NS	mg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--
Hexavalent Chromium	SW7199	18540-29-9	mg/L	c	0.016	0.011	NS	NS	NS	NS	NS	0.011	0.01	0.005
pH	SW9045C	NS	S.U.	-	NS	NS	NS	NS	NS	NS	NS	NS	0.01	0.01
Total Organic Carbon	SM 5310B	NS	mg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	300	100
Total Dissolved Solids	SM 2540C	NS	mg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	30	9.7
Total Suspended Sediment	ASTM D 3977-97	NS	mg/L	-	NS	NS	NS	NS	NS	NS	NS	NS	--	--

NOTES:

1. EPA National Recommended Water Quality Criteria (accessed 18 June 2012 at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm).
2. Oklahoma Water Resources Board (OWRB) Interim Water Quality Standards (WQSs) (https://www.owrb.ok.gov/quality/standards/standards.php) (OWRB 2013) Equations are prescribed in Table 2 of this reference for metals whose toxicity varies with water quality.
3. Project screening levels reflect the lowest value for EPA or OWRB surface water quality criteria.
4. Achievable laboratory limits are for Eurofins Lancaster Laboratories Environmental, LLC.
5. Oklahoma GRO 8082/8015 modified for ground water.
6. Oklahoma DRO 8000/8100 modified for ground water.

µg/L = Microgram(s) per liter
AES = Atomic emission spectroscopy
c = Carcinogenic; nc = Non-carcinogenic
CASRN = Chemical Abstracts Service Registry Number
ICP = Inductively-coupled plasma
mg/L = Milligram(s) per liter
MS = Mass spectrometry
-- = Not provided
NS = Not specified
PCB = Polychlorinated biphenyl
SIM = Selective ion monitoring
DL = Detection limit
RL = Reporting limit

TABLE B-5. SCREENING CRITERIA FOR AIR AND EPA AND PRIVATE LABORATORY REFERENCE LIMITS

Analyte	Analytical Method [1]	Units	CASRN	EPA Indoor Residential Air Screening Level [2]	EPA Crawl Space Residential Air Screening Level [3]	EPA Sub-Slab Residential Air Screening Level [3]	Project Screening Level [4]	Achievable Laboratory Limits [5]		Private Laboratory RL for TO-15 SIM
								DL	RL	
Volatile Organic Compounds (VOCs), including Naphthalene										
Acetone	TO-15 SIM/TO-15	µg/m^3	67-64-1	32,000	32,000	1,066,667	32,000	0.109	1.188	1.188
Benzene	TO-15 SIM/TO-15	µg/m^3	71-43-2	0.36	0.36	12	0.36	0.249	0.31947	0.16
Bromodichloromethane	TO-15 SIM/TO-15	µg/m^3	75-27-4	0.076	0.076	3	**0.076**	0.121	0.670	0.670
Bromoform	TO-15 SIM/TO-15	µg/m^3	75-25-2	2.6	2.6	87	2.6	0.114	1.034	1.034
Bromomethane	TO-15 SIM/TO-15	µg/m^3	74-83-9	5.2	5.2	173	5.2	0.299	1.553	1.553
1,3-Butadiene	TO-15 SIM/TO-15	µg/m^3	106-99-0	0.094	0.094	3	0.094	0.049	0.221	0.221
2-Butanone (Methyl Ethyl Ketone)	TO-15 SIM/TO-15	µg/m^3	78-93-3	5,200	5,200	173,333	5,200	0.147	1.180	1.180
Carbon Disulfide	TO-15 SIM/TO-15	µg/m^3	75-15-0	730	730	24,333	730	0.115	1.557	1.557
Carbon Tetrachloride	TO-15 SIM/TO-15	µg/m^3	56-23-5	0.47	0.47	16	0.47	0.069	0.6292	0.12
Chlorobenzene	TO-15 SIM/TO-15	µg/m^3	108-90-7	52	52	1,733	52	0.041	0.460	0.460
Chloroethane (ethyl chloride)	TO-15 SIM/TO-15	µg/m^3	75-00-3	10,000	10,000	333,333	10,000	0.132	1.31943	0.13
Chloroform	TO-15 SIM/TO-15	µg/m^3	67-66-3	0.12	0.12	4	0.12	0.054	0.4883	0.01
Chloromethane	TO-15 SIM/TO-15	µg/m^3	74-87-3	94	94	3,133	94	0.114	1.032	0.1
3-Chloropropene	TO-15 SIM/TO-15	µg/m^3	107-05-1	0.47	0.47	16	0.47	0.213	1.565	1.565
alpha-Chlorotoluene	TO-15 SIM/TO-15	µg/m^3	100-44-7	0.057	0.057	2	**0.057**	0.072	0.518	0.518
Cumene	TO-15 SIM/TO-15	µg/m^3	98-82-8	420	420	14,000	420	0.059	0.492	0.492
Cyclohexane	TO-15 SIM/TO-15	µg/m^3	110-82-7	6,300	6,300	210,000	6,300	0.072	0.344	0.344
Dibromochloromethane	TO-15 SIM/TO-15	µg/m^3	124-48-1	NS	NS	NS	NS	0.111	0.852	0.852
1,2-Dichlorobenzene	TO-15 SIM/TO-15	µg/m^3	95-50-1	210	210	7,000	210	0.144	0.601	0.601
1,3-Dichlorobenzene	TO-15 SIM/TO-15	µg/m^3	541-73-1	NS	NS	NS	NS	0.114	0.601	0.601
cis-1,2-Dichloroethene	TO-15 SIM/TO-15	µg/m^3	156-59-2	NS	NS	NS	NS	0.107	0.39648	0.079
1,1-Dichloroethane	TO-15 SIM/TO-15	µg/m^3	75-34-3	1.8	1.8	60	1.8	0.077	0.40479	0.081
1,1-Dichloroethene	TO-15 SIM/TO-15	µg/m^3	75-35-4	210	210	7,000	210	0.091	0.39652	0.04
1,2-Dibromoethane (EDB)	TO-15 SIM/TO-15	µg/m^3	106-93-4	0.0047	0.0047	0	**0.0047**	0.115	0.76843	0.15
1,2-Dichloroethane	TO-15 SIM/TO-15	µg/m^3	107-06-2	0.11	0.11	4	0.11	0.081	0.40474	0.081
1,4-Dichlorobenzene	TO-15 SIM/TO-15	µg/m^3	106-46-7	0.26	0.26	9	0.26	0.084	0.60127	0.12
trans-1,2-Dichloroethene	TO-15 SIM/TO-15	µg/m^3	156-60-5	NS	NS	NS	NS	0.075	0.39648	0.4
1,2-Dichloropropane	TO-15 SIM/TO-15	µg/m^3	78-87-5	0.28	0.28	9	0.28	0.055	0.462	0.462
cis-1,3-Dichloropropene	TO-15 SIM/TO-15	µg/m^3	10061-01-5	NS	NS	NS	NS	0.077	0.454	0.454
1,4-Dioxane	TO-15 SIM/TO-15	µg/m^3	123-91-1	0.56	0.56	19	0.56	0.133	0.360	0.360
Ethanol	TO-15 SIM/TO-15	µg/m^3	64-17-5	NS	NS	NS	NS	0.141	0.942	0.942
Ethyl Benzene	TO-15 SIM/TO-15	µg/m^3	100-41-4	1.1	1.1	37	1.1	0.096	0.43419	0.087
4-Ethyltoluene	TO-15 SIM/TO-15	µg/m^3	622-96-8	NS	NS	NS	NS	0.088	0.492	0.492
Freon 11	TO-15 SIM/TO-15	µg/m^3	75-69-4	NS	NS	NS	NS	0.09	0.562	0.562
Freon 113	TO-15 SIM/TO-15	µg/m^3	76-13-1	31,000	31,000	1,033,333	31,000	0.1	0.766	0.766
Freon 114	TO-15 SIM/TO-15	µg/m^3	76-14-2	NS	NS	NS	NS	0.077	0.699	0.14
Freon 12 (dichlorodifluoromethane)	TO-15 SIM/TO-15	µg/m^3	75-71-8	100	100	3,333	100	0.094	0.494	0.099
Heptane	TO-15 SIM/TO-15	µg/m^3	142-82-5	NS	NS	NS	NS	0.041	0.410	0.410
Hexachlorobutadiene	TO-15 SIM/TO-15	µg/m^3	87-68-3	0.13	0.13	4	0.13	0.469	5.333	5.333
Hexane	TO-15 SIM/TO-15	µg/m^3	110-54-3	730	730	24,333	730	0.053	0.352	0.352
2-Hexanone	TO-15 SIM/TO-15	µg/m^3	591-78-6	31	31	1,033	31	0.225	2.048	2.048
Methylene Chloride	TO-15 SIM/TO-15	µg/m^3	75-09-2	100	100	3,333	100	0.069	0.695	0.695
4-Methyl-2-pentanone	TO-15 SIM/TO-15	µg/m^3	108-10-1	3,100	3,100	103,333	3,100	0.078	0.410	0.410
Methyl tert-butyl ether	TO-15 SIM/TO-15	µg/m^3	1634-04-4	110	110	3,667	110	0.054	0.36053	0.36
Naphthalene	TO-15 SIM/TO-15	µg/m^3	91-20-3	0.83	0.83	28	0.83	NS	NS	0.26
Propylbenzene	TO-15 SIM/TO-15	µg/m^3	103-65-1	1,000	1,000	33,333	1,000	0.074	0.492	0.492
2-Propanol	TO-15 SIM/TO-15	µg/m^3	67-63-0	210	210	7,000	210	0.388	1.229	1.229
1,1,2,2-Tetrachloroethane	TO-15 SIM/TO-15	µg/m^3	79-34-5	0.048	0.048	2	**0.048**	0.124	0.68654	0.14
Tetrachloroethene	TO-15 SIM/TO-15	µg/m^3	127-18-4	11	11	367	11	0.061	0.67832	0.14
Toluene	TO-15 SIM/TO-15	µg/m^3	108-88-3	5,200	5,200	173,333	5,200	0.064	0.37681	0.075
1,2,4-Trichlorobenzene	TO-15 SIM/TO-15	µg/m^3	120-82-1	2.1	2.1	70	2.1	0.334	3.711	3.711
Trichloroethene	TO-15 SIM/TO-15	µg/m^3	79-01-6	0.48	0.48	16	0.48	0.107	0.53738	0.075
1,1,1-Trichloroethane	TO-15 SIM/TO-15	µg/m^3	71-55-6	5,200	5,200	NS	5,200	0.065	0.54569	0.11
1,1,2-Trichloroethane	TO-15 SIM/TO-15	µg/m^3	79-00-5	0.18	0.18	6	0.18	0.082	0.54569	0.11
1,2,4-Trimethylbenzene	TO-15 SIM/TO-15	µg/m^3	95-63-6	7.3	7.3	243	7.3	0.034	0.492	0.492
1,3,5-Trimethylbenzene	TO-15 SIM/TO-15	µg/m^3	108-67-8	NS	NS	NS	NS	0.098	0.492	0.492
2,2,4-Trimethylpentane	TO-15 SIM/TO-15	µg/m^3	540-84-1	NS	NS	NS	NS	0.121	2.336	2.336
m,p-Xylene	TO-15 SIM/TO-15	µg/m^3	108-38-3	100	100	3,333	100	0.056	0.43423	0.17
o-Xylene	TO-15 SIM/TO-15	µg/m^3	95-47-6	100	100	3,333	100	0.069	0.43423	0.087
Vinyl Chloride	TO-15 SIM/TO-15	µg/m^3	75-01-4	0.17	0.17	5.67	0.17	0.023	0.255	0.026

NOTES:

1. Analytical laboratory will screen the sample to determine if sample will be analyzed via TO-15 SIM (low level) or TO-15.
2. U.S. Environmental Protection Agency (EPA) Regional Screening Levels (RSLs) Summary Table May 2016 http://www.epa.gov/region9/superfund/prg/.
3. Values calculated based on EPA current residential air RSLs (updated May 2016) modified using the methodology specified in the *EPA OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Source to Indoor Air* , June 2015 by dividing by an attenuation factor of 1 for crawlspace soil gas and 0.03 for sub-slab soil gas.
4. The project screening level was selected to satisfy the EPA requirements asspecified in the *EPA OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Source to Indoor Air*. Yellow-highlighted project screening levels are either below the DL/RL or not a reported analyte for the prescribed analytical method.
5. Achievable laboratory limits are for Eurofins Air Toxics, Inc., Folsom, California; limits determined for Quarter 3 of 2015.

CASRN = Chemical Abstracts Service Registry Number
c/nc = Carcinogen/non-carcinogen
NA = Not applicable
NS = Not specified
RL = Reporting limit
µg/m^3= Microgram(s) per cubic meter
TO-15 = *EPA Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air* , Second Edition.

Appendix C

Analytical Method Reference Sheets and Contract Required Quantitation Limits

EXHIBIT C

ORGANIC TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

NOTE: The Contract Required Quantitation Limit (CRQL) values listed on the following pages are based on the analysis of samples according to the specifications given in Exhibit D.

Changes to the CRQL may be requested under the Modified Analysis (MA) clause in the contract.

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Exhibit C – Organic Target Analyte List and Contract Required Quantitation Limits

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1.0 TRACE VOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 1. TRACE VOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A]

Analyte Name	CAS Number	CRQLs Trace Water (µg/L)
Dichlorodifluoromethane	75-71-8	0.50
Chloromethane	74-87-3	0.50
Vinyl chloride	75-01-4	0.50
Bromomethane	74-83-9	0.50
Chloroethane	75-00-3	0.50
Trichlorofluoromethane	75-69-4	0.50
1,1-Dichloroethene	75-35-4	0.50
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.50
Acetone	67-64-1	5.0
Carbon disulfide	75-15-0	0.50
Methyl acetate	79-20-9	0.50
Methylene chloride	75-09-2	0.50
trans-1,2-Dichloroethene	156-60-5	0.50
Methyl tert-butyl ether	1634-04-4	0.50
1,1-Dichloroethane	75-34-3	0.50
cis-1,2-Dichloroethene	156-59-2	0.50
2-Butanone	78-93-3	5.0
Bromochloromethane	74-97-5	0.50
Chloroform	67-66-3	0.50
1,1,1-Trichloroethane	71-55-6	0.50
Cyclohexane	110-82-7	0.50
Carbon tetrachloride	56-23-5	0.50
Benzene	71-43-2	0.50
1,2-Dichloroethane	107-06-2	0.50
Trichloroethene	79-01-6	0.50
Methylcyclohexane	108-87-2	0.50
1,2-Dichloropropane	78-87-5	0.50
Bromodichloromethane	75-27-4	0.50
cis-1,3-Dichloropropene	10061-01-5	0.50
4-Methyl-2-pentanone	108-10-1	5.0
Toluene	108-88-3	0.50
trans-1,3-Dichloropropene	10061-02-6	0.50
1,1,2-Trichloroethane	79-00-5	0.50
Tetrachloroethene	127-18-4	0.50

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TABLE 1. TRACE VOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A] (CON'T)

Analyte Name	CAS Number	CRQLs Trace Water (µg/L)
2-Hexanone	591-78-6	5.0
Dibromochloromethane	124-48-1	0.50
1,2-Dibromoethane	106-93-4	0.50
Chlorobenzene	108-90-7	0.50
Ethylbenzene	100-41-4	0.50
o-Xylene	95-47-6	0.50
m,p-Xylene	179601-23-1	0.50
Styrene	100-42-5	0.50
Bromoform	75-25-2	0.50
Isopropylbenzene	98-82-8	0.50
1,1,2,2-Tetrachloroethane	79-34-5	0.50
1,3-Dichlorobenzene	541-73-1	0.50
1,4-Dichlorobenzene	106-46-7	0.50
1,2-Dichlorobenzene	95-50-1	0.50
1,2-Dibromo-3-chloropropane	96-12-8	0.50
1,2,4-Trichlorobenzene	120-82-1	0.50
1,2,3-Trichlorobenzene	87-61-6	0.50

2.0 LOW/MEDIUM VOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 2. LOW/MEDIUM VOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A]

Analyte Name	CAS Number	CRQLs Low Water[I] (µg/L)	Low Soil[B] (µg/kg)	Medium Soil[B] (µg/kg)
Dichlorodifluoromethane	75-71-8	5.0	5.0	250
Chloromethane	74-87-3	5.0	5.0	250
Vinyl chloride[C]	75-01-4	5.0	5.0	250
Bromomethane	74-83-9	5.0	5.0	250
Chloroethane	75-00-3	5.0	5.0	250
Trichlorofluoromethane	75-69-4	5.0	5.0	250
1,1-Dichloroethene[C]	75-35-4	5.0	5.0	250
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	5.0	5.0	250
Acetone	67-64-1	10	10	500
Carbon disulfide	75-15-0	5.0	5.0	250
Methyl acetate	79-20-9	5.0	5.0	250
Methylene chloride	75-09-2	5.0	5.0	250
trans-1,2-Dichloroethene	156-60-5	5.0	5.0	250
Methyl tert-butyl ether	1634-04-4	5.0	5.0	250
1,1-Dichloroethane	75-34-3	5.0	5.0	250

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TABLE 2. LOW/MEDIUM VOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A] (CON'T)

Analyte Name	CAS Number	CRQLs		
		Low Water[I] (µg/L)	Low Soil[B] (µg/kg)	Medium Soil[B] (µg/kg)
cis-1,2-Dichloroethene	156-59-2	5.0	5.0	250
2-Butanone[C]	78-93-3	10	10	500
Bromochloromethane	74-97-5	5.0	5.0	250
Chloroform[C]	67-66-3	5.0	5.0	250
1,1,1-Trichloroethane	71-55-6	5.0	5.0	250
Cyclohexane	110-82-7	5.0	5.0	250
Carbon tetrachloride[C]	56-23-5	5.0	5.0	250
Benzene[C]	71-43-2	5.0	5.0	250
1,2-Dichloroethane[C]	107-06-2	5.0	5.0	250
Trichloroethene[C]	79-01-6	5.0	5.0	250
Methylcyclohexane	108-87-2	5.0	5.0	250
1,2-Dichloropropane	78-87-5	5.0	5.0	250
Bromodichloromethane	75-27-4	5.0	5.0	250
cis-1,3-Dichloropropene	10061-01-5	5.0	5.0	250
4-Methyl-2-pentanone	108-10-1	10	10	500
Toluene	108-88-3	5.0	5.0	250
trans-1,3-Dichloropropene	10061-02-6	5.0	5.0	250
1,1,2-Trichloroethane	79-00-5	5.0	5.0	250
Tetrachloroethene[C]	127-18-4	5.0	5.0	250
2-Hexanone	591-78-6	10	10	500
Dibromochloromethane	124-48-1	5.0	5.0	250
1,2-Dibromoethane	106-93-4	5.0	5.0	250
Chlorobenzene[C]	108-90-7	5.0	5.0	250
Ethylbenzene	100-41-4	5.0	5.0	250
o-Xylene	95-47-6	5.0	5.0	250
m,p-Xylene	179601-23-1	5.0	5.0	250
Styrene	100-42-5	5.0	5.0	250
Bromoform	75-25-2	5.0	5.0	250
Isopropylbenzene	98-82-8	5.0	5.0	250
1,1,2,2-Tetrachloroethane	79-34-5	5.0	5.0	250
1,3-Dichlorobenzene	541-73-1	5.0	5.0	250
1,4-Dichlorobenzene[C]	106-46-7	5.0	5.0	250
1,2-Dichlorobenzene	95-50-1	5.0	5.0	250
1,2-Dibromo-3-chloropropane	96-12-8	5.0	5.0	250
1,2,4-Trichlorobenzene	120-82-1	5.0	5.0	250
1,2,3-Trichlorobenzene	87-61-6	5.0	5.0	250

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3.0 SEMIVOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 3. SEMIVOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A]

Analyte Name	CAS Number	CRQLs				
		Low Water By SIM[D] (µg/L)	Low Water[I] (µg/L)	Low Soil By SIM[B,D] (µg/kg)	Low Soil[B] (µg/kg)	Med. Soil[B] (µg/kg)
1,4-Dioxane	123-91-1		2.0		67	2000
Benzaldehyde	100-52-7		10		330	10000
Phenol	108-95-2		10		330	10000
Bis(2-chloroethyl) ether	111-44-4		10		330	10000
2-Chlorophenol	95-57-8		5.0		170	5000
2-Methylphenol[C]	95-48-7		10		330	10000
3-Methylphenol[C,K]	108-39-4		5.0			
2,2'-Oxybis(1-chloropropane)[E]	108-60-1		10		330	10000
Acetophenone	98-86-2		10		330	10000
4-Methylphenol[A,C]	106-44-5		10		330	10000
N-Nitroso-di-n propylamine	621-64-7		5.0		170	5000
Hexachloroethane[C]	67-72-1		5.0		170	5000
Nitrobenzene[C]	98-95-3		5.0		170	5000
Isophorone	78-59-1		5.0		170	5000
2-Nitrophenol	88-75-5		5.0		170	5000
2,4-Dimethylphenol	105-67-9		5.0		170	5000
Bis(2-chloroethoxy)methane	111-91-1		5.0		170	5000
2,4-Dichlorophenol	120-83-2		5.0		170	5000
Naphthalene[F]	91-20-3	0.10	5.0	3.3	170	5000
4-Chloroaniline	106-47-8		10		330	10000
Hexachlorobutadiene[C]	87-68-3		5.0		170	5000
Caprolactam	105-60-2		10		330	10000
4-Chloro-3-methylphenol	59-50-7		5.0		170	5000
2-Methylnaphthalene[F]	91-57-6	0.10	5.0	3.3	170	5000
Hexachlorocyclo-pentadiene	77-47-4		10		330	10000
2,4,6-Trichlorophenol[C]	88-06-2		5.0		170	5000
2,4,5-Trichlorophenol[C]	95-95-4		5.0		170	5000
1,1'-Biphenyl	92-52-4		5.0		170	5000
2-Chloronaphthalene	91-58-7		5.0		170	5000
2-Nitroaniline	88-74-4		5.0		170	5000
Dimethylphthalate	131-11-3		5.0		170	5000
2,6-Dinitrotoluene	606-20-2		5.0		170	5000
Acenaphthylene[F]	208-96-8	0.10	5.0	3.3	170	5000
3-Nitroaniline	99-09-2		10		330	10000
Acenaphthene[F]	83-32-9	0.10	5.0	3.3	170	5000
2,4-Dinitrophenol	51-28-5		10		330	10000
4-Nitrophenol	100-02-7		10		330	10000
Dibenzofuran	132-64-9		5.0		170	5000
2,4-Dinitrotoluene[C]	121-14-2		5.0		170	5000
Diethylphthalate	84-66-2		5.0		170	5000

TABLE 3. SEMIVOLATILES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A] (CON'T)

Analyte Name	CAS Number	CRQLs Low Water By SIM[D] (µg/L)	Low Water[I] (µg/L)	Low Soil By SIM[B,D] (µg/kg)	Low Soil[B] (µg/kg)	Med. Soil[B] (µg/kg)
Fluorene[F]	86-73-7	0.10	5.0	3.3	170	5000
4-Chlorophenyl-phenyl ether	7005-72-3		5.0		170	5000
4-Nitroaniline	100-01-6		10		330	10000
4,6-Dinitro-2-methylphenol	534-52-1		10		330	10000
N-Nitrosodiphenylamine	86-30-6		5.0		170	5000
1,2,4,5-Tetrachlorobenzene	95-94-3		5.0		170	5000
4-Bromophenyl-phenylether	101-55-3		5.0		170	5000
Hexachlorobenzene	118-74-1		5.0		170	5000
Atrazine	1912-24-9		10		330	10000
Pentachlorophenol[F]	87-86-5	0.20	10	6.7	330	10000
Phenanthrene[C,F]	85-01-8	0.10	5.0	3.3	170	5000
Anthracene[F]	120-12-7	0.10	5.0	3.3	170	5000
Carbazole	86-74-8		10		330	10000
Di-n-butylphthalate	84-74-2		5.0		170	5000
Fluoranthene[F]	206-44-0	0.10	10	3.3	330	10000
Pyrene[F]	129-00-0	0.10	5.0	3.3	170	5000
Butylbenzylphthalate	85-68-7		5.0		170	5000
3,3'-Dichlorobenzidine	91-94-1		10		330	10000
Benzo(a)anthracene[F]	56-55-3	0.10	5.0	3.3	170	5000
Chrysene[F]	218-01-9	0.10	5.0	3.3	170	5000
Bis(2-ethylhexyl)phthalate	117-81-7		5.0		170	5000
Di-n-octylphthalate	117-84-0		10		330	10000
Benzo(b)fluoranthene[F]	205-99-2	0.10	5.0	3.3	170	5000
Benzo(k)fluoranthene[F]	207-08-9	0.10	5.0	3.3	170	5000
Benzo(a)pyrene[F]	50-32-8	0.10	5.0	3.3	170	5000
Indeno(1,2,3-cd)pyrene[F]	193-39-5	0.10	5.0	3.3	170	5000
Dibenzo(a,h)anthracene[F]	53-70-3	0.10	5.0	3.3	170	5000
Benzo(g,h,i)perylene[F]	191-24-2	0.10	5.0	3.3	170	5000
2,3,4,6-Tetrachlorophenol	58-90-2		5.0		170	5000

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4.0 PESTICIDES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 4. PESTICIDES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANITATION LIMITS[A,G]

Analyte Name	CAS Number	CRQLs	
		Water (µg/L)	Soil[B] (µg/kg)
alpha-BHC	319-84-6	0.050	1.7
beta-BHC	319-85-7	0.050	1.7
delta-BHC	319-86-8	0.050	1.7
gamma-BHC (Lindane)[C]	58-89-9	0.050	1.7
Heptachlor[C]	76-44-8	0.050	1.7
Aldrin	309-00-2	0.050	1.7
Heptachlor epoxide[C,H]	1024-57-3	0.050	1.7
Endosulfan I	959-98-8	0.050	1.7
Dieldrin	60-57-1	0.10	3.3
4,4'-DDE	72-55-9	0.10	3.3
Endrin	72-20-8	0.10	3.3
Endosulfan II	33213-65-9	0.10	3.3
4,4'-DDD	72-54-8	0.10	3.3
Endosulfan sulfate	1031-07-8	0.10	3.3
4,4'-DDT	50-29-3	0.10	3.3
Methoxychlor[C]	72-43-5	0.50	17
Endrin ketone	53494-70-5	0.10	3.3
Endrin aldehyde	7421-93-4	0.10	3.3
cis-Chlordane[C,J]	5103-71-9	0.050	1.7
trans-Chlordane[C,J]	5103-74-2	0.050	1.7
Toxaphene[C]	8001-35-2	5.0	170

5.0 AROCLORS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 5. AROCLORS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[G]

Analyte Name	CAS Number	CRQLs	
		Water (µg/L)	Soil[B] (µg/kg)
Aroclor-1016	12674-11-2	1.0	33
Aroclor-1221	11104-28-2	1.0	33
Aroclor-1232	11141-16-5	1.0	33
Aroclor-1242	53469-21-9	1.0	33
Aroclor-1248	12672-29-6	1.0	33
Aroclor-1254	11097-69-1	1.0	33
Aroclor-1260	11096-82-5	1.0	33
Aroclor-1262	37324-23-5	1.0	33
Aroclor-1268	11100-14-4	1.0	33

Endnotes:

A. Changes to the Organic Target Analyte List (TAL) (e.g., adding an additional analyte) may be requested under the Modified Analysis clause in the contract.

B. The CRQLs for soil/sediment are based on 100% solids and on the minimum weights and volumes specified in Exhibit D. The moisture content of the samples must be used to adjust the CRQL values appropriately.

C. Toxicity Characteristic Leaching Procedure (TCLP) analyte list. The CRQLs for the TCLP analytes are the "Low Water" CRQLs (Low/Medium Volatiles and Semivolatiles) and the "Water" CRQLs (Pesticides) divided by 1000 in units of mg/L.

D. CRQL for analysis of water and soil samples using SIM technique for PAHs and phenols.

E. Previously known as Bis(2-chloroisopropyl) ether.

F. Target Analyte List for PAHs and Pentachlorophenol analyses request.

G. There is no differentiation between the preparation of low and medium soil samples in this method for analysis.

H. Only the exo_epoxy isomer.

I. Use the water CRQLs for Synthetic Precipitation Leaching Procedures (SPLP).

J. Formerly known as alpha-Chlordane and gamma-Chlordane respectively.

K. Semivolatile target analyte 3-methylphenol is included in this table ONLY for inclusion in the list of TCLP and/or SPLP analytes. Compounds 3-Methylphenol and 4-Methylphenol cannot be separated by the extraction techniques or GC columns used in this method. Therefore, both are represented in this SOW by the 4-methylphenol isomer only. Those data users who wish to analyze 3- and 4-methylphenol separately are encouraged to utilize the CLP-MA process to obtain data for these compounds from the derivatization/GC method (8041A or equivalent).

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EXHIBIT C

INORGANIC TARGET ANALYTE LIST AND
CONTRACT REQUIRED QUANTITATION LIMITS

NOTE: The Contract Required Quantitation Limit (CRQL) values listed on the following pages are based on the analysis of samples according to the specifications given in Exhibit D.

Changes to the CRQL may be requested under the Modified Analysis (MA) clause in the contract.

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Exhibit C - Inorganic Target Analyte List and Contract Required Quantitation Limits

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1.0 ICP-AES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 1. ICP-AES TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A]

		CRQL			
Analyte Name	**CAS Number**	**Water[D] (µg/L)**	**Soil[B] (mg/kg)**	**Wipe (µg)**	**TCLP (mg/L)**
Aluminum	7429-90-5	200	20	20	--
Antimony	7440-36-0	60	6	6	--
Arsenic	7440-38-2	10	1	1	5
Barium	7440-39-3	200	20	20	100
Beryllium	7440-41-7	5	0.5	0.5	--
Cadmium	7440-43-9	5	0.5	0.5	1
Calcium	7440-70-2	5000	500	500	--
Chromium	7440-47-3	10	1	1	5
Cobalt	7440-48-4	50	5	5	--
Copper	7440-50-8	25	2.5	2.5	--
Iron	7439-89-6	100	10	10	--
Lead	7439-92-1	10	1	1	5
Magnesium	7439-95-4	5000	500	500	--
Manganese	7439-96-5	15	1.5	1.5	--
Nickel	7440-02-0	40	4	4	--
Potassium	7440-09-7	5000	500	500	--
Selenium	7782-49-2	35	3.5	3.5	1
Silver	7440-22-4	10	1	1	5
Sodium	7440-23-5	5000	500	500	--
Thallium	7440-28-0	25	2.5	2.5	--
Vanadium	7440-62-2	50	5	5	--
Zinc	7440-66-6	60	6	6	--
Hardness (total)	Hardness	33[C]	--	--	--

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2.0 ICP-MS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 2. ICP-MS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS[A]

Analyte Name	CAS Number	CRQL Water (µg/L)	CRQL Soil[B] (mg/kg)
Aluminum	7429-90-5	20	--
Antimony	7440-36-0	2	1
Arsenic	7440-38-2	1	0.5
Barium	7440-39-3	10	5
Beryllium	7440-41-7	1	0.5
Cadmium	7440-43-9	1	0.5
Calcium	7440-70-2	500	--
Chromium	7440-47-3	2	1
Cobalt	7440-48-4	1	0.5
Copper	7440-50-8	2	1
Iron	7439-89-6	200	--
Lead	7439-92-1	1	0.5
Magnesium	7439-95-4	500	--
Manganese	7439-96-5	1	0.5
Nickel	7440-02-0	1	0.5
Potassium	7440-09-7	500	--
Selenium	7782-49-2	5	2.5
Silver	7440-22-4	1	0.5
Sodium	7440-23-5	500	--
Thallium	7440-28-0	1	0.5
Vanadium	7440-62-2	5	2.5
Zinc	7440-66-6	2	1

3.0 MERCURY BY COLD VAPOR ATOMIC ABSORPTION TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 3. MERCURY BY COLD VAPOR ATOMIC ABSORPTION TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

Analyte Name	CAS Number	CRQL Water[D] (µg/L)	CRQL Soil[B] (mg/kg)	TCLP (mg/L)
Mercury	7439-97-6	0.2	0.1	0.2

4.0 CYANIDE BY SPECTROPHOTOMETRY TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 4. CYANIDE BY SPECTROPHOTOMETRY TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

Analyte Name	CAS Number	CRQL Water[D] (µg/L)	CRQL Soil[B] (mg/kg)
Cyanide	57-12-5	10	0.5

Endnotes:

A. Changes to the Inorganic Target Analyte List (TAL) (e.g., adding an additional analyte) may be requested under the Modified Analysis clause in the contract.

B. The CRQLs for soil/sediment are based on 100% solids and on the minimum weights and volumes specified in Exhibit D. The moisture content of the samples must be used to adjust the CRQL values appropriately.

C. Hardness (total) is reported as a calculation in mg/L.

D. Use the water CRQLs for Synthetic Precipitation Leaching Procedure (SPLP).

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EXHIBIT C

CHLORINATED DIBENZO-*p*-DIOXINS AND CHLORINATED DIBENZOFURANS
AND CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST
AND CONTRACT REQUIRED QUANTITATION LIMITS

NOTE: The Contract Required Quantitation Limit (CRQL) values listed on the following pages are based on the analysis of samples according to the specifications given in Exhibit D.

Changes to the CRQL may be requested under the Modified Analysis (MA) clause in the contract.

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Exhibit C –Chlorinated Dibenzo-*p*-Dioxins and Chlorinated Dibenzofurans and Chlorinated Biphenyl Congeners Target Analyte List and Contract Required Quantitation Limits

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1.0 CHLORINATED DIBENZO-*p*-DIOXINS/CHLORINATED DIBENZOFURANS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 1. CHLORINATED DIBENZO-*p*-DIOXINS/CHLORINATED DIBENZOFURANS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

Analyte Name[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
2,3,7,8-TCDD	1746-01-6	10	1.0
1,2,3,7,8-PeCDD	40321-76-4	50	5.0
1,2,3,4,7,8-HxCDD	39227-28-6	50	5.0
1,2,3,6,7,8-HxCDD	57653-85-7	50	5.0
1,2,3,7,8,9-HxCDD	19408-74-3	50	5.0
1,2,3,4,6,7,8-HpCDD	35822-46-9	50	5.0
OCDD	3268-87-9	100	10
2,3,7,8-TCDF	51207-31-9	10	1.0
1,2,3,7,8-PeCDF	57117-41-6	50	5.0
2,3,4,7,8-PeCDF	57117-31-4	50	5.0
1,2,3,4,7,8-HxCDF	70648-26-9	50	5.0
1,2,3,6,7,8-HxCDF	57117-44-9	50	5.0
1,2,3,7,8,9-HxCDF	72918-21-9	50	5.0
2,3,4,6,7,8-HxCDF	60851-34-5	50	5.0
1,2,3,4,6,7,8-HpCDF	67562-39-4	50	5.0
1,2,3,4,7,8,9-HpCDF	55673-89-7	50	5.0
OCDF	39001-02-0	100	10

1.1 Homologues for Chlorinated Dibenzo-*p*-Dioxins/Chlorinated Dibenzofurans

Data are reported for the total concentration of all detected chlorinated dibenzo-*p*-dioxins (CDDs) or chlorinated dibenzofurans (CDFs) in the following homologues. However, because the number of non-2,3,7,8-substituted isomers that might be detected in a sample is unpredictable, it is not possible to assign CRQLs values to the total homologue concentrations with the exception of Octachlorinated dibenzo-*p*-dioxin (OCDD) and Octachlorinated dibenzofuran (OCDF).

TABLE 2. HOMOLOGUES FOR CHLORINATED DIBENZO-*p*-DIOXINS/ CHLORINATED DIBENZOFURANS

Homologue[C]	CAS Number	No. of Possible Isomers	No. of 2,3,7,8-Substituted Isomers
Total TCDD	41903-57-5	22	1
Total PeCDD	36088-22-9	14	1
Total HxCDD	34465-46-8	10	3
Total HpCDD	37871-00-4	2	1
Total TCDF	55722-27-5	38	1
Total PeCDF	30402-15-4	28	2
Total HxCDF	55684-94-1	16	4
Total HpCDF	38998-75-3	4	2
OCDD	3268-87-9	1	1
OCDF	39001-02-0	1	1

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2.0 CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 3. CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

Analyte Name	CBC[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
PCB-1	2-MoCB	2051-60-7	20	2.0
PCB-2	3-MoCB	2051-61-8	20	2.0
PCB-3	4-MoCB	2051-62-9	20	2.0
PCB-4	2,2'-DiCB	13029-08-8	20	2.0
PCB-5	2,3-DiCB	16605-91-7	20	2.0
PCB-6	2,3'-DiCB	25569-80-6	20	2.0
PCB-7	2,4-DiCB	33284-50-3	20	2.0
PCB-8	2,4'-DiCB	34883-43-7	20	2.0
PCB-9	2,5-DiCB	34883-39-1	20	2.0
PCB-10	2,6-DiCB	33146-45-1	20	2.0
PCB-11	3,3'-DiCB	2050-67-1	20	2.0
PCB-12	3,4-DiCB	2974-92-7	20	2.0
PCB-13	3,4'-DiCB	2974-90-5	20	2.0
PCB-14	3,5-DiCB	34883-41-5	20	2.0
PCB-15	4,4'-DiCB	2050-68-2	20	2.0
PCB-16	2,2',3-TrCB	38444-78-9	20	2.0
PCB-17	2,2',4-TrCB	37680-66-3	20	2.0
PCB-18	2,2',5-TrCB	37680-65-2	20	2.0
PCB-19	2,2',6-TrCB	38444-73-4	20	2.0
PCB-20	2,3,3'-TrCB	38444-84-7	20	2.0
PCB-21	2,3,4-TrCB	55702-46-0	20	2.0
PCB-22	2,3,4'-TrCB	38444-85-8	20	2.0
PCB-23	2,3,5-TrCB	55720-44-0	20	2.0
PCB-24	2,3,6-TrCB	55702-45-9	20	2.0
PCB-25	2,3',4-TrCB	55712-37-3	20	2.0
PCB-26	2,3',5-TrCB	38444-81-4	20	2.0
PCB-27	2,3',6-TrCB	38444-76-7	20	2.0
PCB-28	2,4,4'-TrCB	7012-37-5	20	2.0
PCB-29	2,4,5-TrCB	15862-07-4	20	2.0
PCB-30	2,4,6-TrCB	35693-92-6	20	2.0
PCB-31	2,4',5-TrCB	16606-02-3	20	2.0
PCB-32	2,4',6-TrCB	38444-77-8	20	2.0
PCB-33	2',3,4-TrCB	38444-86-9	20	2.0
PCB-34	2',3,5-TrCB	37680-68-5	20	2.0
PCB-35	3,3',4-TrCB	37680-69-6	20	2.0
PCB-36	3,3',5-TrCB	38444-87-0	20	2.0
PCB-37	3,4,4'-TrCB	38444-90-5	20	2.0
PCB-38	3,4,5-TrCB	53555-66-1	20	2.0
PCB-39	3,4',5-TrCB	38444-88-1	20	2.0
PCB-40	2,2',3,3'-TeCB	38444-93-8	20	2.0
PCB-41	2,2',3,4-TeCB	52663-59-9	20	2.0
PCB-42	2,2',3,4'-TeCB	36559-22-5	20	2.0
PCB-43	2,2',3,5-TeCB	70362-46-8	20	2.0
PCB-44	2,2',3,5'-TeCB	41464-39-5	20	2.0
PCB-45	2,2',3,6-TeCB	70362-45-7	20	2.0

TABLE 3. CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS (CON'T)

Analyte Name	CBC[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
PCB-46	2,2',3,6'-TeCB	41464-47-5	20	2.0
PCB-47	2,2',4,4'-TeCB	2437-79-8	20	2.0
PCB-48	2,2',4,5-TeCB	70362-47-9	20	2.0
PCB-49	2,2',4,5'-TeCB	41464-40-8	20	2.0
PCB-50	2,2',4,6-TeCB	62796-65-0	20	2.0
PCB-51	2,2',4,6'-TeCB	68194-04-7	20	2.0
PCB-52	2,2',5,5'-TeCB	35693-99-3	20	2.0
PCB-53	2,2',5,6'-TeCB	41464-41-9	20	2.0
PCB-54	2,2',6,6'-TeCB	15968-05-5	20	2.0
PCB-55	2,3,3',4-TeCB	74338-24-2	20	2.0
PCB-56	2,3,3',4'-TeCB	41464-43-1	20	2.0
PCB-57	2,3,3',5-TeCB	70424-67-8	20	2.0
PCB-58	2,3,3',5'-TeCB	41464-49-7	20	2.0
PCB-59	2,3,3',6-TeCB	74472-33-6	20	2.0
PCB-60	2,3,4,4'-TeCB	33025-41-1	20	2.0
PCB-61	2,3,4,5-TeCB	33284-53-6	20	2.0
PCB-62	2,3,4,6-TeCB	54230-22-7	20	2.0
PCB-63	2,3,4',5-TeCB	74472-34-7	20	2.0
PCB-64	2,3,4',6-TeCB	52663-58-8	20	2.0
PCB-65	2,3,5,6-TeCB	33284-54-7	20	2.0
PCB-66	2,3',4,4'-TeCB	32598-10-0	20	2.0
PCB-67	2,3',4,5-TeCB	73575-53-8	20	2.0
PCB-68	2,3',4,5'-TeCB	73575-52-7	20	2.0
PCB-69	2,3',4,6-TeCB	60233-24-1	20	2.0
PCB-70	2,3',4',5-TeCB	32598-11-1	20	2.0
PCB-71	2,3',4',6-TeCB	41464-46-4	20	2.0
PCB-72	2,3',5,5'-TeCB	41464-42-0	20	2.0
PCB-73	2,3',5',6-TeCB	74338-23-1	20	2.0
PCB-74	2,4,4',5-TeCB	32690-93-0	20	2.0
PCB-75	2,4,4',6-TeCB	32598-12-2	20	2.0
PCB-76	2',3,4,5-TeCB	70362-48-0	20	2.0
PCB-77	3,3',4,4'-TeCB	32598-13-3	20	2.0
PCB-78	3,3',4,5-TeCB	70362-49-1	20	2.0
PCB-79	3,3',4,5'-TeCB	41464-48-6	20	2.0
PCB-80	3,3',5,5'-TeCB	33284-52-5	20	2.0
PCB-81	3,4,4',5-TeCB	70362-50-4	20	2.0
PCB-82	2,2',3,3',4-PeCB	52663-62-4	20	2.0
PCB-83	2,2',3,3',5-PeCB	60145-20-2	20	2.0
PCB-84	2,2',3,3',6-PeCB	52663-60-2	20	2.0
PCB-85	2,2',3,4,4'-PeCB	65510-45-4	20	2.0
PCB-86	2,2',3,4,5-PeCB	55312-69-1	20	2.0
PCB-87	2,2',3,4,5'-PeCB	38380-02-8	20	2.0
PCB-88	2,2',3,4,6-PeCB	55215-17-3	20	2.0
PCB-89	2,2',3,4,6'-PeCB	73575-57-2	20	2.0
PCB-90	2,2',3,4',5-PeCB	68194-07-0	20	2.0
PCB-91	2,2',3,4',6-PeCB	68194-05-8	20	2.0
PCB-92	2,2',3,5,5'-PeCB	52663-61-3	20	2.0
PCB-93	2,2',3,5,6-PeCB	73575-56-1	20	2.0
PCB-94	2,2',3,5,6'-PeCB	73575-55-0	20	2.00
PCB-95	2,2',3,5',6-PeCB	38379-99-6	20	2.0
PCB-96	2,2',3,6,6'-PeCB	73575-54-9	20	2.0
PCB-97	2,2',3',4,5-PeCB	41464-51-1	20	2.0

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TABLE 3. CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS (CON'T)

Analyte Name	CBC[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
PCB-98	2,2',3',4,6-PeCB	60233-25-2	20	2.0
PCB-99	2,2',4,4',5-PeCB	38380-01-7	20	2.0
PCB-100	2,2',4,4',6-PeCB	39485-83-1	20	2.0
PCB-101	2,2',4,5,5'-PeCB	37680-73-2	20	2.0
PCB-102	2,2',4,5,6'-PeCB	68194-06-9	20	2.0
PCB-103	2,2',4,5',6-PeCB	60145-21-3	20	2.0
PCB-104	2,2',4,6,6'-PeCB	56558-16-8	20	2.0
PCB-105	2,3,3',4,4'-PeCB	32598-14-4	20	2.0
PCB-106	2,3,3',4,5-PeCB	70424-69-0	20	2.0
PCB-107	2,3,3',4',5-PeCB	70424-68-9	20	2.0
PCB-108	2,3,3',4,5'-PeCB	70362-41-3	20	2.0
PCB-109	2,3,3',4,6-PeCB	74472-35-8	20	2.0
PCB-110	2,3,3',4',6-PeCB	38380-03-9	20	2.0
PCB-111	2,3,3',5,5'-PeCB	39635-32-0	20	2.0
PCB-112	2,3,3',5,6-PeCB	74472-36-9	20	2.0
PCB-113	2,3,3',5',6-PeCB	68194-10-5	20	2.0
PCB-114	2,3,4,4',5-PeCB[3]	74472-37-0	20	2.0
PCB-115	2,3,4,4',6-PeCB	74472-38-1	20	2.0
PCB-116	2,3,4,5,6-PeCB	18259-05-7	20	2.0
PCB-117	2,3,4',5,6-PeCB	68194-11-6	20	2.0
PCB-118	2,3',4,4',5-PeCB	31508-00-6	20	2.0
PCB-119	2,3',4,4',6-PeCB	56558-17-9	20	2.0
PCB-120	2,3',4,5,5'-PeCB	68194-12-7	20	2.0
PCB-121	2,3',4,5',6-PeCB	56558-18-0	20	2.0
PCB-122	2',3,3',4,5-PeCB	76842-07-4	20	2.0
PCB-123	2',3,4,4',5-PeCB	65510-44-3	20	2.0
PCB-124	2',3,4,5,5'-PeCB	70424-70-3	20	2.0
PCB-125	2',3,4,5,6'-PeCB	74472-39-2	20	2.0
PCB-126	3,3',4,4',5-PeCB	57465-28-8	20	2.0
PCB-127	3,3',4,5,5'-PeCB	39635-33-1	20	2.0
PCB-128	2,2',3,3',4,4'-HxCB	38380-07-3	20	2.0
PCB-129	2,2',3,3',4,5-HxCB	55215-18-4	20	2.0
PCB-130	2,2',3,3',4,5'-HxCB	52663-66-8	20	2.0
PCB-131	2,2',3,3',4,6-HxCB	61798-70-7	20	2.0
PCB-132	2,2',3,3',4,6'-HxCB	38380-05-1	20	2.0
PCB-133	2,2',3,3',5,5'-HxCB	35694-04-3	20	2.0
PCB-134	2,2',3,3',5,6-HxCB	52704-70-8	20	2.0
PCB-135	2,2',3,3',5,6'-HxCB	52744-13-5	20	2.0
PCB-136	2,2',3,3',6,6'-HxCB	38411-22-2	20	2.0
PCB-137	2,2',3,4,4',5-HxCB	35694-06-5	20	2.0
PCB-138	2,2',3,4,4',5'-HxCB	35065-28-2	20	2.0
PCB-139	2,2',3,4,4',6-HxCB	56030-56-9	20	2.0
PCB-140	2,2',3,4,4',6'-HxCB	59291-64-4	20	2.0
PCB-141	2,2',3,4,5,5'-HxCB	52712-04-6	20	2.0
PCB-142	2,2',3,4,5,6-HxCB	41411-61-4	20	2.0
PCB-143	2,2',3,4,5,6'-HxCB	68194-15-0	20	2.0
PCB-144	2,2',3,4,5',6-HxCB	68194-14-9	20	2.0
PCB-145	2,2',3,4,6,6'-HxCB	74472-40-5	20	2.0

TABLE 3. CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS (CON'T)

Analyte Name	CBC[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
PCB-146	2,2',3,4',5,5'-HxCB	51908-16-8	20	2.0
PCB-147	2,2',3,4',5,6-HxCB	68194-13-8	20	2.0
PCB-148	2,2',3,4',5,6'-HxCB	74472-41-6	20	2.0
PCB-149	2,2',3,4',5',6-HxCB	38380-04-0	20	2.0
PCB-150	2,2',3,4',6,6'-HxCB	68194-08-1	20	2.0
PCB-151	2,2',3,5,5',6-HxCB	52663-63-5	20	2.0
PCB-152	2,2',3,5,6,6'-HxCB	68194-09-2	20	2.0
PCB-153	2,2',4,4',5,5'-HxCB	35065-27-1	20	2.0
PCB-154	2,2',4,4',5,6'-HxCB	60145-22-4	20	2.0
PCB-155	2,2',4,4',6,6'-HxCB	33979-03-2	20	2.0
PCB-156	2,3,3',4,4',5-HxCB	38380-08-4	20	2.0
PCB-157	2,3,3',4,4',5'-HxCB	69782-90-7	20	2.0
PCB-158	2,3,3',4,4',6-HxCB	74472-42-7	20	2.0
PCB-159	2,3,3',4,5,5'-HxCB	39635-35-3	20	2.0
PCB-160	2,3,3',4,5,6-HxCB	41411-62-5	20	2.0
PCB-161	2,3,3',4,5',6-HxCB	74472-43-8	20	2.0
PCB-162	2,3,3',4',5,5'-HxCB	39635-34-2	20	2.0
PCB-163	2,3,3',4',5,6-HxCB	74472-44-9	20	2.0
PCB-164	2,3,3',4',5',6-HxCB	74472-45-0	20	2.0
PCB-165	2,3,3',5,5',6-HxCB	74472-46-1	20	2.0
PCB-166	2,3,4,4',5,6-HxCB	41411-63-6	20	2.0
PCB-167	2,3',4,4',5,5'-HxCB	52663-72-6	20	2.0
PCB-168	2,3',4,4',5',6-HxCB	59291-65-5	20	2.0
PCB-169	3,3',4,4',5,5'-HxCB	32774-16-6	20	2.0
PCB-170	2,2',3,3',4,4',5-HpCB	35065-30-6	20	2.0
PCB-171	2,2'3,3',4,4',6-HpCB	52663-71-5	20	2.0
PCB-172	2,2',3,3',4,5,5'-HpCB	52663-74-8	20	2.0
PCB-173	2,2',3,3',4,5,6-HpCB	68194-16-1	20	2.0
PCB-174	2,2',3,3',4,5,6'-HpCB	38411-25-5	20	2.0
PCB-175	2,2',3,3',4,5',6-HpCB	40186-70-7	20	2.0
PCB-176	2,2',3,3',4,6,6'-HpCB	52663-65-7	20	2.0
PCB-177	2,2',3,3',4',5,6-HpCB	52663-70-4	20	2.0
PCB-178	2,2',3,3',5,5',6-HpCB	52663-67-9	20	2.0
PCB-179	2,2',3,3',5,6,6'-HpCB	52663-64-6	20	2.0
PCB-180	2,2',3,4,4',5,5'-HpCB	35065-29-3	20	2.0
PCB-181	2,2',3,4,4',5,6-HpCB	74472-47-2	20	2.0
PCB-182	2,2',3,4,4',5,6'-HpCB	60145-23-5	20	2.0
PCB-183	2,2',3,4,4',5',6-HpCB	52663-69-1	20	2.0
PCB-184	2,2',3,4,4',6,6'-HpCB	74472-48-3	20	2.0
PCB-185	2,2',3,4,5,5',6-HpCB	52712-05-7	20	2.0
PCB-186	2,2',3,4,5,6,6'-HpCB	74472-49-4	20	2.0
PCB-187	2,2',3,4',5,5',6-HpCB	52663-68-0	20	2.0
PCB-188	2,2',3,4',5,6,6'-HpCB	74487-85-7	20	2.0
PCB-189	2,3,3',4,4',5,5'-HpCB	39635-31-9	20	2.0
PCB-190	2,3,3',4,4',5,6-HpCB	41411-64-7	20	2.0
PCB-191	2,3,3',4,4',5',6-HpCB	74472-50-7	20	2.0
PCB-192	2,3,3',4,5,5',6-HpCB	74472-51-8	20	2.0
PCB-193	2,3,3',4',5,5',6-HpCB	69782-91-8	20	2.0
PCB-194	2,2',3,3',4,4',5,5'-OcCB	35694-08-7	20	2.0
PCB-195	2,2',3,3',4,4',5,6-OcCB	52663-78-2	20	2.0
PCB-196	2,2',3,3',4,4',5,6'-OcCB	42740-50-1	20	2.0
PCB-197	2,2',3,3',4,4',6,6'-OcCB	33091-17-7	20	2.0
PCB-198	2,2',3,3',4,5,5',6-OcCB	68194-17-2	20	2.0

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TABLE 3. CHLORINATED BIPHENYL CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS (CON'T)

Analyte Name	CBC[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
PCB-199	2,2',3,3',4,5,5',6'-OcCB	52663-75-9	20	2.0
PCB-200	2,2',3,3',4,5,6,6'-OcCB	52663-73-7	20	2.0
PCB-201	2,2',3,3',4,5',6,6'-OcCB	40186-71-8	20	2.0
PCB-202	2,2',3,3',5,5',6,6'-OcCB	2136-99-4	20	2.0
PCB-203	2,2',3,4,4',5,5',6-OcCB	52663-76-0	20	2.0
PCB-204	2,2',3,4,4',5,6,6'-OcCB	74472-52-9	20	2.0
PCB-205	2,3,3',4,4',5,5',6-OcCB	74472-53-0	20	2.0
PCB-206	2,2',3,3',4,4',5,5',6-NoCB	40186-72-9	20	2.0
PCB-207	2,2',3,3',4,4',5,6,6'-NoCB	52663-79-3	20	2.0
PCB-208	2,2',3,3',4,5,5',6,6'-NoCB	52663-77-1	20	2.0
PCB-209	DeCB	2051-24-3	20	2.0

2.1 Homologues for Chlorinated Biphenyl Congeners

Data are reported for the total concentration of all detected chlorinated biphenyl congeners in the following homologues. However, because the calculation of the total homologue concentrations is a mathematical computation, it is not possible to assign CRQLs values to these values with the exception of Decachlorobiphenyl (DeCB).

TABLE 4. CHLORINATED BIPHENYL CONGENERS HOMOLOGUES

Homologue[C]	CAS Number
Total MoCB	27323-18-8
Total DiCB	25512-42-9
Total TrCB	25323-68-6
Total TeCB	26914-33-0
Total PeCB	25429-29-2
Total HxCB	26601-64-9
Total HpCB	28655-71-2
Total OcCB	55722-26-4
Total NoCB	53742-07-7
DeCB	2051-24-3

3.0 WORLD HEALTH ORGANIZATION TOXIC CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

TABLE 5. WORLD HEALTH ORGANIZATION TOXIC CONGENERS TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTITATION LIMITS

Analyte Name	CBC[C]	CAS Number	CRQL[A] Water (pg/L)	CRQL[A] Solids[B] (ng/kg)
PCB-77	3,3',4,4'-TeCB	32598-13-3	20	2.0
PCB-81	3,4,4',5-TeCB	70362-50-4	20	2.0
PCB-105	2,3,3',4,4'-PeCB	32598-14-4	20	2.0
PCB-114	2,3,4,4',5-PeCB	74472-37-0	20	2.0
PCB-118	2,3',4,4',5-PeCB	31508-00-6	20	2.0
PCB-123	2',3,4,4',5-PeCB	65510-44-3	20	2.0
PCB-126	3,3',4,4',5-PeCB	57465-28-8	20	2.0
PCB-156	2,3,3',4,4',5-HxCB	38380-08-4	20	2.0
PCB-157	2,3,3',4,4',5'-HxCB	69782-90-7	20	2.0
PCB-167	2,3',4,4',5,5'-HxCB	52663-72-6	20	2.0
PCB-169	3,3',4,4',5,5'-HxCB	32774-16-6	20	2.0
PCB-189	2,3,3',4,4',5,5'-HpCB	39635-31-9	20	2.0

4.0 ADDITIONAL REPORTING REQUIREMENTS

TABLE 6. ADDITIONAL CHLORINATED DIBENZO-*p*-DIOXINS/CHLORINATED DIBENZOFURANS REPORTING REQUIREMENTS

CDD/CDF	SMO ASSIGNED NO.
TEQ (Mammal)	3333-30-0
TEQ (Bird)	2222-20-0
TEQ (Fish)	2222-21-0

TABLE 7. ADDITIONAL CHLORINATED BIPHENYL CONGENERS REPORTING REQUIREMENTS

CB Congener	SMO ASSIGNED NO.
TOTAL PCBs	1111-11-1
TEQ (Mammal)	2222-22-2
TEQ (Bird)	2222-22-3
TEQ (Fish)	2222-22-4

Endnotes:

A. The CRQLs in these tables are equivalent to the concentration of the low calibration (CS1) standard, assuming that all sample weight, volumes, and cleanup procedures are performed according to Exhibit D of this Statement of Work (SOW).

Specific quantitation limits are highly matrix-dependent. The quantitation limit listed herein is provided for guidance and may not always be achievable.

These CRQL values are based on the analysis of samples according to the specification given in Exhibit D. Sample data are reported on a dry weight basis for soil/sediment samples. Sludge and oily matrices are generally reported on a wet weight basis due to their potentially hazardous nature. Tissues (non-human) are reported on a wet weight basis, along with their Percent Lipids (%Lipids) content.

016419

NOTE: The values in these tables are quantitation limits, not absolute detection limits. The amount of material necessary to produce a detector response that can be identified and reliably quantified is greater than that needed to be simply detected above the background noise. For some congeners, the CRQLs may be dependent upon coelutions encountered during analysis.

B. Solids include soil/sediment, sludge, tissue (non-human), biosolids, ash, oil, and oily matrices. For oil samples, if 2.0 g sample size was used, then these CRQLs need to be adjusted accordingly.

C. Abbreviations for chlorination levels:

CDDs/CDFs

TCDD = Tetrachlorinated dibenzo-*p*-dioxin
TCDF = Tetrachlorinated dibenzofuran
PeCDD = Pentachlorinated dibenzo-*p*-dioxin
PeCDF = Pentachlorinated dibenzofuran
HxCDD = Hexachlorinated dibenzo-*p*-dioxin
HxCDF = Hexachlorinated dibenzofuran
HpCDD = Heptachlorinated dibenzo-*p*-dioxin
HpCDF = Heptachlorinated dibenzofuran
OCDD = Octachlorinated dibenzo-*p*-dioxin
OCDF = Octachlorinated dibenzofuran

CBCs

MoCB = Monochlorobiphenyl
DiCB = Dichlorobiphenyl
TrCB = Trichlorobiphenyl
TeCB = Tetrachlorobiphenyl
PeCB = Pentachlorobiphenyl
HxCB = Hexachlorobiphenyl
HpCB = Heptachlorobiphenyl
OcCB = Octachlorobiphenyl
NoCB = Nonachlorobiphenyl
DeCB = Decachlorobiphenyl

Appendix D

Field Forms

FIELD SAMPLING FORM FOR VI ASSESSMENT

Samplers:	Site ID / Bldg ID	**EA Project #:** 14342128 **Client:** EPA Region 6 **Site:** Wilcox Oil Company Superfund Site **Description:** Vapor Intrusion Assessment Sampling

Location ID: _____

Probe Installation Date/Time: _____

Slab Thickness:_____Probe Length: _____

Helium Leak Check Date/Time: _____

He% Shroud_____ He% Tedlar Bag_____ VOC Purge _____

Shut in Check PSI drop in 1 minute: _____

Sample Type /Analysis: ☐ Indoor Air / TO-15 SIM
☐ Sub-Slab / TO-15 SIM
☐ Outdoor Air /TO-15 SIM

Duplicate: ☐ Yes ☐ No

Pressure recorded in Inches of Hg

Summa Sample ID: _____

Summa Canister ID: _____

Initial Gauge Pressure:_____ Initial Reg. Pressure: _____

Flow Control ID: _____

Flow Control Rate: _____

Canister Start Date/Time: _____

Canister End Date/Time: _____

Final Canister Gauge Pressure: _____

Duplicate

Summa Sample ID:_____

Summa Canister ID:_____

Initial Gauge Pressure:____ Initial Reg. Pressure:_____

Flow Control ID:_____

Flow Control Rate:_____

Canister Start Date/Time:_____

Canister End Date/Time:_____

Final Canister Gauge Pressure:_____

Comments/Observations:

_____

_____

_____

_____

_____

Sediment and Surface Water Collection Field Form

Exposure Area:_____

Sample Date:_____

GPS Coordinates:

Weather Conditions:_____

Lat:_____

Surface Water ID:_____

Long:_____

Collection Time:_____

Sediment ID:_____

Sampling Personnel: _____

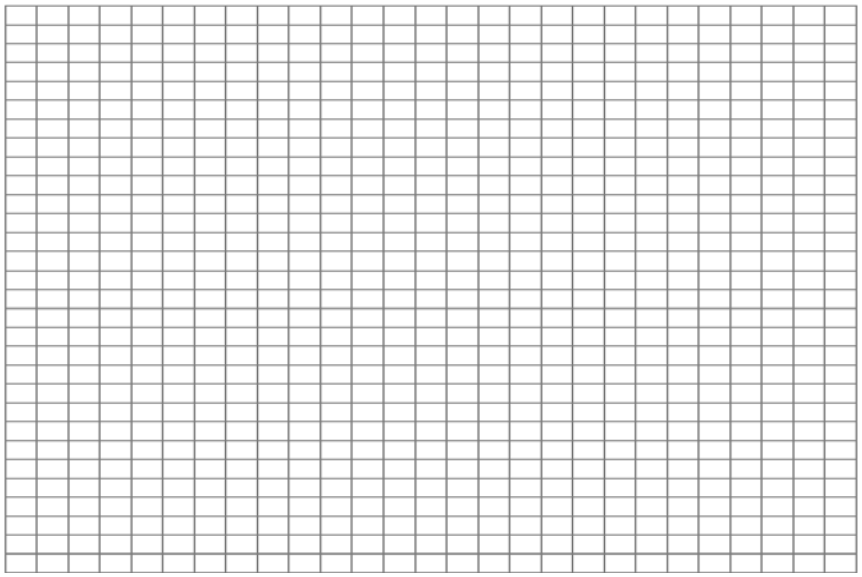
Collection Time:_____

Sediment Description (soil type, color, density/consistency, plasticity, moisture, grain size, angularity/mineralogy, other):_____

Surface Water Parameters:

Temperature: _____°C **pH: _____** **Conductivity: _____ ms/cm** **TDS: _____ ppm** **ORP: _____mv** **Turbidity: _____ntu**

Location Map:



Depth (bgs):

Sampling Method:
Geoprobe
Slide Hammer Probe
Scoop
Ponar
Core Sampler

Pump
Dipper

Analyses:
VOCs
SVOCS
Metals
Hexavalent Chromium
Pesticides
Aroclors

Notes/Comments:_____

Recorded By:_____

Soil Collection Field Form

Exposure Area:_____ **Weather:**_____

Sampling Location:_____ **GPS Coordinates:** **Lat:**_____

Sample ID:_____ **Long:**_____

Sampling Personnel: _____ **Sample Date/Time:**_____

Depth (bgs): **Description** (soil type, color, density/consistency, plasticity, moisture, grain size, angularity/mineralogy, other):

XRF Data:

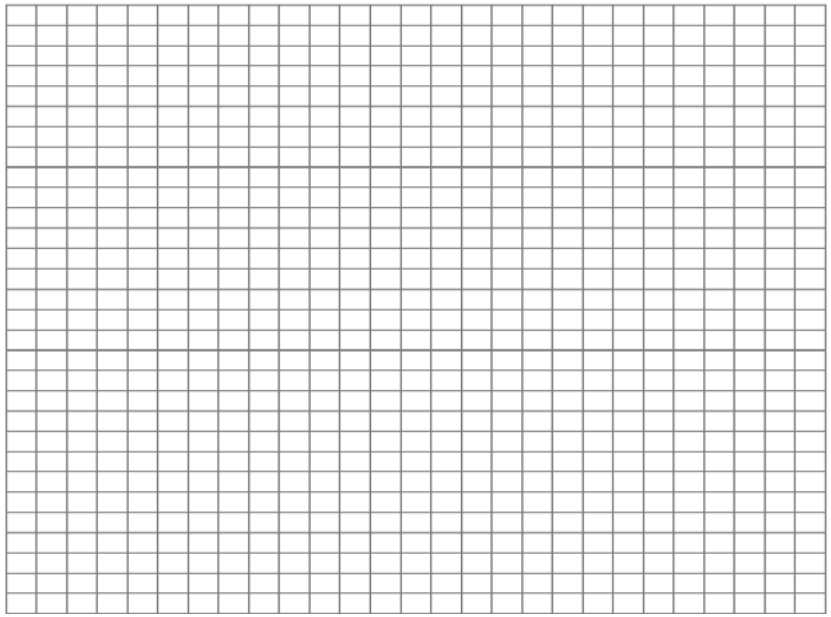
Interval: _____ _____ _____ _____

_____ _____ _____ _____

_____ _____ _____ _____

_____ _____ _____ _____

Location Map:



Sampling Method: (circle)
Geoprobe
Slide Hammer Probe
Scoop
Ponar
Core Sampler
Other

Analyses:
(circle and indicate number of containers)
VOCs
SVOCS
Metals
Hexavalent Chromium
Pesticides
Aroclors

Notes/Comments:

Recorded By: _____

Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

Page: _____ of _____
Date: _____

Ground Water Collection Field Form

Well ID: _____ **Sample ID:** _____ **Sample Time:** _____

Casing diameter/type: | Well location: | Weather:

Screened interval(s): | Sampling personnel:

Total depth: | Sampling method:

Initial depth to water (w/o pump): | Water level indicator:

Final depth to water (w/o pump): | Water quality meter: YSI

Measuring point: **North side of casing** | Pump depth setting: | Pump type/model:

	Δ < 1° C	Δ < 3%	Δ <10%	Δ <10%	Δ < 0.1 pH	Δ < 10 mV	Δ < 0.3 ft	< 1L/min	Δ < 10 NTU		Parameter Stabilization Limits (3 consecutive readings)
Time	**Temp (°C)**	**Conductivity (mS/cm)** or **(µS/cm)**	**DO (%)**	**DO (mg/L)**	**pH**	**ORP (mV)**	**Water Level (feet btoc)**	**Flow Rate (L/min)** or **(mL/min)**	**Turbidity (NTU)**	**Purge Volume (L)** or **(mL)**	**Additional Comments**

Note:

Parameter Stabilization Limits:
(3 consecutive readings) for percent difference type parameters
Percent difference formula =
ABS[((first reading - second reading)/first reading) x 100]
Ex: Readings 12, 16, 15, 13
((12-16)/12)*100 = 33% ((16-15)/16)*100 = 6%
((15-13)/15)*100 = 13% In example, stabilization has not occurred.

Analyses: (circle those collected and indicate the number of containers)

VOCs	Metals	Pesticides
SVOCS	Hexavalent Chromium	Aroclors

Recorded By:_____

016425

Tap Water Collection Field Form

Well ID: _____ **Sample ID:** _____ **Sample Time:** _____

Well owner/location/residence: _____

Street address: _____

Filtration system? (circle one) Y N	Sampling personnel:
Start purge time:	Weather:
End purge time:	Purge Rate (gal/min):

Sample collected at (circle as appropriate): Wellhead tap In-line House tap

Field Parameters:

					Within	Circle One:	
Time:							
Specific Conductance:					**10%**	us/cm	ms/cm
pH:					**+/- 0.5**		
Temperature:					**+/- 1 C**	F°	C°
ORP:						mV	

Notes/Comments: _____

Analyses: (circle those collected and indicate the number of containers)

VOCs	Metals	Pesticides
SVOCS	Hexavalent Chromium	Aroclors

Well Configuration

Recorded By: _____

016426

Appendix E
Sanborn Maps and Historical Aerial Photographs

Wilcox/Lorraine Refinery
Refinery Rd
Bristow, OK 74010

Inquiry Number: 3313889.1
May 01, 2012

Certified Sanborn® Map Report

EDR® Environmental Data Resources Inc

440 Wheelers Farms Road
Milford, CT 06461
800.352.0050
www.edrnet.com

18 001

016428

Certified Sanborn® Map Report

5/01/12

Site Name:
Wilcox/Lorraine Refinery
Refinery Rd
Bristow, OK 74010

Client Name:
Dynamac Corporation
1202 Executive Drive West
Richardson, TX 75081

EDR Inquiry # 3313889.1

Contact: Kris Lloyd

EDR® Environmental Data Resources Inc

The complete Sanborn Library collection has been searched by EDR, and fire insurance maps covering the target property location provided by Dynamac Corporation were identified for the years listed below. The certified Sanborn Library search results in this report can be authenticated by visiting www.edrnet.com/sanborn and entering the certification number. Only Environmental Data Resources Inc. (EDR) is authorized to grant rights for commercial reproduction of maps by Sanborn Library LLC, the copyright holder for the collection.

Certified Sanborn Results:

Site Name: Wilcox/Lorraine Refinery
Address: Refinery Rd
City, State, Zip: Bristow, OK 74010
Cross Street:
P.O. # NA
Project: S109-20F
Certification # 398F-439D-A25F

Maps Provided:

1961
1923
1920
1915

Sanborn® Library search results
Certification # 398F-439D-A25F

The Sanborn Library includes more than 1.2 million Sanborn fire insurance maps, which track historical property usage in approximately 12,000 American cities and towns. Collections searched:

- ✓ Library of Congress
- ✓ University Publications of America
- ✓ EDR Private Collection

The Sanborn Library LLC Since 1866™

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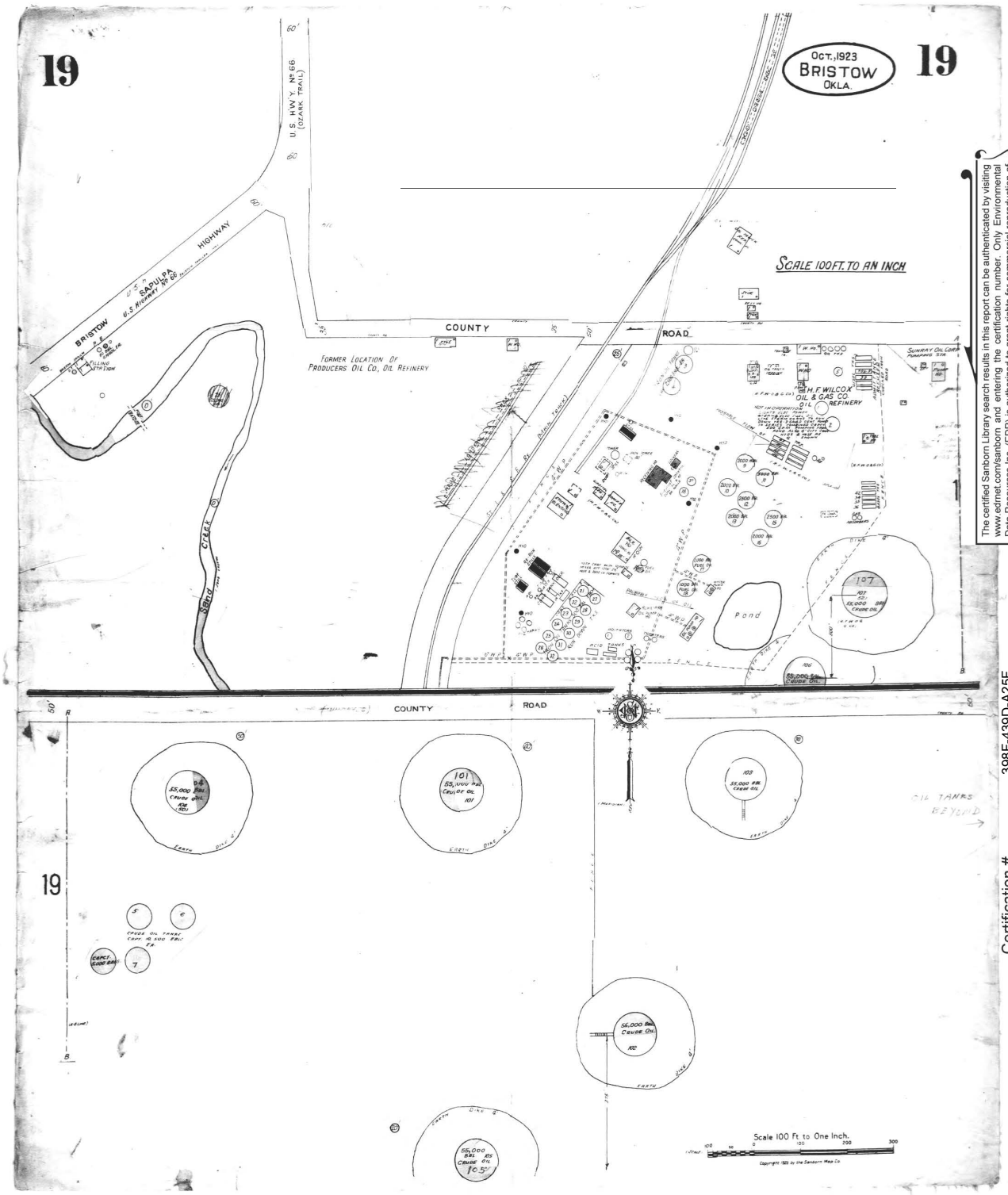
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1961 Certified Sanborn Map



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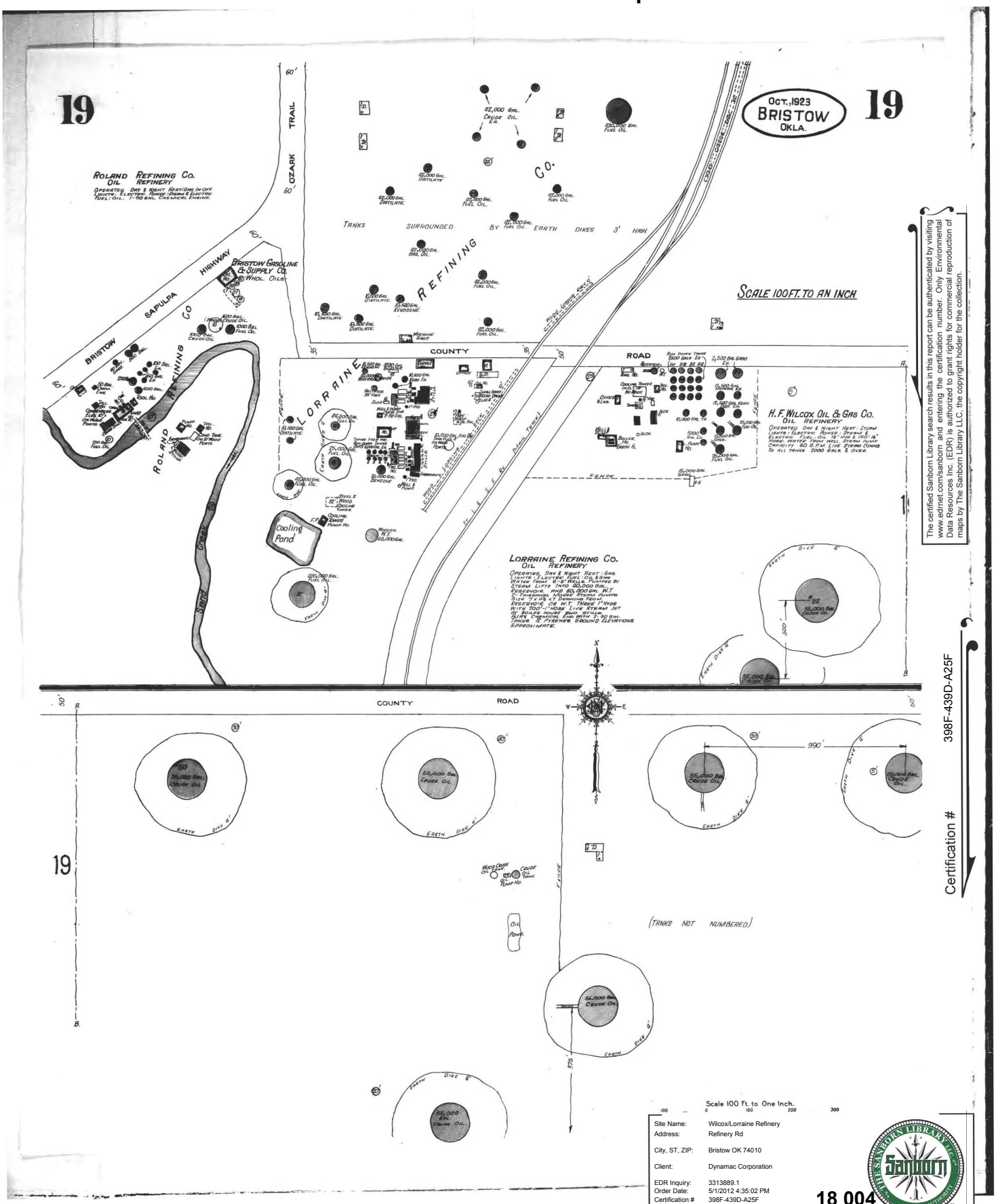
Certification # 398F-439D-A25F

Site Name:	Wilcox/Lorraine Refinery
Address:	Refinery Rd
City, ST, ZIP:	Bristow OK 74010
Client:	Dynamac Corporation
EDR Inquiry:	3313889.1
Order Date:	5/1/2012 4:35:02 PM
Certification #	398F-439D-A25F
Copyright:	1961

18 003

016430

1923 Certified Sanborn Map

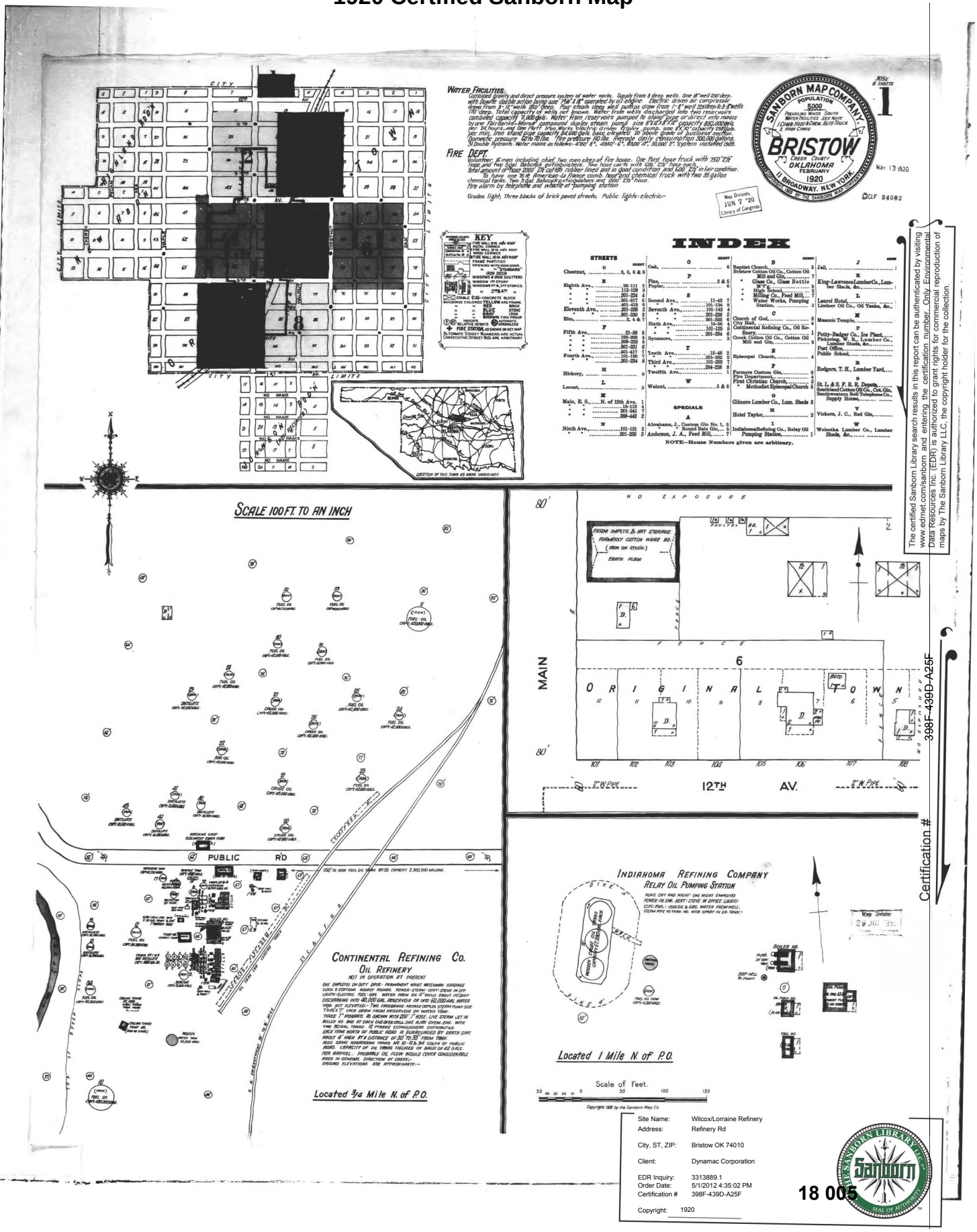


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016431

1920 Certified Sanborn Map

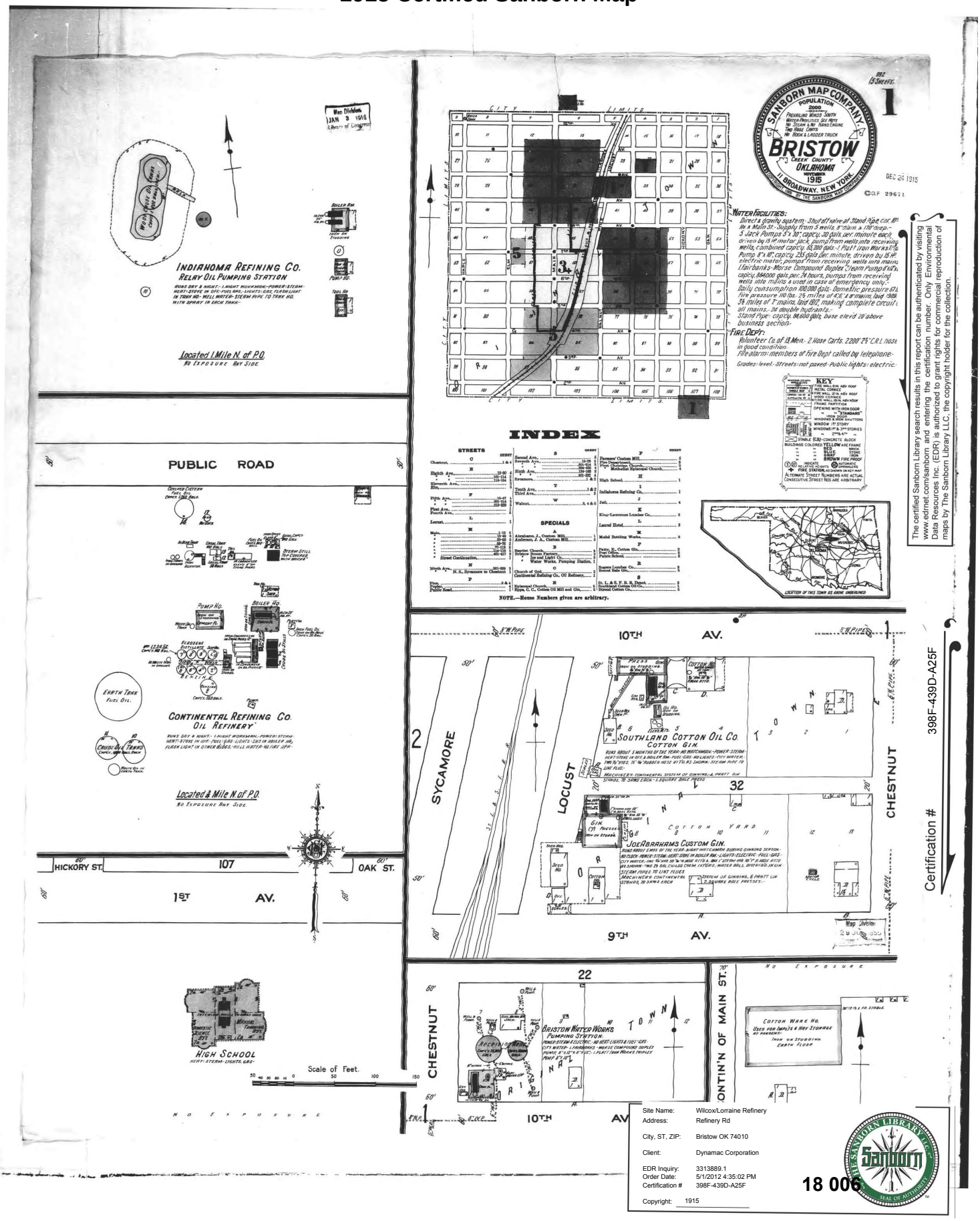


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Certification # 398F-439D-A25F

016432

1915 Certified Sanborn Map



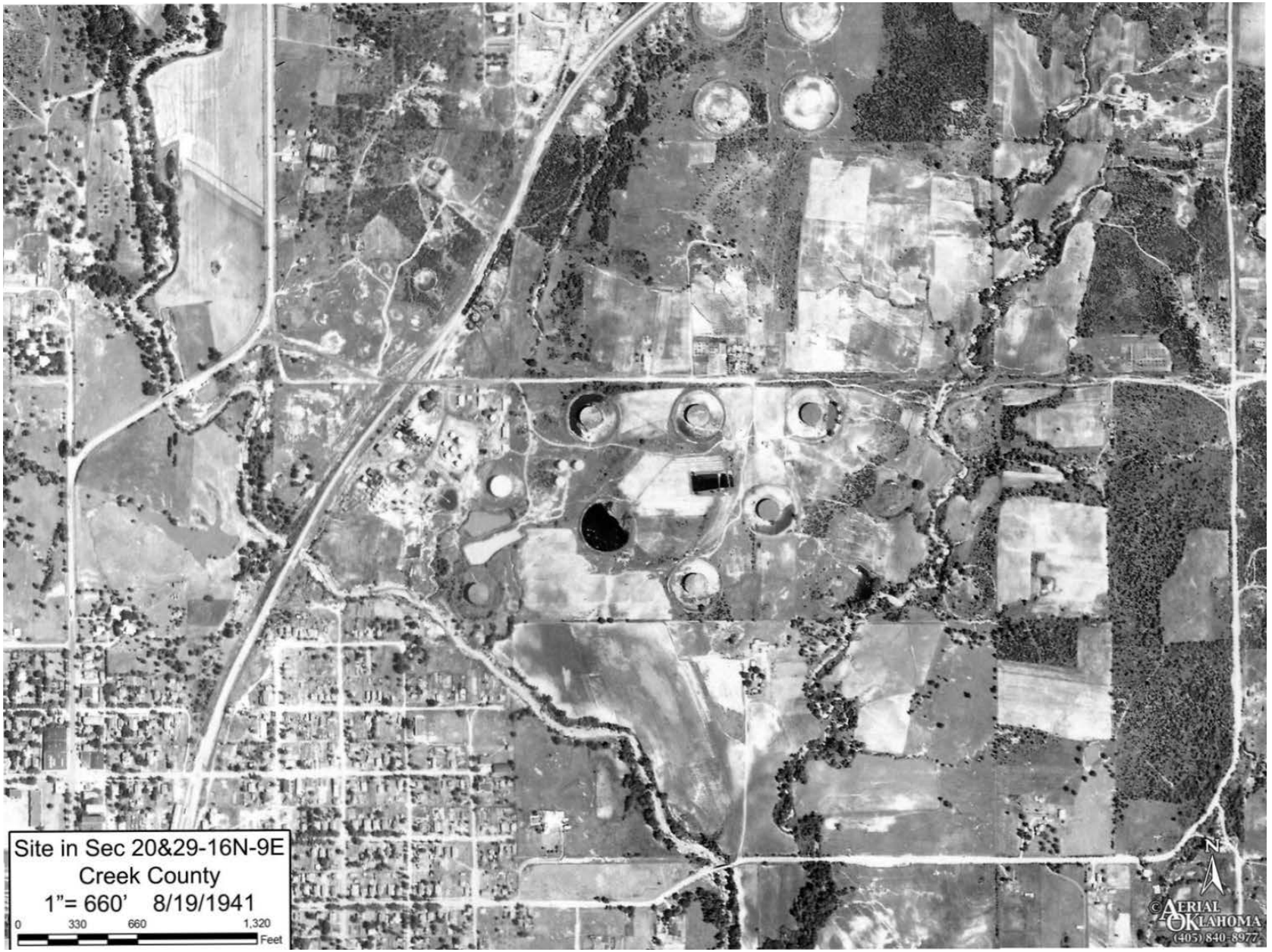
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Certification # 398F-439D-A25F

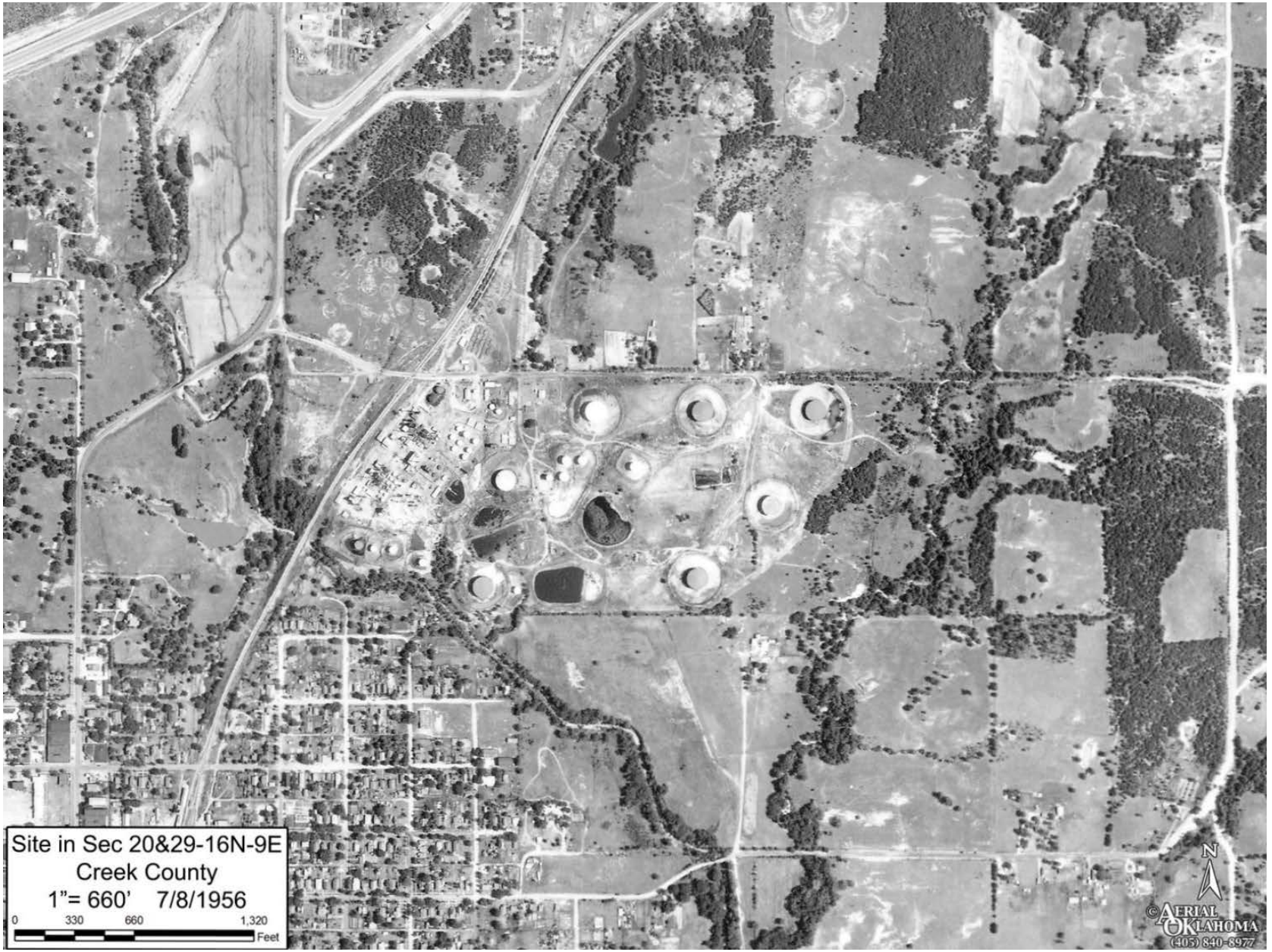
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Address:	Refinery Rd
City, ST, ZIP:	Bristow OK 74010
Client:	Dynamac Corporation
EDR Inquiry:	3313889.1
Order Date:	5/1/2012 4:35:02 PM
Certification #	398F-439D-A25F
Copyright:	1915

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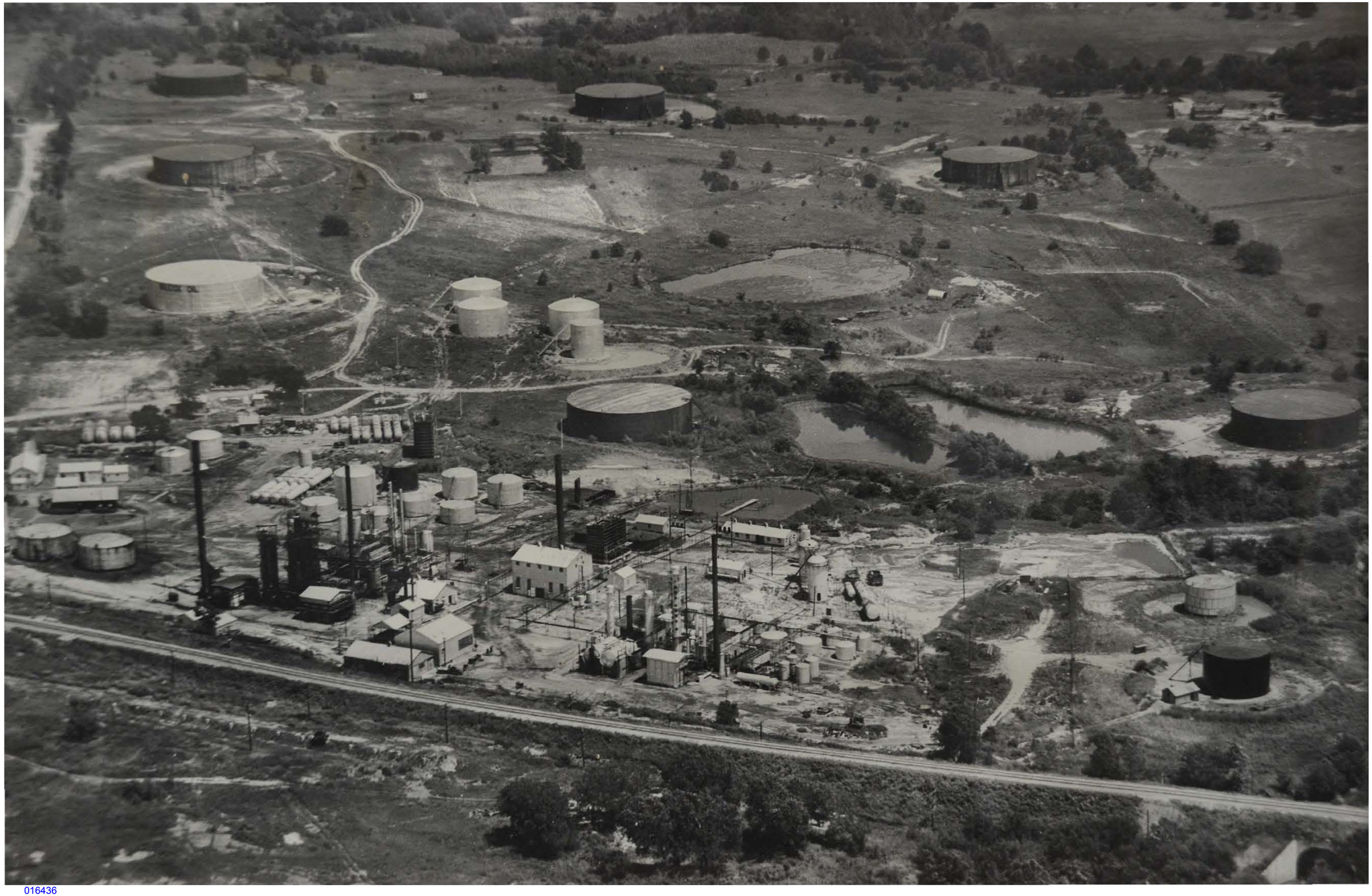
016433


Site in Sec 20&29-16N-9E
Creek County
1"= 660' 8/19/1941
0 330 660 1,320
Feet
N
©AERIAL OKLAHOMA
(405) 840-8977

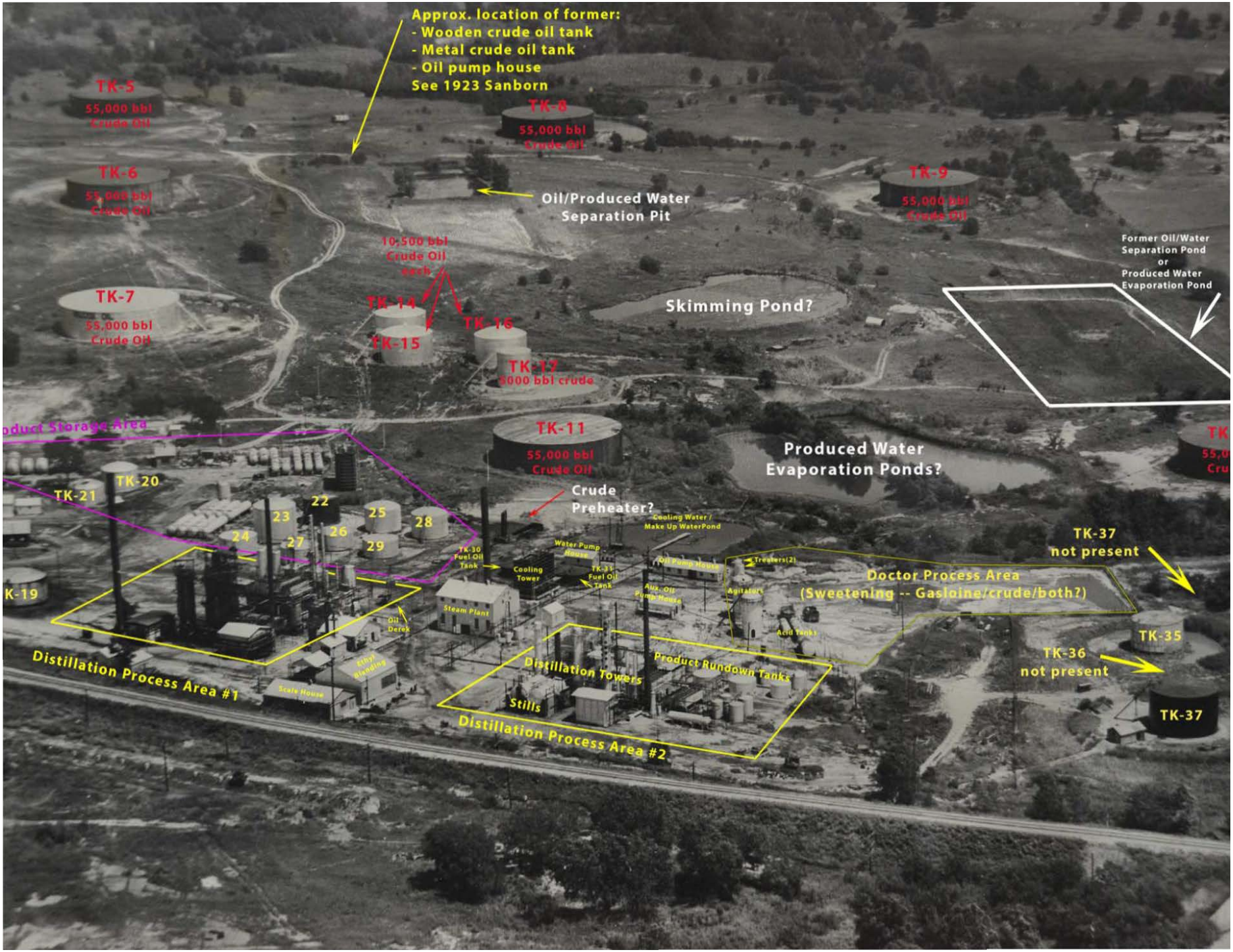
016434


Site in Sec 20&29-16N-9E
Creek County
1"= 660' 7/8/1956
0 330 660 1,320
Feet
N
© Aerial Oklahoma
(405) 840-8977

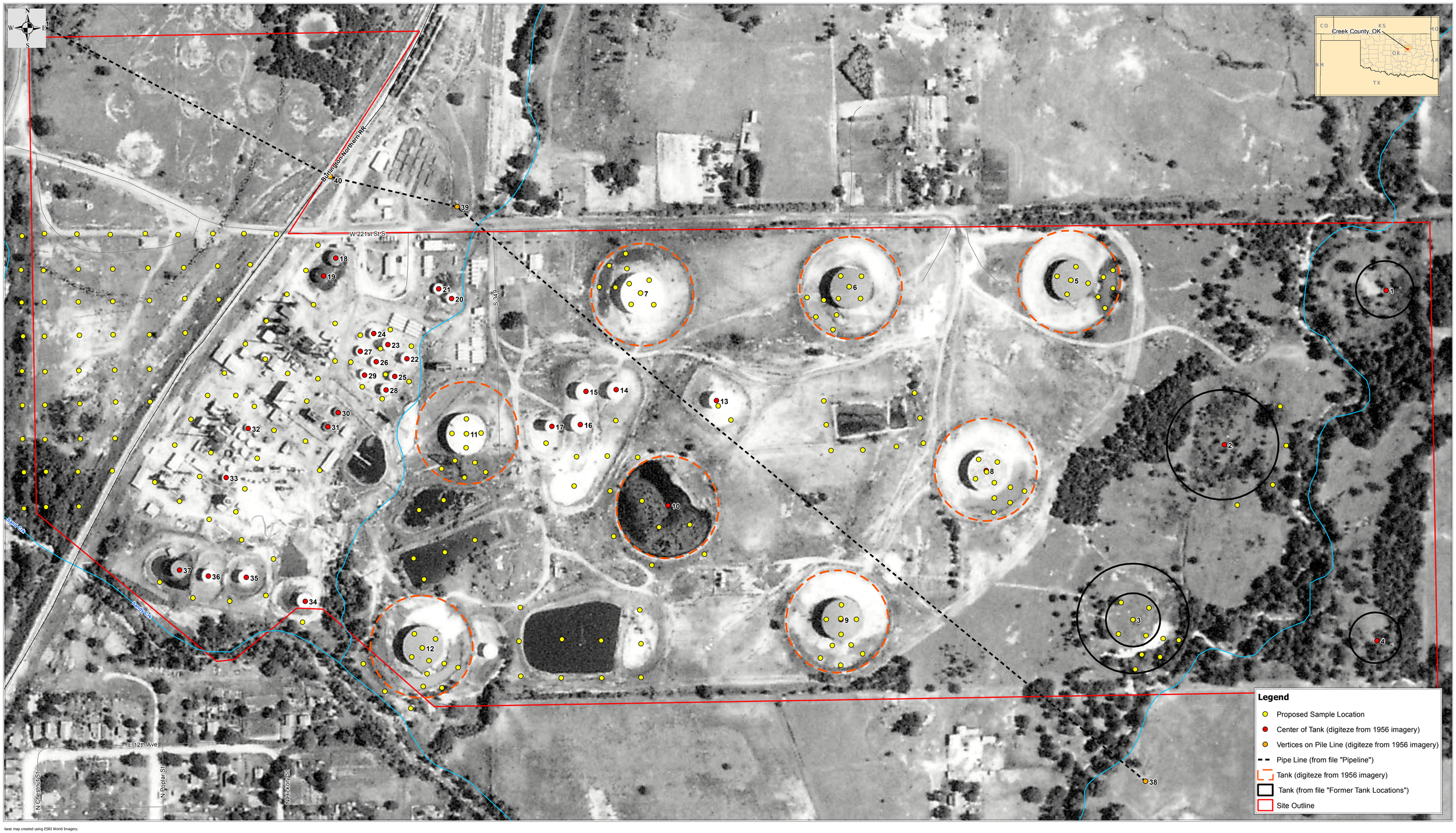
016435



016436


Approx. location of former:
- Wooden crude oil tank
- Metal crude oil tank
- Oil pump house
See 1923 Sanborn
TK-5
55,000 bbl
Crude Oil
TK-8
55,000 bbl
Crude Oil
TK-6
55,000 bbl
Crude Oil
TK-9
55,000 bbl
Crude Oil
Oil/Produced Water
Separation Pit
10,500 bbl
Crude Oil
each
TK-14
TK-15
TK-16
TK-17
8000 bbl crude
TK-7
55,000 bbl
Crude Oil
Skimming Pond?
Former Oil/Water
Separation Pond
or
Produced Water
Evaporation Pond
TK-11
55,000 bbl
Crude Oil
Produced Water
Evaporation Ponds?
Crude
Preheater?
TK-21
TK-20
TK-19
22
23
24
25
26
27
28
29
TK-30
Fuel Oil
Tank
Cooling
Tower
Water Pump
House
TK-31
Fuel Oil
Tank
Cooling Water /
Make Up WaterPond
Oil Pump House
Aux. Oil
Pump House
Steam Plant
Oil
Derek
Ethyl
Blending
Scale House
Distillation Process Area #1
Distillation Towers
Stills
Distillation Process Area #2
Product Rundown Tanks
Treaters(2)
Agitators
Acid Tanks
Doctor Process Area
(Sweetening -- Gasoline/crude/both?)
TK-37
not present
TK-35
TK-36
not present
TK-37

016437



base map created using ESRI World Imagery.

Map Creation Date: 17 July 2015

Coordinate system: Oklahoma State Plane North
FIPS: 3501
Datum: NAD83
Units: Feet

0 125 250 Feet

D R A F T

Data: g:\arcviewprojects\SERAS01\00-277
MXD file: g:\arcinfoprojects\SERAS01\SER00277_Wilcox_Refinery\277_Temp_Site_Features_Locations_Dsize_fX.mxd

U.S. EPA Environmental Response Team
Scientific Engineering Response and Analytical Services
EP-W-09-031
W.A.# 0-277

Figure X
Site Features Locations
Wilcox Refinery Direct-Sensing Investigation
Bristow, Oklahoma

016438

Appendix F

Vapor Intrusion Sampling Procedures

VAPOR INTRUSION SAMPLING PROCEDURES

INTRODUCTION

An inspection of general site conditions will be performed at each property location as part of the air sampling. The inspection will include the following activities:

- Completion of an Indoor Air Quality Questionnaire and Building Inventory (attached)
- Documentation of outdoor weather conditions and indoor temperature
- Selection of air sampling locations.

1. FIELD ACTIVITIES

The semi-permanent, sub-slab soil gas monitoring points will be installed prior to the collection of indoor and outdoor air samples so that sampling activities can occur within the same timeframe as close to simultaneously as possible. Depending on the type of media used to seal the monitoring point, each semi-permanent sub-slab soil gas monitoring point will be allowed to set up for at least 12 hours prior to purging and leak check testing. Once the purging and leak check tests have been performed, indoor air and outdoor ambient air samples will be set up for sample collection. The indoor and outdoor air samples will be collected concurrently over the same time period as the sub-slab samples. Subsequent rounds of sampling will follow the same protocol as implemented during the first round, so that analytical data results from both sampling events will be comparable.

During field activities, field data sheets will be used to record details of the sub-slab soil gas, indoor air, and outdoor ambient air sampling activities, which will include the following information, at a minimum and as applicable:

- Source area identification and building identification
- Sample identification
- Sampling location
- Sub-slab monitoring point installation date and time
- Summa canister and associated flow-control device serial number identification
- Flow-control device sample flow rate (set by laboratory)
- Initial Summa canister pressure using hand-held vacuum gauge
- Summa canister sample duration
- Helium concentration in shroud during leak check testing
- Photoionization detector (PID) reading from sub-slab monitoring point purge
- Significant comments and notes during installation or sample collection activities.

At each location, air samples will be collected for laboratory analysis utilizing the appropriate U.S. Environmental Protection Agency method. Air samples will be collected from two locations per structure, including the first floor and the sub-slab environment. If a basement is present, air samples will be collected from three locations per structure, including the first

floor, basement, and sub-slab environment. An active approach, utilizing laboratory batch-certified Summa canisters regulated for 24-hour sample collection, will be used based on building use and/or project requirements to evaluate the indoor air and sub-slab soil vapor conditions.

2. SUMMA CANISTERS

Six-liter (L) Summa canisters will be used for the collection of air samples. The rationale for this recommendation includes the following:

- The analysis of volatile organic compounds (VOCs) by TO-15, TO-15 selective ion monitoring (SIM), and/or fixed gases by ASTM D-1946 using a smaller volume (1-L) Summa canister requires that the entire sample volume be used for analysis. Therefore, additional sample volume is not available for confirmation analysis should additional quantification be required.
- The dilution factor is lower for 6-L Summa canisters because they are pressurized to 5 pounds per square inch (psi) to retrieve the analytical aliquot, resulting in an expected dilution factor of 1.61 (compared to an expected dilution factor of 2.42 for 1-L Summa canisters, which are pressurized to 15 psi).

The Summa canisters will be paired with flow regulators that will be used at only one location, and then set aside for return to the laboratory for decontamination. The flow regulator, which features a particulate filter and vacuum gauge, will be set to a specified flow rate by the analytical laboratory prior to shipping. The Summa canisters used during this project will be individually certified by the analytical laboratory, and set at a vacuum pressure of approximately negative 30 inches of mercury (in. Hg). Immediately prior to sample collection, the vacuum for each Summa canister will be verified with a handheld pressure gauge to assess for tightness during transit from the laboratory to the field. Before removing the compression plug on the canister during the pressure check, confirm the canister valve is closed and did not come open during shipping. Pressure readings will be recorded on the field data forms and tags. Any Summa canister with a pressure reading less than -25 in. Hg will not be used.

SUB-SLAB SAMPLING PROCEDURES

3. SUB-SLAB MONITOR POINT INSTALLATION

The procedures for the selection and installation of sub-slab soil gas sampling points within buildings are based on applicable guidance. The procedures are intended to provide the specific process used to select and install sample sub-slab soil gas monitoring probes. However, the procedures are also intended to be flexible enough to implement within a variety of buildings and using different materials, based on local availability. The procedures presented below will be followed for the selection and installation of each sub-slab soil gas monitoring point within the buildings to be sampled during the field investigation:

1. Features that tend to be preferential migration pathways for vapors (utility banks, piping corridors, etc.) will be identified and samples will be taken in the vicinity of, but no closer than 6 feet from, these features, if present. A visual assessment of the condition of the floor will also be completed. If a utility clearance determines that the sub-slab soil gas monitoring points cannot occur at the proposed location, then location will be adjusted to the closest practicable point. Sub-slab soil gas sampling locations will be selected to be out of the line of traffic and will be placed a minimum of 6 feet from an exterior wall and/or major cracks in the concrete slab.

2. Once the sampling points are located, semi-permanent sub-slab soil gas monitoring point will be installed to allow for multiple sampling events from identical sub-slab locations. The semi-permanent sub-slab soil gas monitoring point will be installed by drilling a 1-in.-diameter hole into the concrete slab to an approximate depth of 1½ to 2 in. using a hand-held electric hammer drill or equivalent to create an annular space for the semi-permanent point. A ¼-in.-diameter drill bit will then be used in the center of the 1-in.-diameter opening to create a borehole through the remainder of the concrete slab to approximately 2 in. into the underlying material.

3. After drilling through the slab, record the approximate thickness of the slab and clean any dust from the slab and wipe with a dampened towel. A shop vacuum can be used to clear the 1-in.-diameter borehole of loose material before drilling all the way through the slab. Do not vacuum the open hole, because vapors could be transmitted from under the slab into the indoor air that would bias the indoor air sample.

4. Upon completion of the borehole, an appropriate length of ¼-in.-outside diameter (OD) stainless-steel tubing will be cut to extend from ½ inch above the bottom of the 1-in.-diameter annular space borehole to a depth approximately 1 in. below the bottom of the slab. The stainless-steel tubing will then be attached to a ¼-in. stainless-steel union and tightened to secure the tubing in place. The assembly will then be placed into the borehole and checked for tightness within the borehole. The sub-slab soil gas monitoring point will also be equipped with a ¼-in. stainless-steel threaded plug so that it may be sealed from ambient air intrusion and/or sub-slab soil gas leakage to indoor air. The semi-permanent point should be recessed slightly under the surface of the concrete to prevent a tripping hazard.

5. The bottom of the stainless-steel tube will be set at approximately 1 to 2 in. below the concrete slab surface; therefore, the intake interval will be located within the near sub-slab environment, targeting the likeliest source of near-slab soil gas. Caution should be taken not to plug the end of the tube with the underlying material during installation.

6. A thin layer (approximately ¼ in. thick) of melted beeswax will be placed at the base of the 1-in.-diameter annular space borehole to seal the tubing and any potential void spaces between the stainless-steel tube and the ¼-in.-diameter borehole. The beeswax will be allowed to air cool and harden in place.

7. Following beeswax placement and cooling, a ½ to ¾-in.-thick (up to the lowest threads on the union) layer of quick-set expansion-type concrete will be placed into the 1-in.-diameter annular space borehole to cover the beeswax and further seal the sub-slab soil gas monitoring point preventing air communication between the sub- slab environment and the indoor air space.

8. After the sub-slab soil gas monitoring point is installed, the stainless-steel plug will be hand-tightened until snug, being careful not to over-tighten to avoid breaking the concrete seal.

9. The sub-slab soil gas monitoring points will be allowed to set up prior to conducting leak-check testing, purging, and sampling activities.

4. SUB-SLAB MONITOR POINT LEAK TEST PROCEDURE

Ambient air intrusion into gas/air samples may result in a dilution of the gas/air sample, and may produce results that underestimate actual site concentrations; or alternatively, may contaminate the sample with aboveground indoor air contaminants. Leak tests will be conducted at each sub-slab soil gas monitoring point. The leak tests to be employed during the field activities include a shut-in leak test and a tracer leak test. These leak tests will be used to assess whether a good seal was established in the sampling train, ground surface, and the probe interface. A leak can be considered present when the tracer compound is present in the test sample at more than 10 percent of the source concentration.

The tracer test is also designed to check for leaks in aboveground fittings, as well as the sub-slab soil gas monitoring point surface seal interface. The monitoring point seal integrity will be confirmed in real time by analyzing soil gas purge samples for the selected tracer compound. Helium will be used as the tracer compound during field activities; however, other tracer compounds, such as pentane, isopropanol, isobutene, propane, or butane, may be acceptable for use if the selected tracer compound is not a chemical of potential concern (COPC). Additional detail on leak test implementation is provided below. Additional or alternate leak detection methods may be acceptable if fully documented during field implementation.

Sub-Slab Sample Train Shut-In Test

Before connecting the flow regulator, check the Summa canister initial pressure and verify that the canister valve opens and closes correctly during the initial pressure check. A ¼-in. stainless-steel sample train will be connected to the flow regulator using compression fittings. The stainless-steel sample train will consist of a stainless-steel union tee with an attached stainless-steel ball valve located near the connection to the flow regulator for purging of the sample train. At the opposite end of the stainless-steel sample train, attach ¼-in. Teflon or Teflon-lined tubing (less than 3 feet) from the end of stainless-steel sample train to the sampling port for flexibility.

After the Teflon tubing is attached to the sample train, a shut-in test can be performed to check the connections at the flow regulator and along the sample train. With the purge valve closed, attach a hand vacuum pump to the end of the Teflon tube and apply a vacuum between -10 to -20 in. Hg on the sample train. If the vacuum does not drop over a 1-minute time interval, then the sample train is considered to be leak-free. If the vacuum does start dropping, then one of the

connections is compromised and may need to be tightened and rechecked. If the sample connections cannot be determined to be leak-free, the use of another canister and flow regulator or sample train should be considered. Leaks are typically common on connections between flow regulators and canisters because of continuous reuse and possible over-tightening that can damage connections.

After the shut-in test is complete, remove the hand vacuum pump and the Teflon tubing inserted through the ¼-inch opening at the top of the leak test shroud; then connect to the semi-permanent monitoring point installed in the slab. The shroud is then slid down the tubing to create an air chamber above the monitoring point.

Sub-Slab Sample Train Purging

Prior to collection of sub-slab soil gas samples, the sub-slab soil gas monitoring points will be purged of vapor using the calibrated low-flow purge pump to remove approximately three pore volumes from the sampling zone. The pore volume for the sub-slab soil gas monitoring points will be calculated based on known diameter and length, with an assumed 25-percent porosity, plus the internal volume of the tubing. The purge volume is typically between 1 - 3 L, or about one Tedlar bag. The purpose of the purge is to ensure stagnant or ambient air is removed from the sampling system prior to sample collection. The purge will be completed at the same time as the leak test is performed. Purge volumes will be kept to a minimum to decrease the chance of leakage, reduce additional partitioning of potential contaminants into the vapor phase, and unnecessary movement of the soil gas to the sampling probe.

To complete the purge, the purge pump will be connected to the stainless-steel sample train near the canister at the ball valve using a short length of Teflon tubing with flexible Tygon tubing. The internal length of the Tygon tubing will be minimized whenever possible by fully inserting both ends of the tubing being connected. The outlet of the purge pump (Gil Air5 or similar) will be connected to a Tedlar bag using Teflon tubing connected with short lengths of flexible tubing. When purging is complete, the valve should be closed before turning the pump off to insure indoor air is not allowed into the sample train.

Sub-Slab Sample Port Tracer Gas Test

The final portion of the test is to validate the connection of the sample train to the sub-slab monitoring point and the seal of the monitoring point at the concrete slab. During the purge, medical-grade helium tracer gas will be applied directly to a shroud or “bucket” covering the sub-slab soil gas monitoring point by directing a tube from a helium tank source into the shroud. The interior space of the shroud will be monitored for helium concentration using a Radiodetection Helium/Hydrogen Multi-Gas Detector, Model MGD-2002. Once the interior of the shroud reaches approximately 50-percent helium, the purge pump will be activated and allowed to purge approximately 1 - 3 L of volume into the Tedlar bag from the sub-slab soil gas monitoring point. Slight pressure should be placed on the top of the shroud to create a seal at the shroud and concrete interface until the purge is complete. At this time, the helium detector will be removed from the shroud and the shroud plugged to retain the helium concentration. The helium detector will be allowed to equilibrate with atmosphere and later be connected to the Tedlar bag to assess helium concentration. The monitoring point will be considered sealed from

atmospheric air intrusion if the helium meter does not detect 5 percent helium in the Tedlar bag. Additionally, the remaining volume of the Tedlar bag can be used to screen sub-slab soil gas concentrations of VOCs using a ppbRae or equivalent PID. All leak test and purge information should be recorded on the field data sheet.

If helium is detected in the Tedlar bag above 5 percent, the integrity of the monitoring point will be assessed and repaired, if possible. Modeling clay or beeswax may be utilized to seal potential cracks or penetrations in the monitoring point vault. Following confirmation that the monitoring point vault has been sealed from atmospheric air intrusion, the purge process should begin again. If the monitoring point vault is unable to be sealed, it should be abandoned and the location restored to pre-sample conditions. A replacement monitoring point should be installed at least 5 feet away from the initial location.

All sub-slab locations should be leak tested before activating the Summa canisters at other locations in the building. This ensures that if problems are encountered during leak testing, the sampling port can be reinstalled. Sampling should be postponed an additional day to allow for the newly-installed port to set up and ensure that vapor intrusion sample collection occurs within the same timeframe for that building.

5. SUB-SLAB SAMPLING PROCEDURE

After the leak test has been performed on the sample train and sampling ports for the building, the purge valve on the sample train should be checked to make sure it is in the closed position. As the Summa canister is turned on for sample collection, the regulator pressure should be checked against the initial pressure recorded on the canister sample tag. If there is a major difference in pressure, lightly tap on the gauge to ensure it is not sticking. The pressure, date, start time, and serial number of the canister and associated regulator should be recorded on the field sample form or in a field logbook along with the sample identification and any other important information. Typically an indoor air sample is co-located with the sub-slab location and would be initiated concurrently.

The canister setup and the surrounding area should be photographed. The next sub-slab location should be started within a few minutes following the first location to allow end times to stagger for shutdown of canisters. The Summa canister pressure should be checked periodically and gauges should be tapped upon reading to determine if pressure gauge is reading correctly. The Summa canister should be closed at the flow regulator at the designated 24-hour sample time if the appropriate sample volume is collected. Sample volume depends on the amount the laboratory needs to run a sample and may be differ between laboratories. In most cases, if the initial canister pressure is at -30 in. Hg, then a sufficient sample volume would be achieved when the pressure was at -10 in. Hg.

The Summa canister should be closed if internal pressure reaches -5 in. Hg before the designated sample time. This will ensure that the Summa canister is shipped back to the lab under a low negative pressure for sample quality control. The Summa canister stop time will be used as the sample time on the chain-of-custody form. The Summa canister and regulator should be disassembled and packaged together during shipping. All information on the tag and field sampling form should be filled out along with the chain-of-custody form.

A duplicate sub-slab sample can be collected using a duplicate sampling tee. Two Summa canisters with flow regulators can be connected together using a sampling tee with equal lengths that come together to connect into the sampling train. Both canisters are usually started and stopped at the same time even when they differ in ending pressure.

INDOOR AMBIENT AIR SAMPLING PROCEDURES

The following procedures for the collection of indoor air samples are based on applicable guidance and practical experience during the implementation of field activities on other projects. The procedures are intended to provide a specific process to follow for the collection of indoor air and outdoor ambient air samples. However, the procedures are also intended to be flexible enough to implement based on conditions encountered in the field.

Indoor air and outdoor ambient air samples will be collected at each building retained for additional evaluation. Potential indoor air sources of COPCs remaining in buildings, including the location within the building(s) and type of potential impact, will be documented. Portable vapor monitoring equipment may be useful for identifying unknown sources within buildings.

The operation of heating, ventilation, and air conditioning (HVAC) systems during sample collection will be noted on the Building Inventory and Indoor Air Sampling Questionnaire. When sampling activities are conducted, the building HVAC system should be operating in a manner consistent with normal operating conditions during building occupation.

To minimize the potential for interferences or dilution of indoor air samples, occupants will be asked to make a reasonable effort to avoid the following for a minimum of 24 hours prior to initiating the sample collection process:

- Opening windows or vents
- Operating ventilation fans (unless special arrangements are made)
- Smoking adjacent to exterior intake air vents
- Operating or storing unnecessary mechanical equipment in the building; however, necessary mechanical equipment may not be able to be removed, in which case it should be documented in the field notes
- Allowing unnecessary containers of gasoline or oil to remain within the building. Heating fuel tanks inside buildings should be vented outside the building, or their vents should be temporarily sealed to prevent off-gassing inside the building
- Cleaning, waxing, or polishing furniture, floors, or other woodwork with petroleum- or oil-based products
- Using air fresheners or odor eliminators
- Engaging in work tasks that use materials containing volatile chemicals

- Building maintenance activities involving products containing volatile chemicals
- Lawn mowing
- Applying pesticides or insecticides
- Wearing or bringing dry-cleaned clothing into the building.

The list above was based on guidance and may be modified to reflect the conditions of the site.

To collect an indoor air sample for VOC analysis using TO-15 and TO-15 SIM, the flow controller will be connected to the top of the Summa canister using Swagelok connections. A short length (hereafter, "short length" refers to approximately 3 to 4 in.) of tubing may be connected to the top of the flow controller to assist with placement of the sample collection point.

A shut-in test will be performed on the Summa canister and flow regulator and/or sample tubing connections to insure there are no leaks.

Indoor air samples will be collected from the breathing zone by placing the intake end of the sampling tubes approximately 3 to 5 feet above the floor (within the breathing zone), in high-use areas. For the Summa canisters (6-L), the laboratory-set flow rate will result in a 24-hour sample period. To initiate sample collection, the Summa canister valve will be opened to allow air to enter the Summa canister.

Periodically throughout the 24-hour sampling period for the Summa canisters, the pressure inside the canister will be monitored and the time required to achieve the desired end sampling pressure (approximately -5 in. Hg) will be recorded and included on the chain-of-custody record. To terminate sample collection, the Summa canister valve will be closed and the sample will be contained within the canister. The sample identification and collection date/time will be recorded on the sample label attached to each Summa canister. To verify the final pressure following sample collection, the vacuum of the Summa canister can be measured using the same handheld pressure gauge that was used to verify the initial pressure. The initial and final pressures will be recorded on the chain-of-custody record. Digital photographs will be collected of the indoor air sample setup and sampling train.

A duplicate indoor air would consist of setting two Summa canisters with flow regulators side by side with identical sample start and stop times.

Pressure Differential Monitoring

The pressure differential between indoor air and outdoor air will be determined at each building during each indoor air sampling event, using a micromanometer (e.g., a FLUKE 922 Airflow Meter) as follows:

1. Press "pressure" to enter the pressure mode.

2. Connect a single hose to the input port (Input +), while leaving the reference port (Ref -)

unconnected.

3. With the tubing open to ambient conditions (inside the structure), press and hold the zero button to calibrate the meter.

Place the input hose outside, while leaving the meter inside. The micromanometer will display the differential pressure outdoors with respect to the pressure indoors. For instance, a positive reading means that the air outside is positively pressured with respect to the air inside.

OUTDOOR AMBIENT AIR SAMPLING PROCEDURES

In addition to the indoor air samples, outdoor ambient air samples will be collected. Ambient air samples will be collected during the same 24-hour period as the indoor air samples, which represent outdoor air conditions for the entire sampling area. The ambient air samples will be collected in a laboratory batch-certified Summa canister, regulated for a 24-hour sample collection. A section of Teflon or Teflon-lined tubing that is identified as laboratory- or food-grade quality will be extended from the Summa canister to collect the ambient air sample from the breathing zone at approximately 3 to 5 feet above ground surface. Outdoor ambient air samples will be collected at a minimum of one (1) per day during the indoor air monitoring program. Scheduling and overall distribution of indoor air sampling locations will be the basis for determining if more than one (1) ambient air sample is needed per day.

The following procedures for the collection of outdoor ambient air samples are based on applicable guidance and practical experience during the implementation of field activities on other projects. The procedures are intended to provide the specific process to follow to collect outdoor air samples. However, the procedures are also intended to be flexible enough to implement based on conditions encountered in the field.

Outdoor ambient air samples will be collected from outside of each building retained for vapor intrusion assessment from an area generally upwind of the building.

The procedures to collect an outdoor ambient air sample are identical to those described for indoor air samples. The Summa canisters will require temporary shelter during the 24-hour sample collection process, and should be secured from potential tampering. A 1- to 2-foot length of sample tubing may be attached to the canister to provide a drip loop, so that moisture will not directly enter the sampling orifice. Adhesives or materials potentially containing volatile constituents should be avoided when securing the outdoor air sampling apparatuses. Digital photographs will be collected of the outdoor air sample setup and sampling location.

EPA Method TO-15 Standard 75 Compound List

CAS Number	Compound Name	CAS Number	Compound Name
71-55-6	1,1,1-Trichloroethane	67-66-3	Chloroform
79-34-5	1,1,2,2-Tetrachloroethane	74-87-3	Chloromethane
79-00-5	1,1,2-Trichloroethane	156-59-2	cis-1,2-Dichloroethene
75-34-3	1,1-Dichloroethane	10061-01-5	cis-1,3-Dichloropropene
75-35-4	1,1-Dichloroethene	98-82-8	Cumene
120-82-1	1,2,4-Trichlorobenzene	110-82-7	Cyclohexane
95-63-6	1,2,4-Trimethylbenzene	124-48-1	Dibromochloromethane
96-12-8	1,2-Dibromo-3-chloropropane	75-71-8	Dichlorodifluoromethane (CFC 12)
106-93-4	1,2-Dibromoethane	5989-27-5	d-Limonene
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	64-17-5	Ethanol
95-50-1	1,2-Dichlorobenzene	141-78-6	Ethyl Acetate
107-06-2	1,2-Dichloroethane	100-41-4	Ethylbenzene
78-87-5	1,2-Dichloropropane	87-68-3	Hexachlorobutadiene
108-67-8	1,3,5-Trimethylbenzene	179601-23-1	m,p-Xylenes
106-99-0	1,3-Butadiene	80-62-6	Methyl Methacrylate
541-73-1	1,3-Dichlorobenzene	1634-04-4	Methyl tert-Butyl Ether
106-46-7	1,4-Dichlorobenzene	75-09-2	Methylene Chloride
123-91-1	1,4-Dioxane	91-20-3	Naphthalene
78-93-3	2-Butanone (MEK)	123-86-4	n-Butyl Acetate
591-78-6	2-Hexanone	142-82-5	n-Heptane
67-63-0	2-Propanol (Isopropyl Alcohol)	110-54-3	n-Hexane
107-05-1	3-Chloro-1-propene (Allyl Chloride)	111-84-2	n-Nonane
622-96-8	4-Ethyltoluene	111-65-9	n-Octane
108-10-1	4-Methyl-2-pentanone	103-65-1	n-Propylbenzene
67-64-1	Acetone	95-47-6	o-Xylene
75-05-8	Acetonitrile	115-07-1	Propene
107-02-8	Acrolein	100-42-5	Styrene
107-13-1	Acrylonitrile	127-18-4	Tetrachloroethene
80-56-8	alpha-Pinene	109-99-9	Tetrahydrofuran (THF)
71-43-2	Benzene	108-88-3	Toluene
100-44-7	Benzyl Chloride	156-60-5	trans-1,2-Dichloroethene
75-27-4	Bromodichloromethane	10061-02-6	trans-1,3-Dichloropropene
75-25-2	Bromoform	79-01-6	Trichloroethene
74-83-9	Bromomethane	75-69-4	Trichlorofluoromethane
75-15-0	Carbon Disulfide	76-13-1	Trichlorotrifluoroethane
56-23-5	Carbon Tetrachloride	108-05-4	Vinyl Acetate
108-90-7	Chlorobenzene	75-01-4	Vinyl Chloride
75-00-3	Chloroethane		

Please note that additional volatile organic compounds may be added upon request. Please contact the laboratory for more information.

Appendix G

Standard Operating Procedures

Standard Operating Procedure No. 001
for
Sample Labels

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

Revision 0
December 2014

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for the use of sample labels. Every sample will have a sample label uniquely identifying the sampling point and analysis parameters. An example label is provided below. Other formats with similar levels of detail are acceptable.

PROJECT NAME _____ PROJECT NUM. _____
SAMPLE LOCATION/SITE ID _____
DATE: ____/____/____ TIME: _____:_____
ANALYTES: METALS VOC EXPLOSIVES ORGANICS OTHER
FILTERED: [NO] [YES]
PRESERVATIVE: [NONE] [HNO_3] [OTHER _____]
SAMPLER: _____

2. MATERIALS

The following materials may be required: sample label and indelible laboratory marker.

3. PROCEDURE

The following sections describe how to use the sample labeling system.

3.1 LABEL INFORMATION

As each sample is collected/selected, fill out a sample label. Enter the following information on each label:

- Project name
- Project number
- Location/site identification—Enter the media type (i.e., well number, surface water, soil, etc.) sampling number, and other pertinent information concerning where the sample was taken
- Date of sample collection

- Time of sample collection
- Analyses to be performed (NOTE: Due to number of analytes, details of analysis should be arranged with laboratory *prior to start of work)*
- Whether filtered or unfiltered (water samples only)
- Preservatives (water samples only)
- Number of containers for the sample (e.g., 1 of 2, 2 of 2).

3.2 ROUTINE CHECK

Double-check the label information to make sure it is correct. Detach the label, remove the backing, and apply the label to the sample container. Cover the label with clear tape, ensuring that the tape completely encircles the container.

3.3 RECORD INFORMATION

Record the sample number and designated sampling point in the field logbook, along with the following sample information:

- Time of sample collection (each logbook page should be dated)
- Location of the sample
- Organic vapor meter or photoionization meter readings for the sample (when appropriate)
- Any unusual or pertinent observations (oily sheen on groundwater sample, incidental odors, soil color, grain size, plasticity, etc.)
- Number of containers required for each sample
- Whether the sample is a quality assurance sample (split, duplicate, or blank).

3.3.1 Logbook Entry

A typical logbook entry might look like this:

- 7:35 a.m. Sample No. MW-3. PID = 35 ppm
- Petroleum odor present. Sample designated MW-3-001.

NOTE: Duplicate samples will be given a unique sample designation rather than the actual sample number with an added prefix or suffix. This will prevent any indication to the laboratory that this is a duplicate sample. This fictitious sample number will be listed in the logbook along with the actual location of the sample.

3.4 SHIPMENT

Place the sample upright in the designated sample cooler. Make sure there is plenty of ice in the cooler at all times.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

5.1 INCIDENTAL ODORS

Note that although incidental odors should be noted in the logbook, it is unwise from a safety and health standpoint to routinely "sniff test" samples for contaminants.

5.2 DUPLICATE SAMPLE

No indication of which samples are duplicates is to be provided to the laboratory.

6. REFERENCES

U.S. Environmental Protection Agency. 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. QAMS-005/80.

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Standard Operating Procedure No. 002
for
Chain-of-Custody Form

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

Revision 0
December 2014

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for use of the chain-of-custody form. An example is provided as Figure SOP002-1. Other formats with similar levels of detail are acceptable.

2. MATERIALS

The following materials may be required: chain-of-custody form and indelible ink pen.

3. PROCEDURE

- Give the site name and project name/number.
- Enter the sample identification code.
- Indicate the sampling dates for all samples.
- List the sampling times (military format) for all samples.
- Indicate “grab” or “composite” sample with an “X.”
- Specify the sample location.
- Enter the total number of containers per cooler.
- List the analyses/container volume.
- Obtain the signature of sample team leader.
- State the carrier service and airbill number, analytical laboratory, and custody seal numbers.
- Sign, date, and time the “relinquished by” section.
- Upon completion of the form, retain the shipper copy, and affix the other copies to the inside of the sample cooler, in a zip-seal bag to protect from moisture, to be sent to the designated laboratory.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

None.

6. REFERENCES

U.S. Environmental Protection Agency (U.S. EPA). 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans, QAMS-005/80.

———. 1990. Sampler's Guide to the Contract Laboratory Program. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, D.C. December.

———. 1991. User's Guide to the Contract Laboratory Program. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response. January.

EA Engineering, Science, and Technology, Inc., PBC

Company Name:	Project Manager or Contact: Phone:
Project No. Dept.: Task:	Project Name:
Sample Storage Location:	ATO Number:
Page of	**Report #:**

Parameters/Method Numbers for Analysis

Chain-of-Custody Record

EA Laboratories
231 Schilling Circle
Hunt Valley, MD 21031
Telephone: (410) 584-7000

Report Deliverables:
1 2 3 4 D E

EDD: Yes/No

DUE TO CLIENT: _____

Date	Time	Water	Soil	Sample Identification 19 Characters	**No. of Containers**	**EA Labs Accession Number**	Remarks
				XXXXXXXXXXXXXXXXXXX			**LPM**:
				XXXXXXXXXXXXXXXXXXX			
				XXXXXXXXXXXXXXXXXXX			
				XXXXXXXXXXXXXXXXXXX			
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Company Name:	Project Manager or Contact: Phone:	Parameters/Method Numbers for Analysis	Chain-of-Custody Record
Project No. Dept.: Task:	Project Name:		
Sample Storage Location:	ATO Number:		**Report Deliverables:** **1 2 3 4 D E** **EDD: Yes/No** **DUE TO CLIENT: _____**
Page of	**Report #:**		

EA Laboratories
231 Schilling Circle
Hunt Valley, MD 21031
Telephone: (410) 584-7000

Date	Time	Water	Soil	Sample Identification 19 Characters	**No. of Containers**													**EA Labs Accession Number**	Remarks
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Samples by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
Relinquished by: (Signature)	Date/Time	Received by Laboratory: (Signature)	Date/Time	Airbill Number:	Sample Shipped by: (Circle) Fed Ex. Puro. UPS Hand Carried Other:

Cooler Temp. _____C pH: ___ Yes ___ No Comments: **Custody Seals Intact ___ Yes ___ No**

NOTE: Please indicate method number for analyses requested. This will help clarify any questions with laboratory techniques.

Standard Operating Procedure No. 003
for
Subsurface/Utility Clearance

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

1.1 PURPOSE

The purpose of this Standard Operating Procedure is to prevent injury to workers and damage to subsurface structures (including tanks, pipe lines, water lines, gas lines, electrical service, etc.) during ground disturbance activities (including drilling, augering, sampling, use of direct-push technologies, excavation, trenching, concrete coring or removal, fence post installation, grading, or other similar operations).

1.2 LIMITATIONS

The procedures set forth in this document are the suggested procedures but may not be applicable to particular sites based on the site-specific considerations. The Project Manager is responsible for making a site-specific evaluation of each site to determine whether the Subsurface/Clearance Procedures should be utilized or require modification. If safety or other site-specific considerations require a modified or different procedure, the Project Manager should review the modified procedure with the Business Unit Director, Profit Center Manager, or Senior Technical Reviewer.

1.3 SCOPE

This procedure provides minimum guidance for subsurface clearance activities, which must be followed prior to and during ground disturbance activities at EA project sites. Even after completing the subsurface clearance activities required in this procedure, all ground disturbance activities should proceed with due caution.

Deviations from this procedure may be provided on an exception basis for specific situations, such as underground storage tank systems removals, verified aboveground/overhead services/lines, undeveloped land/idle facilities, shallow groundwater conditions, soil stability, or well construction quality assurance/quality control concerns, etc.

EA or its subcontractors are responsible for, and shall ensure that, all ground disturbance activities are completed safely, without incident, and in accordance with applicable federal, state, and local regulations.

This procedure shall not override any site-specific or consultant/contractor procedures that are more stringent or provide a greater degree of safety or protection of health or the environment.

2. PROCEDURES

The EA Project Manager or his designee must complete the Subsurface Clearance Procedure Checklist (Appendix A) in conjunction with the following procedures. The checklist must be completed before initiating any ground disturbance activities. The completed checklist must be submitted to the appropriate team individuals, subcontractors, and/or the client and included in the project files.

2.1 SAFETY

A Health and Safety Plan must be available onsite and followed by all contractors and subcontractors.

All work areas shall be defined and secured with safety cones, safety tape, construction fence, other barriers, or signs as appropriate.

Site work permits must be obtained as required by site procedures. Based on site conditions or classification, the use of intrinsically-safe equipment may be required.

To ensure the safety of all onsite personnel and subsurface structure integrity, consideration should be given to de-energizing and locking out selected site utilities or temporarily shutting down a portion of or the entire facility.

2.2 PREPARATION TASKS

Objective—To gather all relevant information about potential subsurface structures prior to the actual site visit.

2.2.1 Obtain Permits and Site Access

The consultant/contractor is responsible for following all applicable laws, guidance, and approved codes of practice; obtaining all necessary permits and utility clearances; and securing site access permission.

2.2.2 Historic Site Information

Obtain most recent as-built drawings and/or site plans (including underground storage tank, product, and vent lines) as available.

NOTE: As-built drawings may not accurately depict the locations and depths of improvements and subsurface structures and should, therefore, not be **solely** relied upon.

EA should obtain any other site information such as easements, right-of-ways, historical plot plans, fire insurance plans, tank (dip) charts, previous site investigations, soil surveys, boring logs, and aerial photographs, etc. as relevant to the planned ground disturbance activities.

Where applicable, EA should also contact contract personnel who may have historic site knowledge.

2.2.3 Mark-Outs

Objective—To identify location of subsurface structures on surface.

EA must ensure that a thorough mark-out at the site is completed to locate electrical, gas, telephone, water, sewer, low voltage electric lines, product delivery pipelines, fiber optic, and all other subsurface utilities/services.

- Where available, public utility companies must be contacted to identify underground utilities. (This can be accomplished through the One-Call system in most instances.)

- In addition, where available and warranted by site conditions, a private utility/pipeline mark-out company should be contracted to perform an electronic subsurface survey to identify the presence of suspected hazardous or critical underground utilities and subsurface structures. In some cases, this is necessary to confirm public utility mark-outs in the vicinity of planned ground disturbance activities.

EA will review all available site plan subsurface information with the private mark-out company to assist in locating utilities and other subsurface structures.

NOTE: Mark-outs may not accurately depict the exact locations of improvements and subsurface structures and should, therefore, not be **solely** relied upon.

Where possible, EA personnel are encouraged to be onsite at the time of subsurface mark-outs. This is to ensure accuracy and understanding of subsurface structures identified and provides an opportunity to exchange information with mark-out company personnel regarding planned work activities.

Subsurface structures should be marked throughout the entire work area(s) with adequate materials (e.g., site conditions may require paint and tape/flags). Ground disturbance activities must be started within 30 days of mark-out, unless local ordinances specify a shorter time period. If activities are not started within required time period or markings have faded, mark-outs must be redone.

EA personnel will record time and date of mark-out request and list all companies contacted by the service and confirmation number. This should be available for review onsite and checked off after visual confirmation of markings.

2.2.4 Initial Site Visit

Objective—To compare the site plan to actual conditions based on information gathered in Procedures 2 and 3 above, obtain additional site information needed, and prepare a vicinity map.

EA will document all findings and update the site plan with this information. On third party sites, close coordination with the site owner's representatives for mark-outs, review of as-builts, and other information reviews should be conducted prior to work. Project Managers are encouraged to provide updated as-built information to the client.

In some regions, it may be more effective and efficient to conduct the site visit at the same time the contractor and drill rig are mobilized to the site. The inspection should include the following activities and may include others as determined by the consultant/contractor and the Project Manager.

2.2.5 Utilities

EA shall perform a detailed site walk-through for the purpose of identifying all aboveground indicators of subsurface utilities/services that may be leading to or from buildings within the planned work area. The inspection shall include, but not be limited to, the following:

- Utility mark-outs
- Aboveground utilities
- Area lights/signs
- Phones
- Drains
- Junction boxes
- Natural gas meters or connections
- Other utilities including: fire hydrants, on/below grade electrical transformers, splice cages, sewer lines, pipeline markers, cable markers, valve box covers, clean-outs/traps, sprinkler systems, steam lines (including insulated tanks that may indicate steam lines), and cathodic protection on lines/tanks
- Observe paving scars (i.e., fresh asphalt/concrete patches, scored asphalt/concrete).

NOTE: In many cases, the onsite location of low-voltage electrical lines and individual property water and sewer line branches may be approximated by using the following technique:

- Locate the entry/connection location at the facility building
- Attempt to identify utility connections for the mains (water sewer, etc.) by locating clean-outs, valve manways, etc. The location path of the utility is likely with the area between the main connection and facility building connection. Subsurface electrical line locations from the facility building to signs, lamps, etc. can be estimated with the same process.

2.2.6 Other Subsurface Systems

Some other subsurface systems to be cognizant of during subsurface activities include product delivery systems (i.e., at gas stations) and existing remediation systems.

2.2.7 Selection of Ground Disturbance Locations

EA will utilize the information collected to this point in combination with regulatory requirements and project objectives to select ground disturbance locations. Ground disturbance locations should also consider the location of overhead obstructions (e.g., power lines). Work at active gasoline retail locations must consider several special considerations that should be outlined in the site-specific safety and health plan.

2.2.8 Review of Selected Locations with the Client

EA will review the selected ground disturbance locations with the client. EA will not proceed with the subsurface activities until the plan has been discussed with the client. During execution of the project, subsurface activities are required outside of the area previously approved by the client. EA will submit these changes to the client for approval prior to execution.

2.2.9 Ground Disturbance Activity Sequence

EA will plan ground disturbance activities starting at the point farthest from the location of suspected underground improvements. This is done to determine the natural subsurface conditions and to allow EA site personnel to recognize fill conditions.

Experience has shown that the following warning signs may indicate the presence of a subsurface structure:

- Warning tape (typically indicative of underground services).
- Pea gravel/sand/non-indigenous material (typically indicative of tanks or lines).
- Red concrete (typically indicative of electrical duct banks).

- The abrupt absence of soil recovery in a hand auger. This could indicate pea gravel or sand that has spilled out of the auger. This may not be indicative in areas where native soil conditions typically result in poor hand auger recoveries.

- Any unexpected departure from the native soil or backfill conditions as established by prior onsite digging.

If any of these conditions is encountered by EA site personnel, digging should stop and the client should be contacted.

3. SUBSURFACE CLEARANCE METHODS

The method used to delineate the subsurface should be compatible with the inherent associated risk given the type of facility/property, soil stratigraphy, and the location of the ground disturbance activity, such that required delineation is obtained. It should be noted that in areas where there is paving, sufficient paving should be removed to allow clear visibility of the subsurface conditions during clearance activities. The following is a list of potential clearance methods that may be used on a job site:

- Vacuum digging
- Probing
- Hand digging
- Hand augering
- Post-hole digging.

EA personnel will evaluate the potential for electrical shock or fire/explosion for each subsurface disturbance project and will evaluate as necessary the use of non-conductive or non-sparking tools (i.e., fiberglass hand shovels, and thick electrically insulating rubber grips on hand augers or probes). The potential need for the use of non-conductive materials, electrical safety insulated gloves, and footwear will also be evaluated on a case-by-case basis.

3.1 SUBSURFACE CLEARANCE PROCEDURES FOR DRILLING, DIRECT-PUSH TECHNOLGY, AUGERING, FENCE POST INSTALLATION, OR OTHER BOREHOLE INSTALLATION ACTIVITIES

The area to be delineated will exceed the diameter of the largest tool to be advanced and sufficiently allow for visual inspection of any obstructions encountered.

3.2 SUBSURFACE CLEARANCE PROCEDURES FOR TRENCHING/ EXCAVATION ACTIVITIES

Appropriate subsurface clearance methods should be conducted along the length and width of the excavation at a frequency sufficient to ensure adequate precautions have been applied to the entire work area. The frequency and density of investigations will be based on site knowledge, potential hazards, and risks of the work area to surrounding locations (e.g., proximity to a residential area or school).

Whenever subsurface structures are exposed, EA will cease work and mark the area (e.g., flags, stakes, cross bracing) to ensure the integrity of these exposed structures is maintained during subsequent trenching/excavation/backfilling.

Uniform color codes for marking of underground facilities are provided in Appendix B.

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Appendix A

Subsurface Clearance Procedure Checklist

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Subsurface Clearance Procedure Checklist

Site Identification: _____

Project Consultant/Contractor: _____

Section 1: Safety, Preparation Tasks, and Mark-Outs

Activity	Yes	No	N/A	Comments including Justification if Response Is No or Not Applicable
Health and Safety Plan is available and all contractors and subcontractors are familiar with it.				
All applicable local, state, and federal permits have been obtained.				
Site access/permission has been secured.				
Most recent as-built drawings and/or site plans (including underground storage tank, product, and vent lines) obtained.				
Reviewed site information to identify subsurface structures relevant to planned site activities (easements, rights-of-way, historical plot plans, fire insurance plans, tank dip charts, previous site investigations, soil surveys, boring logs, aerial photographs, etc.).				
Utility mark-outs have been performed by public utility company(s). Mark-outs clear/visible.				
Subsurface structure mark-outs performed by private mark-out company. Mark-outs clear/visible.				
Additional Activities: Were dig locations reviewed with site representative?				

Section 2: Initial Site Visit and Selecting Ground Disturbance Locations

Activity	Yes	No	N/A	Comments including Justification if Response Is No or Not Applicable
Location of all aboveground indicators of subsurface utilities/services that may be leading to or from buildings within the planned work area has been identified.				
Location of utility mark-outs by all utility companies previously contacted has been identified within required time period.				
Location of all subsurface structure mark-outs by private mark-out company has been identified within required time period.				
Location of area lights/signs and associated subsurface lines identified.				
Location of all phones and associated subsurface lines identified.				
Location of all drains and associated interconnecting lines identified.				
Location of all electrical junction boxes and associated interconnecting lines identified				
Location of all natural gas meters or connections and all interconnecting lines identified				

Completed by: _____
Name

Signature: _____ _____
Company Date

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Appendix B

Uniform Color Codes for Excavation

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APWA UNIFORM COLOR CODE

WHITE - Proposed Excavation

PINK - Temporary Survey Markings

RED - Electric Power Lines, Cables, Conduit and Lighting Cables

YELLOW - Gas, Oil, Steam, Petroleum or Gaseous Materials

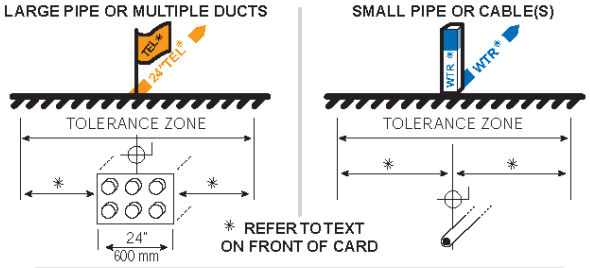
ORANGE - Communication, Alarm or Signal Lines, Cables or Conduit

BLUE - Potable Water

PURPLE - Reclaimed Water, Irrigation and Slurry Lines

GREEN - Sewers and Drain Lines

TYPICAL MARKING



Customize with your center's phone and address information

GUIDELINES FOR UNIFORM TEMPORARY MARKING OF UNDERGROUND FACILITIES

This marking guide provides for universal use and understanding of the temporary marking of subsurface facilities to prevent accidents and damage or service interruption by contractors, excavators, utility companies, municipalities or any others working on or near underground facilities.

ONE-CALL SYSTEMS
The One-Call damage prevention system shall be contacted prior to excavation.

PROPOSED EXCAVATION
Use white marks to show the location, route or boundary of proposed excavation. Surface marks on roadways do not exceed 1.5" by 18" (40 mm by 450 mm). The facility color and facility owner identity may be added to white flags or stakes.

USE OF TEMPORARY MARKING
Use color-coded surface marks (i.e., paint or chalk) to indicate the location or route of active and out-of-service buried lines. To increase visibility, color coded vertical markers (i.e., stakes or flags) should supplement surface marks. Marks and markers indicate the name, initials or logo of the company that owns or operates the line, and width of the facility if it is greater than 2" (50 mm). Marks placed by other than line owner/operator or its agent indicate the identity of the designating firm. Multiple lines in joint trench are marked in tandem. If the surface over the buried line is to be removed, supplementary offset markings are used. Offset markings are on a uniform alignment and clearly indicate the actual facility is a specific distance away.

TOLERANCE ZONE
Any excavation within the tolerance zone is performed with non-powered hand tools or non-invasive method until the marked facility is exposed. The width of the tolerance zone may be specified in law or code. If not, a tolerance zone including the width of the facility plus 18" (450 mm) measured horizontally from each side of the facility is recommended.

ADOPT UNIFORM COLOR CODE
The American Public Works Association encourages public agencies, utilities, contractors, other associations, manufacturers and all others involved in excavation to adopt the APWA Uniform Color Code, using ANSI standard Z535.1 Safety Colors for temporary marking and facility identification.

Rev. 4/99

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Standard Operating Procedure No. 004
for
Sample Packing and Shipping

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

Revision 0
December 2014

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for the packing and shipping of samples to the laboratory for analysis.

2. MATERIALS

The following materials may be required:

Clear tape	Plastic garbage bags
Custody seals	Sample documentation
Ice	Waterproof coolers (hard plastic or metal)
Metal cans with friction-seal lids (e.g., paint cans)	Zip-seal plastic bags
Packing material[1]	

3. PROCEDURE

Check cap tightness and verify that clear tape covers label and encircles container. Wrap sample container in bubble wrap or closed cell foam sheets. Enclose each sample in a clear zip-seal plastic bag.

Place several layers of bubble wrap, or at least 1 in. of vermiculite on the bottom of the cooler. Line cooler with open garbage bag, place all the samples upright inside a garbage bag, and tie the bag.

Double bag and seal loose ice to prevent melting ice from soaking the packing material. Place the ice outside the garbage bags containing the samples.

Pack shipping containers with packing material (closed-cell foam, vermiculite, or bubble wrap). Place this packing material around the sample bottles or metal cans to avoid breakage during shipment.

Enclose all sample documentation (i.e., Field Parameter Forms, chain-of-custodies) in a waterproof plastic bag and tape the bag to the underside of the cooler lid. If more than one cooler is being used, each cooler will have its own documentation.

Seal the coolers with signed and dated custody seals so that if the cooler were opened, the custody seal would be broken. Place clear tape over the custody seal to prevent damage to the seal.

1. Permissible packing materials are: (a) (non-absorbent) bubble wrap or closed cell foam packing sheets, or (b) (absorbent) vermiculite. Organic materials such as paper, wood shavings (excelsior), and cornstarch packing "peanuts" will not be used.

Refer to SOP Nos. 001, 002, 016, and 039.

Tape the cooler shut with packing tape over the hinges and place tape over the cooler drain. Ship all samples via overnight delivery on the same day they are collected if possible.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Any samples suspected to be of medium/high contaminant concentration or containing dioxin must be enclosed in a metal can with a clipped or sealable lid (e.g., similar to a paint can). Label the outer metal container with the sample number of the sample inside.

6. REFERENCES

U.S. Environmental Protection Agency (U.S. EPA). 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans, QAMS-005/80.

———. 1990. Sampler's Guide to the Contract Laboratory Program. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, D.C. December.

———. 1991. User's Guide to the Contract Laboratory Program. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response. January.

Standard Operating Procedure No. 005
for
Field Decontamination

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

All personnel or equipment involved in intrusive sampling, or that enter a hazardous waste site during intrusive sampling, must be thoroughly decontaminated prior to leaving the site to minimize the spread of contamination and prevent adverse health effects. This Standard Operating Procedure describes the normal decontamination of sampling equipment and site personnel.

2. MATERIALS

The following materials may be required:

0.01N HCl	Non-phosphate laboratory detergent (liquinox)
0.10N nitric acid	Plastic garbage bags
Aluminum foil or clean plastic sheeting	Plastic sheeting, buckets, etc. to collect wash water and rinsates
Approved water	Pressure sprayer, rinse bottles, brushes
High performance liquid chromatography (HPLC)-grade water[1]	Reagent grade alcohol[2]

3. PROCEDURE

3.1 SAMPLE BOTTLES

At the completion of each sampling activity, the exterior surfaces of the sample bottles must be decontaminated as follows:

- Ensure the bottle lids are on tight.
- Wipe the outside of the bottle with a paper towel to remove gross contamination.

3.2 PERSONNEL DECONTAMINATION

Review the project Health and Safety Plan for the appropriate decontamination procedures.

1. For the purposes of this Standard Operating Procedure, HPLC-grade water is considered equivalent to "deionized ultra filtered water," "reagent-grade distilled water," and "deionized organic-free water." The end product is water that is pure with no spurious ions or organics to contaminate the sample. The method of generation is left to the individual contractor.
2. For the purposes of this Standard Operating Procedure, the term "reagent grade alcohol" refers to either pesticide grade isopropanol or reagent grade methanol.

3.3 EQUIPMENT DECONTAMINATION

3.3.1 Water Samplers

3.3.1.1 Bailers

After each use, polytetrafluoroethelyne (PTFE) double check valve bailers used for groundwater sampling will be decontaminated as follows:

- Discard all ropes used in sampling in properly marked sealable container, or as directed by the Health and Safety Plan. NOTE: No tubing is to be used in conjunction with a bailer in collecting samples.
- Scrub the bailer to remove gross (visible) contamination, using appropriate brush(es), approved water, and non-phosphate detergent.
- Rinse off detergent three times with approved water.
- Rinse bailer with reagent grade alcohol.
- Rinse bailer three times with HPLC-grade water.
- Rinse bailer with 0.10N nitric acid solution.
- Rinse bailer three times with HPLC-grade water.
- Allow bailer to air dry.[3]
- Wrap bailer in aluminum foil or clean plastic sheeting, or store in a clean, dedicated polyvinyl chloride or PTFE storage container.
- Dispose of used decontamination solutions with drummed purge water.
- Rinse bailer with HPLC-grade water immediately prior to re-use.

3.3.1.2 Pumps

Submersible pumps will be decontaminated as follows:

3. If the bailer has just been used for purging and is being decontaminated prior to sampling, do not air dry. Double rinse with HPLC-grade water and proceed to collect samples.

- Scrub the exterior of the pump to remove gross (visible) contamination, using appropriate brush(es), approved water, and non-phosphate detergent. (Steam cleaning may be substituted for detergent scrub.)

- Calculate the volume of pump plus any tubing which is not disposable and not dedicated to a single well. Pump three volumes of non-phosphate laboratory detergent solution to purge and clean the interior of the pump.

- Rinse by pumping no less than nine volumes of approved water to rinse.

- Rinse pump exterior with reagent grade alcohol.

- Rinse pump exterior with HPLC-grade water.

- Allow pump to air dry.

- Wrap pump in aluminum foil or clean plastic sheeting, or store in a clean, dedicated polyvinyl chloride or PTFE storage container.

- Prior to reusing pump rinse exterior again with HPLC-grade water. (Double rinse in Bullet 5 above may be substituted for this step).

3.3.1.3 Dip Samplers

All dip samplers, whether bucket, long-handled, or short-handled, will be decontaminated in the same manner as provided in Section 3.3.1.1.

3.3.1.4 Labware

Labware, such as beakers, which are used to hold samples for field measurements, water chemistry, etc., will be decontaminated according to the procedures in Section 3.3.1.1.

3.3.1.5 Water Level Indicators

Electric water level indicators, weighted measuring tapes, or piezometers used in the determination of water levels, well depths, and/or non-aqueous phase liquid levels will be decontaminated in accordance with Section 3.3.1.1. Clean laboratory wipes may be substituted for brushes. Tapes, probes, and piezometers should be wiped dry with clean laboratory wipes, and coiled on spools or clean plastic sheeting rather than allowed to air dry.

3.3.2 Solid Materials Samplers

Solid materials samplers include soil and sediment sampling probes, augers, trowels, shovels, sludge samplers, and other sampling equipment (e.g., core tubes, grab samples, core catchers, core liners, scoops, spoons, etc.), which will be decontaminated as follows:

- Scrub the sampler to remove gross (visible) contamination, using appropriate brush(es), approved water, and non-phosphate laboratory detergent.
- Rinse off detergent with approved water.
- Rinse sampler with reagent grade alcohol.
- Rinse sampler with HPLC-grade water.
- For non-metallic samplers only, rinse sampler with 0.10N nitric acid solution.
- For non-metallic samplers only, rinse sampler with HPLC-grade water.
- Allow sampler to air dry.
- Wrap sampler in aluminum foil clean plastic sheeting, or store in a new zipseal bag (size permitting) or clean, dedicated polyvinyl chloride or PTFE storage container.
- Dispose used decontamination solutions properly according to the site-specific Health and Safety Plan.
- Rinse sampler with HPLC-grade water immediately prior to re-use.

For larger sediment sampling equipment, if sediment can be collected from the interior of a sampling device and away from potentially contaminated surfaces of the sampler, a site water rinse may be sufficient between stations. A site water rinse may also be sufficient for vessel surfaces between sample locations. However, all tools and equipment coming into contact with the sample should be decontaminated in accordance with the procedures above. Wash water from decontamination activities should be collected and disposed of properly. Specific projects and programs may have additional decontamination requirements.

3.3.3 Other Sampling and Measurement Probes

Soil (or sediment) gas sampling probes will be decontaminated as solids sampling devices.

Temperature, pH, conductivity, redox, and dissolved oxygen probes will be decontaminated according to manufacturer's specifications. If no such specifications exist, remove gross contaminant and triple rinse probe with HPLC-grade water. A summary of the decontamination procedures to be used must be included in the instrument-specific standard operating procedure.

Measuring tapes that become contaminated through contact with soil or sediment during field use will be decontaminated as follows:

- Wipe tape with a clean cloth or laboratory wipe that has been soaked with non-phosphate laboratory detergent solution to remove gross contamination. Rinse cloth in the solution and continue wiping until tape is clean.

- Wipe tape with a second clean, wet cloth (or laboratory wipe) to remove soap residues.

- Dry tape with a third cloth (or laboratory wipe) and rewind into case, or re-coil tape.

3.3.4 Drilling Rigs, Sediment Sampling Vessels, and Other Heavy Equipment

All drilling rigs, sediment sampling vessels, and associated equipment such as augers, drill casing, rods, samplers, tools, recirculation tank, and water tank (inside and out) will be decontaminated prior to site entry after over-the-road mobilization and immediately upon departure from a site after drilling a hole. Supplementary cleaning will be performed prior to site entry when there is a likelihood that contamination has accumulated on tires and as spatter or dust enroute from one site to the next.

- Place contaminated equipment in an enclosure designed to contain all decontamination residues (water, sludge, etc.).

- Steam clean equipment until all dirt, mud, grease, asphaltic, bituminous, or other encrusting coating materials (with the exception of manufacturer-applied paint) have been removed.

- Water used will be taken from an approved source.

- Containerize in 55-gal drums; sample; characterize; and, based on sample results, dispose of all decontamination residues properly.

Other heavy equipment includes use of backhoes, excavators, skid steers, etc. If heavy equipment is utilized during field activities, i.e., a backhoe for test pitting, the bucket should not come in contact with soil to be sampled. If the bucket contacts the soil to be sampled, then it should be decontaminated between sample locations, following the same procedures as listed above for a drill rig.

3.3.5 High Performance Liquid Chromatography-Grade Water Storage

Dedicated glass storage containers will be used solely for dispensing HPLC-grade water. New HPLC-grade water containers will be decontaminated as follows:

- Clean with tap water from approved source and non-phosphate laboratory detergent while scrubbing the exterior and interior of the container with a stiff-bristled brush.

- Rinse thoroughly with approved water.

- Rinse with 0.01N nitric acid.
- Rinse with approved water.
- Rinse thoroughly with HPLC-grade water.
- Fill clean container with HPLC-grade water. Cap with one layer of PTFE-lined paper and one layer of aluminum foil. Secure cap with rubber band and date the container.

Used HPLC-grade water containers will be decontaminated as follows:

- Clean the exterior with tap water from an approved source, non-phosphate laboratory detergent, and a stiff-bristled brush.
- Rinse the exterior thoroughly with HPLC-grade water.
- Rinse the interior twice with pesticide-grade isopropanol.
- Rinse interior thoroughly with HPLC-grade water.
- Fill clean container with HPLC-grade water. Cap with one layer of PTFE-lined paper and one layer of aluminum foil. Secure cap with rubber band and date the container.

3.3.6 Ice Chests and Reusable Shipping Containers

- Scrub exterior/interior with approved brush and liquinox detergent.
- Rinse off detergent three times with approved water.
- Let air dry and properly store until re-use.

NOTE: If container/ice chest is severely contaminated, clean as thoroughly as possible, render unusable, and properly dispose.

4. MAINTENANCE

HPLC-grade water will be stored only in decontaminated glass containers with aluminum foil lids as stipulated above. The water may not be stored for more than nor used more than 3 days after manufacture.

HPLC-grade water will be manufactured onsite. An approved tap water source will be used as the influent to the system. Procedures for system setup, operation, and maintenance will conform to manufacturer's specifications.

5. PRECAUTIONS

Dispose of all wash water, rinse water, rinsates, and other sampling wastes (tubing, plastic sheeting, etc.) in properly marked, sealable containers, or as directed by the Health and Safety Plan.

Once a piece of equipment has been decontaminated, be careful to keep it in such condition until needed.

Do not eat, smoke, or drink onsite.

6. REFERENCES

Site-specific Health and Safety Plan.

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Standard Operating Procedure No. 006
for
Summa Canister Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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APPENDIX A: SUBATMOSPHERIC/PRESSURIZED SAMPLING EQUIPMENT
APPENDIX B: SUMMA AIR SAMPLING WORK SHEET

1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to describe a procedure for the sampling of volatile organic compounds (VOCs) in ambient air. The method is based on samples collected as whole air samples in Summa-passivated stainless steel canisters. The VOCs are subsequently separated by gas chromatography and measured by mass-selective detector or multidetector techniques. This method presents procedures for sampling into canisters at final pressures both above and below atmospheric pressure (respectively referred to as pressurized and subatmospheric pressure sampling). This method is applicable to specific VOCs that have been tested and determined to be stable when stored in pressurized and subatmospheric pressure canisters. The organic compounds that have been successfully collected in pressurized canisters by this method are listed in the VOC Data Sheet below:

Compound (Synonym)	Formula	Molecular Weight	Boiling Point (°C)	Melting Point (°C)	CAS Number
Freon 12 (Dichlorodifluoromethane	Cl_2CF_2	120.91	-29.8	-158.0	
Methyl chloride (Chloromethane)	CH_3Cl	50.49	-24.2	-97.1	74-87-3
Freon 114 (1,2-Dichloro-1,1,2,2-tetrafluoroethane)	$ClCF_2CClF_2$	170.93	4.1	-94.0	
Vinyl chloride (Chloroethylene	CH_2=CHCl	62.50	-13.4	-1,538.0	75-01-4
Methyl bromide (Bromomethane)	CH_3Br	94.94	3.6	-93.6	74-83-9
Ethyl chloride (Chloroethane)	CH_3CH_2Cl	64.52	12.3	-136.4	75-00-3
Freon 11 (Trichlorofluoromethane)	CCl_3F	137.38	23.7	-111.0	
Vinylidene chloride (1,1-Dichloroethene)	$C_2H_2Cl_2$	96.95	31.7	-122.5	75-35-4
Dichlormethane (Methylene chloride)	CH_2Cl_2	84.94	39.8	-95.1	75-09-2
Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	CF_2ClCCl_2F	187.38	47.7	-36.4	
1,1-Dichloroethane (Ethylidene chloride)	CH_3CHC1_2	98.96	57.3	-97.0	74-34-3
cis-1,2-Dichloroethylene	CHCl=CHCl	96.94	60.3	-80.5	
Chloroform (Trichloromethane)	$CHCl_3$	119.38	61.7	-53.5	67-66-3
1,2-Dichloroethane (Ethylene dichloride)	$ClCH_2CH_2C1$	98.96	83.5	-35.3	107-06-2
Methyl chloroform (1,1,1-Trichloroethane)	CH_3CCl_3	`133.41	74.1	-30.4	71-55-6
Benzene (Cyclohexatriene)	C_6H_6	78.12	80.1	5.5	71-43-2
Carbon tetrachloride (Tetrachloromethane)	CCl_4	153.82	76.5	-23.0	56-23-5
1,2-Dichloropropane (Propylene dichloride)	$CH_3CHClCH_2Cl$	112.99	96.4	-100.4	78-87-5
Trichloroethylene (Trichloroethene)	$ClCH=CCl_2$	131.29	87	-73.0	79-01-6
cis-1,3-Dichloropropene (*cis*-1,3-Dichloropropylene)	CH_3CCl=CHCl	110.97	76		
trans-1,3-Dichloropropene (*cis*-1,3-Dichloropropylene)	$ClCH_2CH$=CHCl	110.97	112.0		
1,1,2-Trichloroethane (Vinyl trichloride)	CH_2 $ClCHCl_2$	133.41	113.8	-36.5	79-00-5
Toluene (Methyl benzene)	$C_6H_5CH_3$	92.15	110.6	-95.0	108-88-3
1,2-Dibromoethane (Ethylene dibromide)	$BrCH_2CH_2Br$	187.88	131.3	9.8	106-93-4
Tetrachloroethylene (Perchloroethylene)	$Cl_2C=CCl_2$	165.83	121.1	-19.0	127-18-4
Chlorobenzene (Phenyl chloride)	C_6H_5Cl	112.56	132.0	-45.6	108-90-7
Ethylbenzene	$C_6H_5C_2H_5$	106.17	136.2	-95.0	100-41-4
m-Xylene (1,3-Dimethylbenzene)	$1,3\text{-}(CH_3)_2C_6H_4$	106.17	139.1	-47.9	
p-Xylene (1,4-Dimethylxylene)	$1,4\text{-}(CH_3)_2C_6H_4$	106.17	138.3	13.3	
Styrene (Vinyl benzene)	$C_6H_5CH=CH_2$	104.16	145.2	-30.6	100-42-5
1,1,2,2-Tetrachloroethane	$CHCl_2CHCl_2$	167.85	146.2	-36.0	79-34-5
o-Xylene (1,2-Dimethylbenzene)	$1,2\text{-}(CH_3)_2C_6H_4$	106.17	144.4	-25.2	
1,3,5-Trimethylbenzene (Mesitylene)	$1,3,5\text{-}(CH_3)_3C_6H_6$	120.20	164.7	-44.7	108-67-8

Compound (Synonym)	Formula	Molecular Weight	Boiling Point (°C)	Melting Point (°C)	CAS Number
1,2,4-Trimethylbenzene (Pseudocumene)	1,2,4-$(CH_3)_3C_6H_6$	120.20	169.3	-43.8	95-63-6
m-Dichlorobenzene (1,3-Dichlorobenzene)	1,3-$Cl_2C_6H_4$	147.01	173.0	-24.7	541-73-1
Benzyl chloride (*a*-Chlorotoluene)	$C_6H_5CH_2Cl$	126.59	179.3	-39.0	100-44-7
o-Dichlorobenzene (1,2-Dichlorobenzene)	1,2-$Cl_2C_6H_4$	147.01	180.5	-17.0	95-50-1
p-Dichlorobenzene (1,4-Dichlorobenzene)	1,4-$Cl_2C_6H_4$	147.01	174.0	53.1	106-46-7
1,2,4-Trichlorobenzene	1,2,4-$Cl_3C_6H_3$	181.45	213.5	17.0	120-82-1
Hexachlorobutadiene (1,1,2,3,4,4-Hexachloro-1,3-butadiene)					

These compounds have been measured at the parts per billion by volume level. These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations, or limitations imposed by the procedure or other procedure limitations. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency endorsement or recommendation for use.

2. METHOD SUMMARY

Both subatmospheric pressure and pressurized sampling modes use an initially evacuated canister. Both modes may also use a mass flow controller/vacuum pump arrangement to regulate flow. With the above configuration, a sample of ambient air is drawn through a sampling train comprised of components that regulate the rate and duration of sampling into a pre-evacuated Summa-passivated canister. Alternatively, subatmospheric pressure sampling may be performed using a fixed orifice, capillary, or adjustable micrometering valve in lieu of the mass flow controller/vacuum pump arrangement for taking grab samples or short duration time-integrated samples. Usually, the alternative types of flow controllers are appropriate only in situations where screening samples are taken to assess for future sampling activities.

3. SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

After the air sample is collected, the canister valve is closed, an identification tag is attached to the canister, and the canister is transported to a laboratory for analysis. Upon receipt at the laboratory, the canister tag data are recorded. Sample holding times and expiration should be determined prior to initiating field activities.

4. INTERFERENCES AND POTENTIAL PROBLEMS

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

5. EQUIPMENT/APPARATUS

The following equipment/apparatus (Appendix A) is required.

5.1 SUBATMOSPHERIC PRESSURE SAMPLING EQUIPMENT

1. ***VOC Canister Sampler***—Whole air sampler capable of filling an initially evacuated canister by action of the flow controlled pump from vacuum to near atmospheric pressure (Andersen Samplers Inc., Model 87-100 or equivalent).

2. ***Sampling Inlet Line***—Stainless steel tubing to connect the sampler to the sample inlet.

3. ***Sample Canister***—Leak-free stainless steel pressure vessels of desired volume with valve and Summa-passivated interior surfaces (Scientific Instrumentation Specialist, Inc., ID 83843, Andersen Samplers, Inc., or equivalent).

4. ***Particulate Matter Filter***—2-micrometer (µm) sintered stainless steel in-line filter (Nupro Co., Model SS-2F-K4-2, or equivalent).

5. ***Chromatographic Grade Stainless Steel Tubing and Fittings***—For interconnections (Alltech Associates, Cat. No. 8125, or equivalent). All materials in contact with sample, analyte, and support gases should be chromatographic grade stainless steel.

6. ***Fixed Orifice, Capillary, or Adjustable Micrometering Valve***—Used in lieu of the electronic flow controller/vacuum pump for grab samples or short duration time-integrated samples.

5.2 PRESSURIZED SAMPLING EQUIPMENT

1. ***VOC Canister Sampler***—Whole air sampler capable of filling an initially evacuated canister by action of the flow controlled pump from vacuum to near atmospheric pressure (Andersen Samplers Inc., Model 87-100).

2. ***Sampling Inlet Line***—Stainless steel tubing to connect the sampler to the sample inlet.

3. ***Sample Canister***—Leak-free stainless steel pressure vessels of desired volume with valve and Summa passivated interior surfaces (Scientific Instrumentation Specialist, Inc., ID 83843, Andersen Samplers, Inc., or equivalent).

4. ***Particulate Matter Filter***—2-µm sintered stainless steel in-line filter (Nupro Co., Model SS-2F-K4-2, or equivalent).

5. ***Chromatographic Grade Stainless Steel Tubing and Fittings***—For interconnections (Alltech Associates, Cat. No. 8125, or equivalent). All materials in contact with sample, analyte, and support gases should be chromatographic grade stainless steel.

6. REAGENTS

Not applicable.

7. PROCEDURE

7.1 SUBATMOSPHERIC PRESSURE SAMPLING

7.1.1 Sampling Using a Fixed Orifice, Capillary, or Adjustable Micrometering Valve

1. Prior to sample collection, the appropriate information is completed on the Summa Air Sampling Work Sheet (Appendix B).

2. A canister, which is evacuated to 0.05-millimeter Hg and fitted with a flow restricting device, is opened to the atmosphere containing the VOCs to be sampled.

3. The pressure differential causes the sample to flow into the canister.

4. This technique may be used to collect grab samples (duration of 10-30 seconds) or time-integrated samples (duration of 12-24 hours). The sampling duration depends on the degree to which the flow is restricted.

5. A critical orifice flow restrictor will have a decrease in the flow rate as the pressure approaches atmospheric.

6. Upon sample completion at the location, the appropriate information is recorded on the Summa Air Sampling Work Sheet. VOCs are to be sampled.

7.1.1.1 Sampling Using a Fixed Orifice Valve Summa Canister

1. Before leaving to the field and receiving the sample canister, field personnel will need to verify in the Sampling and Analysis Plan the type of sample or samples to be collected.

2. Before leaving to the field and receiving the sample canister, field personnel will need to verify in the Sampling and Analysis Plan the total amount of time the sample canister will need to be deployed at the sample collection location to collect the actual air sample.

3. Before leaving to the field and receiving the sample canister, field personnel will need to contact and verify with the laboratory providing the sample canister that the flow controller and critical orifice provided in the sample canister will allow for the type of sample and the total amount of time needed to collect the sample requested in the Sampling and Analysis Plan.

   Field personnel will also need to ask the laboratory providing the sample canister if the sample canister has a built-in vacuum gauge and if the flow controller has a built-in vacuum gauge. The importance of a vacuum gauge is identified in Steps 5 and 7.

4. Upon receiving the sample canister, field personnel will need to inspect the sample canister shipment and familiarize themselves with the sample canister and equipment associated with the sample canister.

   Typical items associated with a sample canister are: pre-filter, flow controller, flow controller vacuum gauge, sample canister valve, sample canister inlet, sample canister vacuum gauge, brass dust cap, and rain guard.

5. Before sampling is started and equipment is attached to the sample canister, record the sample canister vacuum gauge reading, the canister's serial number, and the flow controller serial number on the appropriate field data form.

   NOTE: There are some instances when a sample canister is not equipped with a built-in sample canister vacuum gauge (Step 7).

6. Attach a string tied sample container tag to the frame of the sample canister. At a minimum, the sample container tag should contain the: sample name, analysis method, sample date, sampler, and sample time.

   NOTE: Do not attach adhesive-type labels to the sample canister.

7. When ready to sample, remove the brass dust cap from the sample canister inlet.

   If a test gauge is to be used to record the sample canister vacuum, attach the gauge to the sample canister inlet and record the sample canister vacuum reading on the appropriate field data form. See Steps 8, 9, and 10 for equipment tightening information.

   In the event a sample canister is not equipped with a built-in vacuum gauge, the laboratory will often provide a flow controller with a built-in vacuum gauge which can be used to record the sample canister vacuum.

8. Connecting equipment/flow controller to the sample canister inlet, tighten the equipment/flow controller fitting nut to the sample canister inlet finger tight, being careful not to cross the threads.

To ensure that the equipment/flow controller is being correctly installed onto the sample canister inlet, hold the flow controller and gently rotate the flow controller back and forth while finger tightening the flow controller fitting nut to the sample canister inlet.

9. Once the equipment/flow controller fitting nut is finger tightened to the sample canister inlet and it has been verified that the equipment/flow controller fitting nut threads are aligned properly to the sample canister inlet, using a flat profile wrench (typically a 9/16- or ½-in.), tighten the equipment/flow controller fitting nut.

   DO NOT use adjustable end wrenches or pliers to tighten a fitting nut.

   NOTE: To tighten an equipment/fitting nut, a 1/8 in. should be sufficient. DO NOT over-tighten any equipment/fitting connections. Over-tightening will cause leaks.

   IMPORTANT: DO NOT use Teflon™ tape or other sealants on any equipment/fitting threads; they are not necessary.

10. To begin sampling, open the sample canister valve by turning it counter-clockwise one full turn.

    NOTE: Canister valves can be of two types: rotary and toggle.

    Record the start time and the initial sample canister vacuum gauge reading on the appropriate field data form.

11. Field personnel need to periodically check the sample canister vacuum gauge throughout the sampling period to ensure that sufficient vacuum remains in the sample canister for the time the sample canister will need to be deployed to collect the sample.

12. Once the sampling period is complete, close the sample canister valve finger tight or snug. DO NOT over-tighten the sample canister valve as this may possibly damage the sample canister valve.

    NOTE: It is preferable to stop the sampling period when the sample canister vacuum gauge reads -5" Hg. Allowing the sampling period to extend past -5" Hg may possibly result in an unusable sample.

13. Record the stop time and the ending sample canister vacuum gauge reading on the appropriate field data form.

14. Disassemble the equipment/flow controller in reverse order of the above assembly instructions. Return all equipment/flow controller to the original packaging material and shipping container in the manner in which they were received.

15. Complete the chain-of-custody form, ensuring all fields are entered, repackage the sample canister and its associated equipment in the original shipping container, secure the outside of the shipping container with custody seals to ensure the integrity of the sample canister, and return the sample canister to the procured laboratory.

7.1.2 Sampling Using a Mass Flow Controller/Vacuum Pump Arrangement (Andersen Sampler Model 87-100)

1. Prior to sample collection, the appropriate information is completed on the Summa Air Sampling Work Sheet (Appendix B).

2. A canister is connected in line with the sampler and is opened to the atmosphere containing the VOCs to be sampled.
3. A whole air sample is drawn into the system through a stainless steel inlet tube by a direct drive blower motor assembly.

4. A small portion of this whole air sample is pulled from the inlet tube by a specially modified inert vacuum pump in conjunction with a mass flow controller.

5. The initially evacuated canister is filled by action of the flow controlled pump to near atmospheric pressure.

6. A digital time-program is used to pre-select sample duration and start and stop times.

7. Upon sample completion at the location, the appropriate information is recorded on the Canister Sampling Field Data Sheet.

7.2 PRESSURIZED SAMPLING

7.2.1 Sampling Using a Mass Flow Controller/Vacuum Pump Arrangement (Anderson Sampler Model 87-100)

1. Prior to sample commencement at the location, the appropriate information is completed on the Canister Sampling Field Data Sheet.

2. A canister is connected in line with the sampler and is opened to the atmosphere.

3. A whole air sample is drawn into the system through a stainless steel inlet tube by a direct drive blower motor assembly.

4. A small portion of this whole air sample is pulled from the inlet tube by a specially modified inert vacuum pump in conjunction with a mass flow controller.

5. The initially evacuated canister is filled by action of the flow controlled pump to a positive pressure not to exceed 25 pounds per square inch gauge.

6. A digital time-programmer is used to pre-select sample duration and start and stop times.

7. Upon sample completion at the location, the appropriate information is recorded on the Canister Sampling Field Data Sheet.

8. CALCULATIONS

A flow control device is chosen to maintain a constant flow into the canister over the desired sample period. This flow rate is determined for the canister and is filled to approximately 88.1 kPa for subatmospheric pressure sampling or to approximately one atmosphere above ambient pressure for pressurized sampling over the desired sample period. The flow rate can be calculated by:

$$F = \frac{(P)(V)}{(T)(60)}$$

where

F = Flow rate (cm^3/min)
P = Final canister pressure, atmospheres absolute
V = Volume of the canister (cm^3)
T = Sample period (hours).

For example, if a 6-liter canister is to be filled to 202-kPa (two atmospheres) absolute pressure in 24 hours, the flow rate can be calculated by:

$$F = \frac{(2)(6000)}{(24)(60)} * 8.3 cm^3/min$$

If the canister pressure is increased, a dilution factor is calculated and recorded on the sampling data sheet.

where

$$\text{Dilution Factor} = \frac{Ya}{Xa}$$

Xa = Canister pressure (kPa, pounds per square inch absolute) absolute before dilution.
Ya = Canister pressure (kPa, pounds per square inch absolute) absolute after dilution.

After sample analysis, detected VOC concentrations are multiplied by the dilution factor to determine concentration in the sampled air.

9. QUALITY ASSURANCE/QUALITY CONTROL

The following general quality assurance procedures apply (VIP-8, U.S. Environmental Protection Agency 600/9-87-010):

1. Data must be documented on standard volume sets when sampling ambient air: chain-of-custody records, field data sheets, or using solid adsorbents (atmospheric site logbooks. Environ. 18:855-859, 1984).

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

3. Duplicates, replicates, or other quality assurance/quality control samples may be collected as appropriate or as defined in project-specific Work Plans and Quality Assurance Project Plans.

10. DATA VALIDATION

Not applicable.

11. SAFETY AND HEALTH

When working with potentially hazardous materials, follow U.S. Environmental Protection Agency, Occupational Safety and Health Administration, and Corporate safety and health practices. Specifically, pressurization of Summa canisters should be performed in a well ventilated room, or preferably under a fume hood. Care must be taken not to exceed 40 pounds per square inch in the canisters. Canisters are under pressure, albeit only 20-30 pounds per square inch, and should not be dented or punctured. They should be stored in a cool dry place and always be placed in their plastic shipping boxes during transport and storage.

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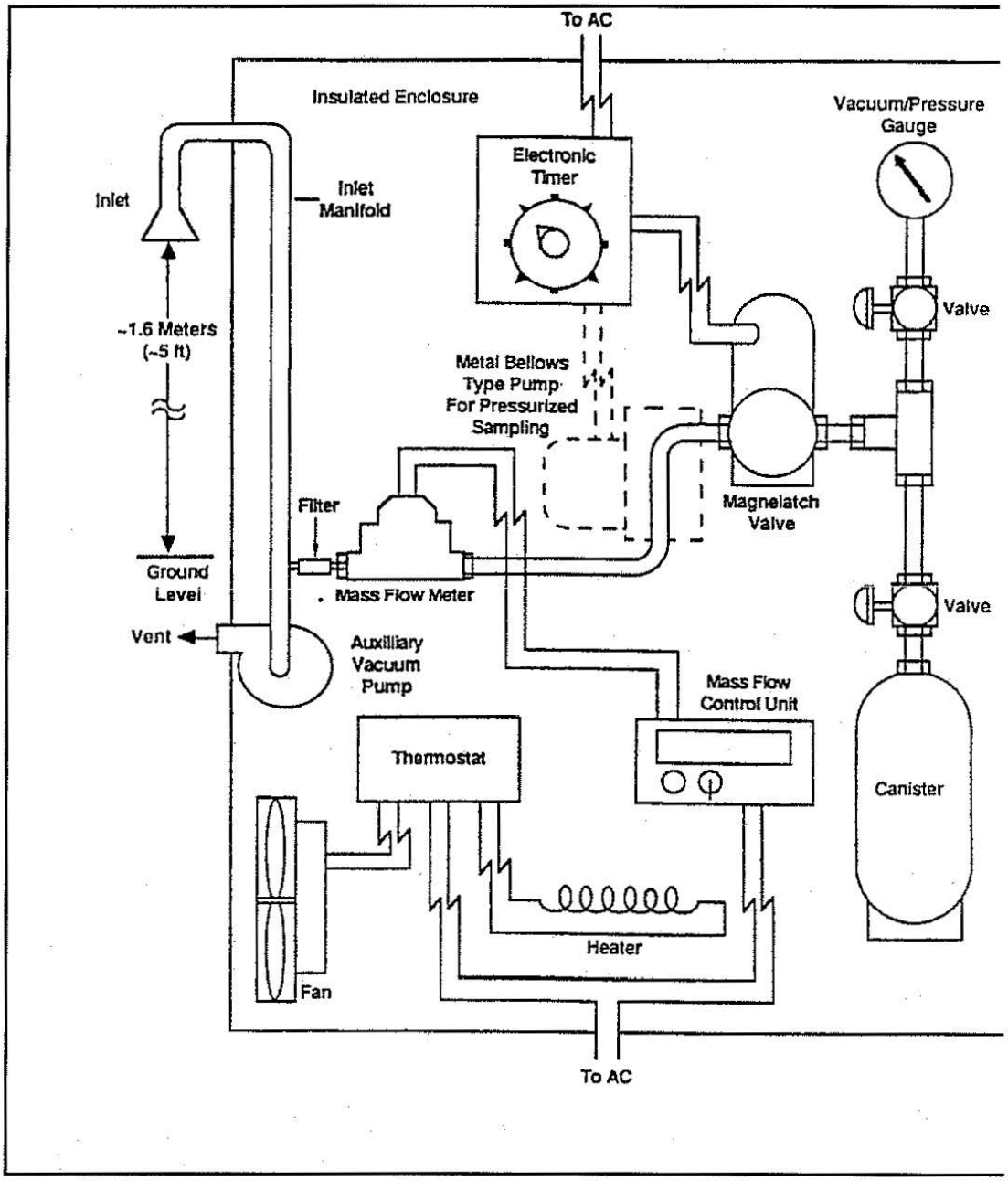
Appendix A

Equipment/Apparatus

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Appendix A

Subatmospheric/Pressurized Sampling Equipment



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Appendix B

Summa Air Sampling Work Sheet

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APPENDIX B

SUMMA AIR SAMPLING WORKSHEET

Site:		**Site No.:**	
Samplers:		**Work Assignment Manager:**	
Date:		**Project Leader:**	

Sample No.					
Location:					
Summa ID					
Orifice Used					
Analysis/Method					
Time (Start)					
Time (Stop)					
Total Time					
SUMMA WENT TO AMBIENT	**Yes/No**	**Yes/No**	**Yes/No**	**Yes/No**	**Yes/No**
Pressure Gauge					
Pressure Gauge					
Flow Rate (Pre)					
Flow Rate (Post)					
Flow Rate (Avg.)					
MET Station Onsite: Yes/No					

General Comments:

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Standard Operating Procedure No. 007
for
Surface Water Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for sampling surface water. This procedure can be applied to the collection of surface water samples from marine and estuarine systems, streams, rivers, ditches, lakes, ponds, and lagoons. Surface water samples provide an indication of the amount of contaminant in the surface water. It is, therefore, important to collect a representative sample.

2. MATERIALS

The following materials may be required:

0.45-µ disposable filters	Sample bottles
Cooler with ice	Short-handled dip sampler (PTFE or stainless steel)
Long-handled dip sampler (polytetrafluoroethelyne [PTFE] or stainless steel)	Stainless steel or PTFE-lined bucket
Peristaltic pump with 0.45-µM filters and disposable Tygon tubing	Niskin bottle (or similar sampling device)

3. PROCEDURE

For all surface water samples, use a Global Positioning System to record sampling coordinates and mark the sampling locations on a site map. Photograph (if cameras are allowed onsite) and describe each location, place a numbered stake above the visible high water mark on the bank closest to the sampling location, and/or mark adjacent trees with surveyor's flagging. The photographs and descriptions must be adequate to allow the sampling station to be relocated at some future date by someone other than the original sampling crew. Use a long-handled dip sampler where access is poor or non-contact with water is suggested in the Health and Safety Plan.

Sampling should be performed deliberately and methodically to minimize disturbance of bottom sediments, yet as quickly as possible to ensure a representative sample. If wading in a stream, sample downstream of the sampling location to prevent disturbance of the bottom. To prevent contamination of the exterior of the sample container, and/or potential contamination of the surface water sample by laboratory contaminants on the exterior of the bottle, the sample container should never be dipped into the water, rather a decontaminated sampling device should be used to collect unfiltered samples.

Sampling with the PTFE or stainless steel sampler (long-handled or measuring cup-type):

- Remove the cap from the sample bottle.
- Dip a sample of surface water using the sampler.

- Tilt sample bottle and gently pour sample from sampler into the bottle. Allow the sample to trickle down the side of the bottle. Avoid aerating the sample.

- Add preservative as required by SOP No. 039. Replace cap, and place in cooler immediately.

Sampling with stainless steel or PTFE-lined bucket:

- Remove cap from sample bottle.

- Gently dip collection bucket in the water. Fill bucket and carefully lift from water body.

- Tilt sample bottle and gently pour sample from sampler into the bottle. Allow the sample to trickle down the side of the bottle. Avoid aerating the sample.

- Add preservative as specified by the project-specific Sampling and Analysis Plan. Replace cap, and place in cooler immediately.

– OR –

- Use smaller sampling cup to transfer sample from bucket to sample bottle as described above.

Sampling with a Niskin bottle (or similar device):

- Prepare the bottle for deployment by placing the ends of the bottle in the open position and lock the ends into the trigger mechanism.

- Lower the bottle to desired depth of sampling (on either a wire cable or rope).

- Place a messenger (triggering device) on the cable/rope and deploy by allowing free-fall down the cable/rope.

- Bring the bottle back to the surface and pour sample into a sample container.

Sampling with a peristaltic pump and Tygon tubing:

- Cut a length of Tygon tubing to the depth of sampling specified by the client or project-specific Sampling and Analysis Plan.

- Insert one end of the tubing into the intake hose on the peristaltic pump.

- Place a weight on the tubing and lower to the specified depth;

- Cut a length of tubing and insert into the output (out-flow) hose on the peristaltic pump.

- After applying power to the peristaltic pump, proceed to pump site water through the tubing apparatus. Approximately five times the hose volume should be pumped through the tubing before sampling.

- Fill the required sample containers.

- If filtering is required, obtain filtered sample by placing a 0.45-µM in-line filter on the end of the output tube and fill the required sample containers.

Both filtered and unfiltered samples may be required for metals analyses. Bulk samples for filtration will be collected using the stainless steel or PTFE-lined bucket method described above. Sample filtration must be performed immediately upon retrieval of the bulk sample as follows.

Filtration will be performed immediately after collecting sample. Set up filtration equipment prior to collecting sample. Filtration may be accomplished by gravity or, if necessary due to slow filtering, a peristaltic pump will be used to pressure filter the sample. Vacuum filtration will not be used due to the possibility of analyte volatilization.

Gravity filtration will be accomplished as follows:

- Using decontaminated forceps, place a 0.45-µM membrane in a decontaminated filter funnel.

- Slowly pour sample into the funnel and collect filtrate directly into appropriate sample container(s).

- Add preservative(s) as required by project-specific Sampling and Analysis Plan. Immediately cap container and place in cooler.

- Dispose of filter membrane.

Pressure filtration will be accomplished as follows:

- Using previously assembled disposable tubing, 45-µ in-line filter, and peristaltic pump, filter sample from collection bucket into appropriate container.

- Adjust pump rate to avoid aeration of sample.

- Fill container, preserve as indicated in SOP No. 039, immediately cap container, and place in cooler.

- Dispose of filter and tubing.

Refer to SOP Nos. 001, 002, 004, 005, 016, and 039.

4. MAINTENANCE

Refer to manufacturer's specifications for maintenance procedures on generators and pumps.

5. PRECAUTIONS

Avoid disturbing bottom sediments.

Consult the Health and Safety Plan prior to collecting any samples for personal protective equipment such as dermal and respiratory protection and personal flotation devices when sampling in or near deep water or from boats.

Always decontaminate the sampling and filtration equipment, and change gloves between sampling locations to minimize the risk of cross-contamination.

Always set up generators downwind of working area. Never service generators onsite.

6. REFERENCES

None.

Standard Operating Procedure No. 008
for
pH Measurement

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the pH of all types of aqueous solutions, including drinking water, saline water, and industrial and domestic wastes. As a measure of the hydrogen ion content of a solution, pH gives a general indication of the acidity or alkalinity of a water sample.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Φ ® 12 pH Meter
Automatic temperature compensator (ATC) probe
Beakers
Combination (pH) electrode
Commercial buffer solutions (standards) of pH 4.00, 7.00, and 10.00
HPLC-grade water
Laboratory wipes for blotting electrodes
Wash bottle

3. PROCEDURE

3.1 CALIBRATION CHECK

Calibration of the pH meter will be checked on a daily basis. A two-point calibration should be used as follows:

1. Prepare beakers of buffer solutions of pH 4.00, 7.00, and 10.00.
2. Calibration should closely bracket the expected pH range of the samples to be taken.
3. Turn on instrument, clear instrument.
4. Rinse the electrode with distilled water and blot excess.
5. Immerse probes in beaker of pH 4.00 or 7.00 standard, swirl gently.
6. Press pH key, then STD key.

7. Keep the probes in the sample until the reading stabilizes. The reading should be the pH of the standard.

8. Rinse the electrode with distilled water and blot excess.

9. Repeat the procedure with pH 7.00 and 10.00 standards.

10. Record the initial readings.

11. If the measured values vary from the expected value by greater than 0.2 pH units, recalibrate the instrument with fresh aliquots of buffer solution. If the discrepancy persists, alert the Field Operations Leader, who has the option of trying to fix the meter or obtaining a second pH meter.

12. Record all measurements in the field logbook.

13. Verify calibration by reading the pH of the third buffer solution.

14. Refer to SOP No. 016.

3.2 pH MEASUREMENTS

Measurements of pH will be taken using the two-point standardization method as follows:

1. Connect the ATC and pH electrodes to the appropriate inputs.

2. Turn on instrument, clear instrument.

3. Prepare two small beakers of standard buffer solutions. Ideally, the pH values of these standards will "bracket" the expected pH value of the sample and be as close as possible to the pH of the sample.

4. Rinse a small beaker with distilled water, then sample water. Fill the beaker with sample water.

5. Rinse the probes with distilled water. Blot excess.

6. Immerse electrode and ATC in first standard. Swirl gently. Press pH key and STD key. Wait for display to stop flashing.

7. Rinse the probes with distilled water. Blot excess.

8. Immerse electrode and ATC in second standard. Swirl gently. Press STD key. Wait for display to stop flashing.

9. Rinse the probes with distilled water. Blot excess.

10. Immerse the probes in the sample and swirl gently, keeping the probes in the sample until the display stops flashing.

11. Record the sample pH and temperature after stabilization. Note any problems such as meter drift.

12. Rinse the probes with distilled water. Blot excess.

13. Repeat Steps 9 through 12 for additional samples.

Decontaminate probe according to manufacturer's specifications.

Decontaminate beakers according to SOP No. 005, Section 3.3.1.4 (Labware).

4. MAINTENANCE

The following steps will be taken to maintain the pH meter:

1. Check the batteries each time the meter is used.

2. Keep the probe stored in a 0.1 M KCl solution adjusted to pH 4 when the meter is not in use. Alternatively, the electrode may be rinsed with deionized water and the protective cap put on, trapping any residual water inside it (do not blot the electrode dry prior to putting the cap on).

5. PRECAUTIONS

Remove coatings of oil material or particulate matter that can impair electrode response by gentle wiping or detergent washing, followed by distilled water rinsing.

As noted in Section 1, these procedures may not apply to alternate manufacturer's equipment.

Calibration is always performed using the pH 7.00 and one end point (pH4.00 or 11.00) standard. **Never** calibrate the instrument using two end points only.

6. REFERENCES

Beckman Instruments, Inc. Users Manual for Φ® 10 pH Meter, Φ® 11 pH meter, and Φ® 12 pH/ISE Meter.

Franston, M.H. et al. (eds). 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. American Public Health Association, American Water Works Association and Water Pollution Control Federation.

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. March.

Standard Operating Procedure No. 009
for
Temperature Measurement

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the temperature of a solid or liquid sample, in particular, for measuring water temperature. Groundwater temperature does not vary dramatically over the course of a year. Therefore, groundwater temperature can be used to help identify an aquifer, identify stream reaches where groundwater inflow is occurring, identify thermal gradients in lakes or ponds, and also indicate when sufficient water has been removed from a well during purging.

2. MATERIALS

The following materials may be required: digital reading thermocouple thermometer in combination meter or in a stick. Accuracy = ±0.5°C.

3. PROCEDURE

Rinse the probe with distilled water. Insert the probe into the sample, and leave it in the sample until the temperature stabilizes. Record the temperature reading, being sure to indicate °C or °F. Decontaminate the probe according to Section 3.3 of SOP No. 005 (Field Decontamination).

Refer to SOP Nos. 005 and 016.

NOTE: °C = (°F - 32) (5/9)
°F = ([9/5]°C) + 32.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

None.

6. REFERENCES

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. March.

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Standard Operating Procedure No. 010
for
Water Level and
Well Depth Measurements

Prepared by

EA Engineering, Science, and Technology, Inc.
11019 McCormick Road
Hunt Valley, Maryland 21031

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August 2007

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring water level and well depth. This procedure is applicable to the sampling of monitoring wells and must be performed prior to any activities which may disturb the water level, such as purging or aquifer testing.

2. MATERIALS

The following materials may be required:

Electric water level indicator (dipmeter) with cable measured at 0.01-ft increments OR weighted steel tape and chalk OR transducer and datalogger
Oil/water interface probe
Plastic sheeting
Photoionization detector or intrinsically safe flame ionization detector

3. PROCEDURE

3.1 PRELIMINARY STEPS

Locate the well and verify its position on the site map. Record whether positive identification was obtained, including the well number and any identifying marks or codes contained on the well casing or protective casing. Gain access to the top of the well casing.

Locate the permanent reference mark at the top of the casing. This reference point will be scribed, notched, or otherwise noted on the top of the casing. If no such marks are present, measure to the top of the highest point of the well casing and so note this fact in the field logbook. Determine from the records and record in the notebook the elevation of this point.

Record any observations and remarks regarding the completion characteristics and well condition, such as evidence of cracked casing or surface seals, security of the well (locked cap), and evidence of tampering.

Keep all equipment and supplies protected from gross contamination; use clean plastic sheeting. Keep the water level indicator probe in its protective case when not in use.

3.2 OPERATION

Sample the air in the well head for gross organic vapors by lifting the well cap only high enough for an organic vapor meter (photoionization detector or flame ionization detector) probe to be entered into the well casing. This will indicate the presence of gross volatile contaminants as well as indicating potential sampler exposure.

Remove cap. Allow well to vent for 60-90 seconds. Resample headspace. Record both readings. If the second reading is lower than the first, use the second reading to determining whether respiratory protection will be required during subsequent water level and well depth determinations, and sampling.

Note that all headspace sampling must be performed at arm's length and from the upwind side of the well if possible.

Refer to SOP Nos. 011, 023, or 024 as appropriate.

If non-aqueous phase liquid (NAPL) contamination is suspected[1], use an interface probe to determine the existence and thickness of NAPLs.

Open the probe housing, turn the probe on, and test the alarm. Slowly lower the probe into the well until the alarm sounds. A continuous alarm indicates a NAPL while an intermittent alarm indicates water. If a NAPL is detected, record the initial level (first alarm). Mark the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable sufficiently to record the depth.

Continue to slowly lower the probe until it passes into the water phase. Slowly retract the probe until the NAPL alarm sounds and record that level in the manner as described above.

Record the thickness of the light NAPL[2] (Section 3.3).

Continue to slowly lower the interface probe through the water column to check for the presence of dense NAPL.

Measure and record the thickness of the dense NAPL layer (if any) as described above.

Slowly raise the interface probe, recording the depth to each interface as the probe is withdrawn. If there is a discrepancy in depths, clean the probe sensors and re-check the depths.

NOTE: Air/liquid interface depth is more reliable if probe is lowered into liquid. NAPL/water depths are more accurate if probe is moved from water into NAPL.

Always lower and raise interface probe slowly to prevent undue mixing of media.

1. Interface probes will be used in all wells for first round sampling, regardless of site history. If no NAPLs are detected during the first round of sampling, this step may be omitted during subsequent sampling events **unless** conditions such as site history or headspace vapors would indicate otherwise.
2. If NAPL is viscous, such as coal tar or weather bunker oil, several confirmation measurements should be made after decontamination of the probe to verify that the NAPL is not sticking to the probe and causing erroneous readings. One way to accomplish this would be to partially fill a 5-gal bucket with water and dip the probe to ensure that decontamination has effectively removed the NAPL.

Always perform NAPL check in wells installed in areas with suspected NAPL contamination. Always perform NAPL check if headspace test reveals presence of volatiles. Always perform NAPL check the first time a well is sampled. **If** a well has been sampled previously **and** no NAPLs were present **and** none of the preceding conditions are met, the NAPL check may be omitted.

If no NAPL is present, use an electronic water level detector as follows:

- Remove the water level indicator probe from the case, turn on the sounder, and test check the battery and sensitivity scale by pushing the red button. Adjust the sensitivity scale until you can hear the buzzer.

- Slowly lower the probe and cable into the well, allowing the cable reel to unwind. Continue lowering until the meter buzzes. Very slowly, raise and lower the probe until the point is reached where the meter **just** buzzes. Marking the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable and record the depth.

Alternatively use a steel tape with an attached weight if aquifer gradients are lower than 0.05 ft/ft. Due to the possibility of adding unknown contaminants from chalk colorants, only white chalk is permitted.

Rub chalk onto the first 1 ft of the steel tape and slowly lower the chalked end into the well until the weighted end is below the water surface. (A small splash can be heard when the weighted end hits the water surface.)

Using the method described above read and record the length from the steel tape.

Remove the steel tape. The chalk will be wet or absent where the tape was below the water surface. Locate, read, and record this length. Subtract wetted length from total length and record the difference. This is the depth to water table.

Transducers and dataloggers will be used where water level fluctuations over time are to be measured, such as tidal fluctuation studies (SOP No. 045) and aquifer (hydraulic) tests (SOP No. 033). Note that transducers are inappropriate for measuring well depth.

Slowly lower the transducer into the well until it is below the lowest possible piezometric level (typically 2-3 ft below the water table).

Tape the umbilical to the protective casing to prevent the transducer from falling further.

Attach the umbilical leads to the datalogger.

Turn datalogger on.

To measure the well depth, lower electric water level indicator probe or tape until slack is noted. Very slowly raise and lower the cable until the exact bottom of the well is "felt." Measure (cable) or read the length (tape) and record the depth.

Note that if the electric water level indicator is used to determine depth of well, the offset distance between the tip of the probe and the electrode must be added to the reading to determine actual depth.

Withdraw the probe or tape. Decontaminate the probe(s) and cable(s).

3.3 DATA RECORDING AND MANIPULATION

Record the following computations:

- Date and time
- Weather
- Method of measurement
- Casing elevation
- NAPL surface elevation = casing elevation – depth to NAPL
- NAPL thickness = depth to bottom of NAPL – depth to top of NAPL
- Water level elevation = casing elevation – depth to water
- Well bottom elevation = casing elevation – depth to bottom (or read directly from tape).

Refer to SOP Nos. 005 and 016.

4. CALIBRATION

No calibration is needed.

5. PRECAUTIONS

Depending upon the device used, correction factors may be required for some measurements. Check instrument batteries prior to each use. Exercise care not to break the seals at the top of the electric water level indicator probe.

6. REFERENCES

McAlary, T.A. and J.F. Barker. 1987. Volatilization Losses of Organics during Groundwater Sampling from Low Permeability Materials in Groundwater Monitoring Review. Fall.

Thornhill, J.T. 1989. Accuracy of Depth to Groundwater Measurements in U.S. Environmental Protection Agency Superfund Groundwater Issue EPA/540/4-89/002.

Standard Operating Procedure No. 011
for
Photoionization Detector

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for field operations with the photoionization detector (MiniRae). The photoionization detector uses an ultraviolet emitting lamp designed to detect, measure, and display the total concentration of airborne ionizable gases and vapors. This information is used to determine control measures such as protection and action levels.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Battery pack	Tedlar bag
Calibration gas (100 ppm isobutylene)	Tygon tubing
Microtip/MiniRae	Regulator

3. STARTUP/CALIBRATION PROCEDURE

Turn the instrument on by pressing the back of the power switch located on the handle of the instrument.

The message “Warming up now, please wait” will be displayed for up to 3 minutes. After normal display appears, the instrument is ready for calibration.

Fill a Tedlar bag with the desired calibration gas (usually 100 ppm Isobutylene).

Press SETUP button and select the desired Cal Memory using the arrow keys (normally set to 200 ppm). Press EXIT button to leave setup function.

Press CAL button and expose instrument to Zero Gas. (Usually clean outdoor air will be suitable. If any doubt exists as to the cleanliness of the background air a commercial source of zero gas should be used.)

The instrument then asks for the Span Gas concentration. Enter the known span gas concentration and then connect the Tedlar bag containing the Span Gas.

NOTE: The span gas concentration is dependent upon both the concentration of the span gas used and the rating of the UV lamp in the instrument at time of calibration. If using 100 ppm isobutylene and the standard 10.6 eV lamp, the span gas concentration will be 56 ppm.

Press enter and the instrument sets its sensitivity. Once the display reverts to normal, the instrument is calibrated and ready for use. Remove the Span Gas from the inlet probe. The instrument should be calibrated at least once a day.

4. BATTERY CHARGING

Ensure instrument is off. Set the voltage selector switch on the bottom of the battery charger to the appropriate AC line voltage. Press the release button on the bottom of the instrument and remove the battery pack by sliding it backwards. Plug charger into the battery pack and then into an AC outlet and allow the battery to charge for at least 8 hours. After charging, remove the charger, first from the outlet then from the battery pack, and slide the battery pack back onto the instrument.

5. PRECAUTIONS

Instrument does not carry an Intrinsic Safety Rating and must not be used in a hazardous location where flammable concentrations of gases or vapors are constantly present.

All calibration, maintenance, and servicing of this device, including battery charging, must be performed in a safe area away from hazardous locations.

Do not open or mutilate battery cells. Do not defeat proper polarity orientation between the battery pack and battery charger. Substitution of components may affect safety rating.

6. REFERENCES

Instrument User's Manual.

Standard Operating Procedure No. 012
for
Specific Conductance Measurements

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the specific conductance of any aqueous solution, including drinking water, saline water, and industrial and domestic wastes. Conductivity is the ability of an aqueous solution to pass an electrical current. The current is primarily carried by dissolved inorganic ions such as chlorides, nitrates, sulfates, along with cations such as sodium, calcium, magnesium and others. Organic compounds do not carry current and, therefore, have almost no conductivity.

2. MATERIALS

The following materials may be required:

Conductivity meter with integral temperature compensation; accuracy = ±2 percent at 25°C (77°F)
Conductivity cell
Appropriate conductivity reference solution
High performance liquid chromatography (HPLC)-grade water (see SOP No. 005, Footnote 2)
Thermometer (optional, Section 5)

3. PROCEDURE

3.1 CALIBRATION

The specific conductivity meter should be calibrated at the beginning of each day[1] as follows:

1. Thoroughly rinse the probe with appropriate conductivity reference solution.

2. Zero meter if appropriate.

3. Measure the specific conductance of fresh appropriate conductivity reference solution record it in the field notebook, and adjust the calibration knob until the meter reads properly.

4. Rinse probe with HPLC-grade water.

5. Measure the specific conductance of HPLC-grade water and record in the field logbook. If specific conductivity of HPLC-grade water is not 0 (±2 percent) recalibrate instrument.

1. The meter should be recalibrated any time the readings are suspect (e.g., out of expected range).

3.2 OPERATION

The specific conductivity meter will be operated as follows:

1. Thoroughly rinse the probe and sample beaker with sample water.

2. Measure the temperature of the sample water. Convert Fahrenheit temperature readings to Celsius using C = 5/9(F - 32) if Celsius temperature is not obtained directly.

3. Place the probe in the sample beaker with sufficient sample to completely submerge the probe. Swirl the probe to remove any air bubbles trapped in the probe.

4. Select the highest multiplier scale on the meter and turn the instrument on. Progressively use lower multiplier scales until a mid-scale deflection is obtained.

5. If appropriate, check probe accuracy by pressing cell test button. If value change is >10 percent check probe.

6. Record the temperature and conductivity values.

7. Specific conductivity values are corrected for temperature using:

   K^25^oC = {*K measured*} over {1+ 0.0191 (t-25)}

   where

   K = Conductivity in µmhos
   t = Temperature, °C

8. Decontaminate the probe (see SOP No. 005, Section 3.3.3).

Refer to SOP Nos. 005 and 016.

4. MAINTENANCE

The following steps will be taken to properly maintain the conductivity meter:

1. Check the batteries each time the instrument is used.

2. Inspect the probe on a daily basis for damage or loss of platinum black plating from the electrode. If the platinum is damaged, alert the Field Team Leader and arrange to get a new cell.

3. Follow manufacturer's specifications regarding storage of probe between uses.

5. PRECAUTIONS

Be certain there is no air in the cell before taking a reading. If conductivity meter does not have integral temperature compensation, use a thermometer to determine temperature of the sample.

6. REFERENCES

Manufacturer's Manual.

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. March.

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Standard Operating Procedure No. 013
for
Collection of Monitoring Well Samples

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for the collection of groundwater samples from monitoring wells.

2. MATERIALS

The following materials may be required:

0.45 µM filters	Polyvinyl chloride bailer (for purging only)
Bladder pump (dedicated to one well only)	Sample bottles and labels
Conductivity meter	Stainless steel bailer (for purging and sampling)
Dissolved oxygen meter	Submersible pump and hose (for purging only)
Generator	Thermometer (optional)[1]
Logbook or book of field parameter forms	Transparent bailer with a double check valve
Peristaltic pump with tubing for filtering samples	Turbidity meter
pH meter with oxidation-reduction potential probe	Tygon tubing
Photoionization detector organic vapor analyzer.	Variable speed, low flow submersible pump (e.g., Grundfos MP1 groundwater sampling pump) (for purging and sampling)
Plastic sheeting	Water level indicator
Polypropylene rope	
Polytetrafluoroethelyne (PTFE) bailer with PTFE-coated stainless steel cable, double check valve top, and controlled flow bottom discharge attachment[2] for volatile organic compound (VOC) sampling (40-mL vials), and top discharge attachment for collecting larger samples (1-L bottles) (for purging and sampling)	

3. PROCEDURE

3.1 GENERAL

Groundwater sampling will follow these general steps:

- Arrive onsite
- Set up apparatus (generators, pumps, etc.)
- Glove
- Organic vapor check, water level, and well depth measurements

1. Temperature compensation and measurement capabilities are generally available as integral functions of pH meters and conductivity meters. If this is the case, a separate thermometer is not required.
2. Although use of a controlled flow bottom discharge valve is historically preferred, use of such a device can cause aeration of the sample.

- Sample non-aqueous phase liquids (NAPLs) (as required)

- Begin purge procedure

  — If using bailer to purge and sample, see Section 3.6
  — If using pump to purge and bailer to sample, see Section 3.7
  — If using bladder or low-flow pump to purge and sample, see Section 3.8

- Decontaminate/reglove

- Take samples

  — If with bailer, see Section 3.6
  — If with bladder or low flow pumps, see Section 3.8

- Decontaminate/dispose of wastes, move equipment to next site.

3.2 GENERAL RULES FOR GROUNDWATER FIELD PARAMETER LOGBOOK

Use only one site or installation per logbook, and only one sampling location per page or form (if using pre-printed forms). The same book may be used for more than one sampling event. First five pages will be reserved for index, general notes, etc. Sign and date each entry. Last five pages will be reserved for recording calibration data for the pH, temperature, turbidity, oxidation-reduction potential, dissolved oxygen, and conductivity meters. Use the page number or a separately recorded "Cal Reference Number" to refer to each calibration. As appropriate, insert the cardboard flap under the form being filled out, so that writing does not go through to the pages below. As appropriate, fill in the forms from front to back of the logbook, tearing out the white copy for each sample when the sample has been collected. This copy goes in the cooler with the sample, directly to the laboratory. The original copy must be torn out before you write on the back of the duplicate form. As appropriate, duplicate copies, index pages, and calibration sheets remain intact.

3.3 GROUNDWATER SAMPLING GENERAL RULES

Groundwater samples will be collected from the least contaminated wells first, progressing to the most contaminated[3]. Upon arrival at the well site, immediately set up and organize the purging, sampling, and filtration equipment. If needed, due to muddy or contaminated ground, remoteness from sampling vehicle, and\or for placement of hose(s) and\or power cord if a pump is used, place clean plastic sheeting at, or around the well, to serve as a clean staging area for purging and sampling equipment, as conditions warrant. Care must be exercised not to step on plastic sheeting. If the well is remote from the sampling vehicle, set up the filtration equipment

3. First round samples are to be collected from upgradient wells first, moving to downgradient wells under the assumption that upgradient wells will be less contaminated than downgradient wells. Results of first round analysis may mandate a change in sampling sequence.

and place rope, wrapped bailer, and pre-labeled sample containers on the plastic sheet, from the well. When a pump is to be used, situate the portable generator on level ground approximately 15 ft away from and downwind from the well. All generator maintenance (oil and fueling) is to be performed offsite. If the hose(s) and/or power cord of the pump are not on a reel, place the pump with its hose and power cord on the plastic sheeting downhill from the well.

Check well headspace for organic vapor which may pose a health and safety hazard and indicate the presence of NAPL. Measure depth(s) to and thickness(es) of NAPL(s) as appropriate. Measure the depth to water and depth of well. From the water depth, well diameter, sand pack length, etc., calculate the equivalent volume (1 EV) of water in the well.

1 EV = volume in casing + volume in saturated sand pack. Therefore, if the water table lies below the top of the sandpack, use the following equation:

$$1\ EV = (\pi R_w^2 h_w) + (0.30\pi(R_s^2 - R_w^2)h_w) * (0.0043)$$

If the water table lies above the top of the sandpack use this equation:

$$1\ EV = [(\pi R_w^2 h_w) + (0.30\pi(R_s^2 - R_w^2)h_s)] * (0.0043)$$

where

R_s = Radius of sandpack in inches
R_w = Radius of well casing in inches
h_s = Height of sandpack in inches
h_w = Water depth in inches

0.0043 gal/in.^{3}
Assumed filter pack porosity = 30 percent.

Samples will always be collected in order of decreasing volatility (i.e., the samples to be analyzed for the volatile constituents should be collected first). Deliver the VOC sample to the vial by allowing the water to trickle down the inside wall of the vial at a rate no greater than approximately 100 ml/min. Other samples may be delivered at a faster rate. Sampling rates will at no time exceed 1 L/min. Procedures for each class of samples are contained in the site-specific Quality Assurance Project Plan.

When collecting samples for volatile analysis, care should be taken to prevent analyte loss by volatilization. The following procedures should be adhered to when collecting these samples:

- Avoid excessive aeration and agitation of sample.
- Fill vial so that a reverse meniscus is present by adjusting the flow rate from the sampling device.

- Place septum on vial so that the PTFE side is in contact with the sample. After the cap is on the bottle, check for air bubbles in the sample. If air bubbles are present, properly dispose of that sample and recollect the sample in the same vial.

- Make sure vial is labeled and immediately transfer the vial to the cooler with ice.

Filtered and unfiltered samples will be taken for inorganics (metals) analyses. The samples will be filtered through an in-line 0.45-µM filter (preferred method), or by gravity through a 0.45-µM membrane placed in a filter funnel. Use forceps to place the membrane into the funnel and pour sample through funnel until appropriate volumes have been filtered.

If necessary, due to slow filtering, a peristaltic pump may be used to filter the sample through an in-line filter. Connect the pump to the generator, attach tygon tubing to the bottom discharge valve on the bailer. Start pump and collect sample from the end of the in-line filter directly into the proper container, preserved, and placed in the cooler. Filtered samples will be preserved in the field with acid to a pH of less than 2. Make sure sample bottle is labeled and the cap is on tightly. Then place in cooler with ice immediately.

— OR —

If a low flow pump is used collect the samples, filtered samples will be taken by installing a 0.45-µM filter in-line and pumping the water through the filter. Collect sample from the end of the in-line filter directly into the proper container, preserved, and placed in the cooler. Filtered samples will be preserved in the field with acid to a pH of less than 2. Make sure sample bottle is labeled and the cap is on tightly. Then place in cooler with ice immediately.

Unfiltered samples will be collected by slowly pouring the sample water into the appropriate sample container, being careful not to agitate or cause bubbles to form. Do not overfill bottles. Make sure sample bottle is labeled and the cap is on tightly, then place the sample in cooler with ice immediately.

All samples will be delivered to the laboratory as soon as possible. If possible, samples will be shipped on the same day as they are collected. If samples must be retained due to weekend sampling (Friday through Sunday), the laboratory will be notified as to the time sensitive nature of the samples.

3.4 SAMPLING OF NON-AQUEOUS PHASE LIQUIDS

If NAPLs are detected in the well, a sample from all layers must be collected prior to any purging activities. NAPLs may be indicated by the presence of volatiles in the well headspace, and confirmed by the oil/water interface probe.

Collecting light non-aqueous phase liquid (LNAPL) will be accomplished using a transparent bailer with a double check valve. This bailer will be slowly lowered until the bottom of the bailer is 1-2 in. below the LNAPL-water interface, then slowly withdrawn. Verify that the interface was sampled by visual inspection of the bailer contents through the side of the bailer. Measure the thickness of the LNAPL in the bailer and note in the Field Logbook. Sample for laboratory analysis. An additional field verification may be performed by decanting the remainder of the contents of the bailer into a glass jar, adding a hydrophobic dye such as Sudan IV, or Redoil, shaking the sample and looking for coloration of NAPL. Alternate field tests are: examine the sample under ultraviolet light (many fluoresce), or allow the sample to stand overnight, and examine for interface and/or volatiles in the headspace the following day. Refer to following sections on purging and sample collection for setup and general operation.

Collecting dense non-aqueous phase liquids (DNAPLs) will be accomplished using a transparent bailer with a double check valve. The bailer must be lowered very slowly to the bottom of the well and raised slowly out of the well in a controlled fashion. Sample for analysis as above. The same field check described above may be employed for DNAPL. Refer to following sections on purging and sample collection for set up and general operation.

If NAPLs are present in the well, **and** a low-flow pump is to be used for purging and sampling, the well will be allowed to re-equilibrate prior to purging and sampling. This will be accomplished by allowing the well to stand undisturbed for at least 8 hours prior to purging and sample collection.

3.5 WELL PURGING GENERAL RULES

Water within the casing of a well will stagnate, degas, lose volatiles, possibly precipitate metals due to changes in redox potential, and may react with the screen and/or casing material. It is, therefore, necessary to purge a sufficient volume of this stagnant water from the well and/or casing to ensure that a representative sample of formation water can be obtained. Traditionally, the volume of water to be purged was arbitrarily set at 3-5 equivalent volumes. Recent advances in sampling technologies have caused a re-thinking of such arbitrary purge volumes. It is for this reason that monitoring of select chemical and physical properties of the sample medium will be used instead of strict volumes to determine when a representative sample may be taken from a well.

Acceptable purge/sampling devices include: bailers, high-discharge submersible pumps (purge only), and variable speed, low-flow pumps which include both submersible pumps (purge and sample) and dedicated bladder pumps (purge and sampling). It is recommended to purge and sample at similar rates with one type device per well. An acceptable exception to this general rule is to use a high-discharge submersible pump to purge a deep, fast-recharging well, and a bailer to sample the same well.

Peristaltic, gas-lift, and centrifugal pumps can cause volatilization, produce high pressure differentials, and can result in variability in the analysis of some analytes of interest. These types of pumps will not be used to purge or sample wells.

To prevent groundwater from cascading down the sides of the screen into an open hole, thereby aerating the sample, purge rates will closely match recharge rates. If the static water level is within the casing, the initial purge rates may be set high enough to lower the water level to the top of the screen, then reduced to maintain that level.

Purging will be accomplished with either a submersible pump, a low-flow (submersible or bladder) pump, or bailer. The choice of bailer or pump will be based on depth to water table, volume to be purged, and permeability of the aquifer. If the well recharges rapidly and/or has greater than 20 gal (estimated EV) to be purged, water may be removed with a submersible pump or a low-flow pump. If the well recharges slowly and/or has less than 20 gal to be purged, water will be removed with a bailer or a low-flow pump.

Purging will be accomplished with as minimal disturbance to the surrounding formation as possible.

Purge water will be containerized onsite until analysis of samples is completed. Based on sample results, accumulated purge water will be properly disposed.

If the water level is within the screened interval and the well recharge rate is less than 0.1 L/min, purge the well using a low-flow pump as follows:

1. Draw the water down to within 1 ft of the top of the pump.

2. Allow the well to recover.

3. Check and record field parameters.

4. Repeat Steps 1 through 3 then collect samples for metals analysis only[4].

5. Note the event in the Field Logbook, and report the problem to the Project Manager. If this extremely low recharge problem consistently occurs in a given well, the well may be considered for re-development and/or replacement.

6. If adjacent wells have elevated VOC levels, additional soil gas surveys will be considered in the vicinity of the low recharge well to help determine the need for replacement.

3.6 PURGING AND SAMPLING WITH BAILERS

Bailers may be used for both purging and sampling wells if: (a) the well recharge rate is less than 4 L/min, (b) depth to the water table is less than 50 ft, and (c) less than 20 gal are to be purged (5 EV < 20 gal)[5].

4. Analyte losses due to volatilization in a drained well are too high for valid VOC sampling (McAlary and Barker 1987).

When purging with a bailer, either a polyvinyl chloride, PTFE, or stainless steel bailer may be used. The bailer will be attached to either a spool of PTFE-coated stainless steel cable or polypropylene rope. If using cable, attach it to the bailer using stainless steel cable clamps. Thoroughly decontaminate the cable after each use, prior to rewinding cable onto spool. Cable clamps and raw cable ends may serve to trap contamination. Exercise particular caution in decontaminating these areas. If using rope, attach the rope to the bailer using a bowline knot, dispense the needed length (a few feet more than the well depth) and cut the remainder away; then, at the end opposite the bailer, make a slip knot and place it around the well casing or protective posts to prevent losing the bailer and rope down the well. The polypropylene rope will be not reused; it will be properly disposed of. Either type of bailer will be repeatedly lowered gently into the well until it fills with water, removed, and the water will be discharged into an appropriate container until purging is complete. Care must be taken not to unduly agitate the water, as this tends to aerate the sample, increase turbidity, makes stabilization of required parameters difficult to achieve, and generally prolongs purging.

After purging 2 EV, obtain a sample of groundwater and measure the following stabilization parameters: temperature, conductivity, pH, turbidity, redox potential (Eh), and dissolved oxygen level at each successive half-well volume. When three of these stabilization parameters are in agreement within approximately 10 percent in three consecutive half-well volume samples, sufficient water has been purged from the well. The results of these tests should be recorded in the sampling logbook. Should these parameters not reach agreement, no more than five well volumes will be purged.

Immediately upon completion of purging, collect samples for laboratory analysis using a PTFE bailer on a PTFE-coated stainless steel cable. The bailer will be equipped with double check valve top and controlled flow bottom discharge attachments for VOC sampling (40-mL vials), and top discharge attachment for collecting larger samples (1-L bottles).

Slowly, so as not to agitate the water, lower the bailer into the well, using a spool of PTFE-coated cable. Allow bailer to fill, withdraw smoothly. Refill bailer as needed.

If the controlled flow bottom discharge attachment is used for VOC sampling, attach it to the bottom of the bailer. Using the stopcock valve on the bailer to control the flow, fill sample vials as described above in Section 3.3.

Remove check valve top and pour unfiltered sample into inorganics sample bottles.

Collect filtered samples as described in Section 3.3. Decontaminate bailer and cable.

5. These numbers are based on the following assumptions: (1) In purging, it is preferable to remove water at approximately the recharge rate; (2) 4 L/min is estimated as the approximate maximum rate at which water can be removed with a bailer from depths of 20-50 ft; and (3) 20 gal is estimated to be at the limit of the sampler's endurance, at which point fatigue and sloppiness of technique begin.

3.7 PURGING WITH PUMP, SAMPLING WITH BAILER

If the recharge rate of the well is greater than 30 L/min, or the water level is deeper than 50 ft, or more than 20 gal of purge water will be generated (5 EV > 20 gal), then purging and sampling may be accomplished using a submersible pump/bailer combination.

When purging with a pump, gradually lower the intake until it is submerged within the screened interval. Lower an electronic water level probe to the top of the screen (as determined from completion records) to the monitor water level, start pump, and slowly lower the pump as the water level continues to fall. Care should be exercised to lower the water column to the top of the screened interval (water level probe will stop beeping) but not below the top of the screen if possible. This will ensure that the stagnant layer has been removed, but should minimize the detrimental effects of over pumping the well. Secure hose(s) and/or power cord to casing and place discharge hose into the proper container, downhill and as far away from the well as possible. Determine and record the discharge rate.

Discharge rate = volume of container/time to fill container

The discharge rate will be established at approximately equal to or just greater than the well's recharge rate (determined from well development). If well development records are incomplete, recharge rate can be determined by monitoring the rise/fall of the water level within the casing as one purges the well. If the water level is static at a given pumping rate, but fluctuates up or down as pumping rate is decreased or increased, the pumping rate at which the water level is static is the recharge rate.

After purging 2 EV, obtain a sample of groundwater and measure the following stabilization parameters: temperature, conductivity, pH, turbidity, redox potential (Eh), and dissolved oxygen level at each successive half-well volume. When three of these stabilization parameters are in agreement within approximately 10 percent in three consecutive half-well volume samples, sufficient water has been purged from the well. The results of these tests should be recorded in the sampling logbook. Should these parameters not reach agreement, no more than five well volumes will be purged.

Immediately upon completion of purging, collect samples for laboratory analysis using a PTFE bailer on a PTFE-coated stainless steel cable. The bailer will be equipped with double check valve top and controlled flow bottom discharge attachments for VOC sampling (40-mL vials), and top discharge attachment for collecting larger samples (1-L bottles). Filtration of metals samples will be accomplished using either an in-line filter attached to the bottom of the bailer, or a funnel and appropriate filter (Section 3.3).

Slowly, so as not to agitate the water, lower the bailer into the well, using a spool of PTFE-coated cable. Allow bailer to fill, withdraw smoothly, fill sample containers as described in Section 3.6. Decontaminate bailer and cable in and decontaminate pump.

3.8 PURGING AND SAMPLING WITH LOW-FLOW PUMP

To obtain representative samples, subsurface disturbances should be kept to a minimum, thereby preventing sample alteration due to sampling actions. The reasoning behind the use of low-flow pumps to purge and sample monitoring wells is that these pumps minimize physical disturbance (turbulence) at the sampling point and chemical changes (aeration) in the medium. For these reasons, the low-flow pump is the preferred method for both purging and sampling in most cases. For the purposes of this SOP, "low-flow pumps" are defined as either dedicated bladder pumps or variable speed submersible pumps. Practical operational flow rates for these sampling devices range from 0.1 L/min to 30 L/min.

Low-flow pumps may be used for purging and sampling any well having recharge greater than 0.1 L/min, which is the practical lower limit of pump performance. Below that pumping rate, pump inefficiencies and/or overheating may alter the physical and chemical properties of the sample. If the pump is continuously operated at sampling rates higher than the well recharge rate, the water level will be lowered in the well, possibly allowing aeration of the sample which is unacceptable sampling procedure. Low-flow pumps are suitable for sampling wells with recharge rates lower than 0.1 L/min if precautions are taken to avoid aeration of the sample.

Low flow submersible pumps will be used as follows:

- Lower the pump into the well, slowly so as not to agitate the water, until the pump is at the mid-point of the screened interval or the mid-point of the water column if the static water table lies below the top of the screen[6]

- Attach the pump's umbilical cord (which will consist of power cord and sampling tubing) to the protective casing, or lock the cord spool so that the pump cannot move vertically in the well during sampling.

- Lower the water level probe into the well behind the pump until it just touches water. This will allow the sampler to monitor the water level while purging and sampling, and prevent the inadvertent drying of the well.

6. This assumes a 10-ft screened interval. If the screened interval is greater than 10 ft, multiple samples should be taken as follows:
   - If the screen is 10-12 ft, sample the canter of the water column, as outlined above.
   - If the screen is longer than 12 ft, and the water column is 10 ft or less, sample the center of the water column.
   - If the screen is longer than 12 ft, and the water column fills the screen, or extends above the screen, sample at 1/3 and 2/3 the height of the water column, or about every 6 ft.

- Begin purging at the pump's lowest setting, then gradually increase rate[7] until the pumping rate matches the aquifer recharge rate. **If the water level is above the top of the screen**, the pumping rate may be allowed to slightly exceed recharge rate, lowering the water level to no less than 1 ft above the screen, then reduced until it matches recharge rate and purging continued. **If the water level is below the top of the screen**, always keep the purge rate lower than well's recharge rate.

- Monitor stabilization parameters listed in Section 3.6 beginning immediately, using an in-line monitoring system. Record parameters regularly, at a rate of one set of parameters per each 1-3 liters of water removed from the well. When these parameters stabilize to within 10 percent over three consecutive readings, reduce[8] flow rate to 0.1 L/min (if needed) and begin collecting VOC samples directly from the discharge line.

- If the well recharges at a rate less than 0.1 L/min, purge until the water level is even with the top of the screen, allow the well to recover, and sample immediately.

- Remove and decontaminate water level probe and pump.

4. MAINTENANCE

Refer to manufacturer's requirements for maintenance of pumps and generators.

5. PRECAUTIONS

Refer to the site-specific Health and Safety Plan for appropriate personal protective equipment.

6. REFERENCES

Garske, E.E. and M.R. Schock. 1986. An Inexpensive Flow-Through Cell and Measurement System for Monitoring Selected Chemical Parameters in Groundwater.

Gass, T.E., J.F. Barker, R. Dickhout, and J.S. Fyfe. 1991. Test Results of the Grundfos Groundwater Sampling Pump, in Proceedings of the Fifth National Symposium on Aquifer Restoration and Groundwater Monitoring.

7. Some sources indicate that the pumping rate should not exceed 1 L/min, with 0.5 L/min being preferable. The optimal purge rate is highly aquifer dependent, and may range from less than 0.5 L/min to greater than 10 L/min. The purge rate for a given well will, therefore, be a field decision, based on well development, purge, and sampling records rather than SOP mandate.
8. Sampling should occur at the same rate as purging as long as aeration of sample does not occur.

McAlary, T. A. and J.F. Barker. 1987. Volatilization Losses of Organics During Groundwater Sampling From Low Permeability Materials, in Groundwater Monitoring Review. Fall.

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Standard Operating Procedure No. 014
for
Collection of Production Well Samples

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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December 2014

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for the collection of groundwater samples from production wells. This protocol will allow for collection of samples from both active production wells and inactive production wells (Section 3).

2. MATERIALS

The following equipment may be required:

Conductivity meter	pH meter
Dissolved oxygen meter	Sample bottles and labels
Logbook or field parameter form	Temperature meter
Oxidation-reduction potential probe	Turbidity meter

3. PROCEDURE

Upon arrival at the well site, immediately set up and organize the sampling and ancillary equipment. If needed, due to muddy or contaminated ground and/or remoteness from sampling vehicle, place plastic sheeting at or around the sampling location as conditions warrant. Exercise caution not to step on and contaminate the sheeting.

If the well is remote from the sampling vehicle, set up the filtration equipment and place sample containers on the plastic sheet, uphill of the sampling location.

If a pump is to be used for filtration, situate the portable generator on level ground approximately 15 ft away from and downwind from the sampling location. All generator maintenance (oil and fueling) is to be preformed offsite.

If the well is currently in use, as close as possible to the well, open a tap to a high flow rate and allow the well to purge.

Obtain a sample of groundwater for temperature, conductivity, oxidation-reduction potential, dissolved oxygen, turbidity, and pH measurements. Record values in sampling logbook.

Take samples for physical stabilization (water quality) parameters every 5 minutes during the well purging process.

Allow the well to purge until the water quality parameters of pH, temperature, conductivity, turbidity, oxidation-reduction potential, and dissolved oxygen measurements stabilize within 10 percent in three consecutive 5-minute sampling periods, purging will be considered complete and sampling may proceed. Slow water flow rate to a trickle.

For procedures for collecting samples, with the exception of the sample source being a bailer, refer to SOP No. 013.

If the well is not currently in use, use a pump and bailer, or low-flow pump for sampling. Refer to SOP No. 013 for purging and sampling protocol. Decontaminate equipment. Refer to SOP Nos. 001, 002, 004, 005, 013, and 016.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Not applicable.

6. REFERENCES

U.S. Army Toxic and Hazardous Materials Agency. 1990. Installation Restoration Quality Assurance Program, December 1985, 1st Edition, March 1987, 2nd Edition.

Standard Operating Procedure No. 016
for
Surface Water, Groundwater, and Soil/Sediment Field Logbooks

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for recording surface water, groundwater, soil/sediment sampling information, instrument calibration data, and data from hydrologic testing in the field logbooks. Acceptable field logbooks are: bound, unprinted books such as a surveyor's field book, or a federal supply service No. 7530-00-222-3525 record book (or equivalent); or they may be company-proprietary, pre-printed forms bound into a field logbook. Example forms are provided herein. Alternate, equivalent forms are acceptable.

2. MATERIALS

The following material may be required: applicable field logbook and indelible ink pen.

3. PROCEDURE

Information pertinent to soil/sediment, groundwater, or surface water sampling will be recorded in the appropriate logbook. Each page/form of the logbook will be consecutively numbered. Entries will be made in indelible ink. Corrections will consist of line-out deletions that are initialed and dated. If using carbon paper or self-duplicating forms, before entering data in logbook, insert a sheet protector between form sets to isolate first blank form from remaining forms.

3.1 SOIL/SEDIMENT LOGBOOK (Requires Figures SOP016-1 and SOP016-3)

3.1.1 Field Parameter Form (Items on Figures SOP016-1 and SOP016-2)

1. HIGH CONCENTRATION EXPECTED?: Answer "Yes" or "No."

2. HIGH HAZARD?: Answer "Yes" or "No."

3. SITE: Record the complete name of the site.

4. AREA: Record the area designation of the sample site.

5. INST CODE: Record the 2-letter installation code appropriate for the installation or site. Correct abbreviations can be found on Pages 3-6 of the IRDMS User's Guide for chemical data entry.

6. FILE NAME: Record "CSO" for a soil sample or "CSE" for a sediment sample.

7. SITE TYPE: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on Pages 18-21 of the IRDMS User's Guide for chemical data entry. This entry must match the Site Type on the map file form.

8. SITE ID: Record a code up to 10 characters or numbers which is unique to the site.

9. FIELD SAMPLE NUMBER: Record a code specific for the sample.

10. DATE: Enter the date the sample was taken.

11. TIME: Enter the time (12-hour or 24-hour clock acceptable as long as internally consistent) the sample was taken.

12. AM PM: Circle "AM" or "PM" to designate morning or afternoon (12-hour clock).

13. SAMPLE PROG: Record "GQA" (Groundwater Quality Assessment) or other appropriate sample program.

14. DEPTH (TOP): Record the total depth sampled.

15. DEPTH INTERVAL: Record the intervals at which the plug will be sampled.

16. UNITS: Record the units of depth (feet, meters)

17. SAMPLE MEASUREMENTS: Check the appropriate sampling method.

18. CHK: Check off each container released to a laboratory.

19. ANALYSIS: Record the type of analysis to be performed on each sample container.

20. SAMPLE CONTAINER: Record the sample container type and size.

21. NO.: Record the number of containers.

22. REMARKS: Record any remarks about the sample

23. TOTAL NUMBER OF CONTAINERS FOR SAMPLE: Record the total number of containers.

24. SITE DESCRIPTION: Describe the location where the sample was collected.

25. SAMPLE FORM: Record the form of the sample (i.e., clay, loam, etc.) using The Unified Soil Classification System.

26. COLOR: Record the color of the sample as determined from standard Munsell Color Charts.

27. ODOR: Record the odor of the sample or "none." See SOP No. 001 Section 5.

28. PID (HNu): Record the measured PID (HNu) values.

29. UNUSUAL FEATURES: Record anything unusual about the site or sample.

30. WEATHER/TEMPERATURE: Record the weather and temperature.

31. SAMPLER: Record your name.

3.1.2 Map File Form (Figure SOP016-3)

1. The map file logbook form will be located on the reverse of the field parameter logbook form, or on an adjoining page of the field logbook (if level book is used).

2. SITE ID: Record the Site ID from the field parameter form.

3. POINTER: Record the field sample number for the sample being pointed to.

4. DESCRIPTION/MEASUREMENTS: Describe the location where the sample was taken, along with distances to landmarks.

5. SKETCH/DIMENSIONS: Diagram the surroundings and record the distances to landmarks.

6. MAP REFERENCE: Record which U.S. Geological Survey Quad Map references the site.

7. COORDINATE DEFINITION: Write the compass directions the X- and Y-Coordinates of the map run.

8. COORDINATE SYSTEM: Write "UTM" (Universal Transverse Mercator).

9. SOURCE: Record the 1-digit code representing the Map Reference.

10. ACCURACY: Give units (e.g., write "1-M" for 1 meter).

11. X-COORDINATE: Record the X-Coordinate of the sample site location.

12. Y-COORDINATE: Record the Y-Coordinate of the sample site location.

13. UNITS: Record the unit's map sections are measured in.

14. ELEVATION REFERENCE: Record whether topography was determined from a map or a topographical survey.

15. ELEVATION SOURCE: Record the 1-digit code representing the elevation reference.

16. ACCURACY: Record the accuracy of the map or survey providing the topographical information.

17. ELEVATION: Record the elevation of the sampling site.

18. UNITS: Write the units in which the elevation is recorded.

19. SAMPLER: Write your name.

3.2 SURFACE WATER LOGBOOK (Requires Figures SOP016-2 and SOP016-3)

3.2.1 Field Parameter Form (Items Unique to Figure SOP016-3)

1. CAL REF: Record the calibration reference for the pH meter.

2. pH: Record the pH of the sample.

3. TEMP: Record the temperature of the sample in degrees Celsius.

4. COND: Record the conductivity of the water.

5. For all other sections, see Section 3.2.1.

3.3 GROUNDWATER SAMPLING LOGBOOK (Requires Figures SOP016-2, SOP016-3, and SOP016-4)

3.3.1 Field Parameter Form (Items on Figure SOP016-4)

1. WELL NO. OR ID: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on Pages 18-21 of the IRDMS User's Guide for chemical data entry.

2. SAMPLE NO.: Record the reference number of the sample.

3. WELL/SITE DESCRIPTION: Describe the location where the sample was taken, along with distances to landmarks.

4. X-COORD and Y-COORD: Record the survey coordinates for the sampling site.

5. ELEV: Record the elevation where the sample was taken.

6. UNITS: Record the units the elevation was recorded in.

7. DATE: Record the date in the form MM/DD/YY.

8. TIME: Record the time, including a designation of AM or PM.

9. AIR TEMP.: Record the air temperature, including a designation of C or F (Celsius or Fahrenheit).

10. WELL DEPTH: Record the depth of the well in feet and inches.

11. CASING HT.: Record the height of the casing in feet and inches.

12. WATER DEPTH: Record the depth (underground) of the water in feet and inches.

13. WELL DIAMETER: Record the diameter of the well in inches.

14. WATER COLUMN HEIGHT: Record the height of the water column in feet and inches.

15. SANDPACK DIAM.: Record the diameter of the sandpack. Generally, this will be the same as the bore diameter.

16. EQUIVALENT VOLUME OF STANDING WATER: Use one of the following equations, to determine one equivalent volume (EV):

    1 EV = Volume in casing + volume in saturated sand pack. Or to restate:

    $1\ EV = (BR_w^2h_w + 0.30B(R_s^2-R_w^2)h_s) * (0.0043)$

    where
    R_s = Radius of sandpack in inches
    R_w = Radius of well casing in inches
    h_s = Height of sandpack in inches
    h_w = Water depth in inches

    $0.0043 = gal/in.^3$
    and filter pack porosity is assumed as 30 percent

    — OR —

    Volume in casing = $(0.0043\ gal/in.^3)(B)(12\ in./ft)(R_c^2)(W_h)$

    where
    R_c = Radius of casing in inches
    W_h = Water column height in feet

    Vol. in sandpack = $(0.0043\ gal/in.^3)(B)(12\ in./ft)(R_b^2 - R_c^2)(W_h)(0.30)$

    (if W_h is less than the length of the sandpack),

— PLUS —

Vol. in sandpack = $(0.0043 \text{ gal/in.}^3)(B)(12 \text{ in./ft})(R_b^2 - R_c^2)(S_h)(0.30)$

(if W_h is greater than the length of the sandpack).

where
R_b = Radius of the borehole
S_h = Length of the sandpack.

Show this calculation in the comments section.

17. VOLUME OF BAILER OR PUMP RATE: Record bailer volume or pump rate.

18. TOTAL NUMBER OF BAILERS OR PUMP TIME: Record the number of bailers required to remove 3 equivalent volumes (EV) of water from the well or the total purge time and volume as applicable.

19. WELL WENT DRY? Write "YES" OR "NO."

20. NUMBER OF BAILERS OR PUMP TIME: Record the number of bailers or pump time which made the well go dry.

21. VOLUME REMOVED: Record the volume of water (gal) removed before the well went dry.

22. RECOVERY TIME: Record the time required for the well to refill.

23. PURGE AGAIN?: Answer "YES" or "NO."

24. TOTAL VOL. REMOVED: Record the total volume of water (in gal) removed from the well.

25. CAL REF.: Record the calibration reference for the pH meter.

26. TIME: Record time started (INITIAL T[0]), 2 times DURING the sampling and the time sampling ended (FINAL).

27. pH: Record the pH at start of sampling (INITIAL), twice DURING the sampling and at the end of sampling (FINAL).

28. TEMP: Record the water temperature (Celsius) at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).

29. COND: Record the conductivity of the water at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).

30. D.O.: Record the dissolved oxygen level in the water at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).

31. TURBIDITY: Record the readings from the turbidity meter (nephelometer) and units at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).

32. ORD: Record the oxidation/reduction (RedOx) potential of the water sample at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).

33. HEAD SPACE: Record any positive readings from organic vapor meter reading taken in well headspace prior to sampling.

34. NAPL: Record the presence and thickness of any non-aqueous phase liquids (light or dense)

35. COMMENTS: Record any pertinent information not already covered in the form.

36. SIGNATURE: Sign the form.

3.4 FIELD CALIBRATION FORMS (Maintained as a separate logbook, or incorporated into sampling logbooks)

3.4.1 Items on Figure SOP016-5

1. Record time and date of calibration. Note whether 12- or 24-hour clock was used.

2. Record calibration standard reference number.

3. Record meter I.D. number

4. Record initial instrument reading, recalibration reading (if necessary), and final calibration reading on appropriate line.

5. Record value of reference standard (as required).

6. COMMENTS: Record any pertinent information not already covered on form.

7. SIGNATURE: Sign form.

3.5 GROUNDWATER HYDROLOGY TESTS LOGBOOK (Must include Figures SOP016-6 and SOP016-7 and/or SOP016-8, OR SOP016-9 or SOP016-10)

3.5.1 Field Permeability Test Data Sheet (Items on Figures SOP016-6)

1. CONTRACTOR: Organization performing the test.

2. SEQ. #: Enter page number of this set of forms (page # of #).

3. PROJECT NAME: Record the name assigned by the contractor's organization to the project.

4. PROJECT NO.: Record the contractor assigned project number or the contract number.

5. LOCATION: Specific location

6. CLIENT: Agency or company with the contract under which the work is being performed.

7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.

8. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.

9. TEST TYPE: Short description of the type of test to be performed.

10. RISING/FALLING HEAD WITH SLUG: Check if the test involved the insertion/removal of and inert object.

11. RISING/FALLING HEAD WITHOUT SLUG: Check if the test involved the addition/removal of a quantity of water.

12. START DATE: Date on which the test was begun.

13. CLOCK TIME: Time each datum (depth to groundwater level) is collected. Note whether 12- or 24-hour clock was used.

14. ELAPSED TIME: Time since the last datum was collected.

15. DEPTH TO GWL (ft): Depth to the top of the groundwater table (Groundwater Level) as measured by manual methods.

16. REC. (ft): Water level as reported by transducer/datalogger (this is the depth of water above the transducer.

17. TIME: Time the discharge rate check was begun (addition or removal of water method). Note whether 12- or 24-hour clock was used.

18. FLOW METER (Addition or removal of water method): The amount of water added or removed as registered by the flowmeter, in gal of liters.

19. DISCHARGE RATE: Flowmeter reading divided by time interval (gal/min or liters/min).

20. SIGNATURE: The person completing this form must sign the form at the end of the test.

21. DATE: Date the form was signed.

3.5.2 Groundwater Levels – Single Well (Items on Figure SOP016-7)

1. CONTRACTOR: Organization performing the test.

2. SEQ. #: Enter page number of this set of forms (page # of #).

3. PROJECT NO.: Record the contractor assigned project number or the contract number.

4. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.

5. PROJECT NAME: Record the name assigned by the contractor's organization to the project.

6. LOCATION: Specific location.

7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.

8. CLIENT: Agency with the contract under which the work is being performed.

Well Data

9. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.

10. MEASURED UP(+)/DOWN(-) FROM: Describe the starting point for the previous measurement.

11. MP ELEVATION: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.

12. DATUM = MSL OR: Is the datum for the previous elevation Mean Sea Level? If not, what? Also tell whether it was derived from a map elevation (write "MAP") or survey data (write "SURVEY").

13. MEASURING POINT DESCRIPTION: Describe the point used as the origin for all down-hole (water table) measurements. NOTE: Remedial investigation wells are required to have a permanently marked reference (measuring) point (refer to SOP No. 019).

14. REMARKS: Record any pertinent observations about the site/well conditions not specifically required in the preceding.

15. DATE: Date of each water level reading

16. TIME: Time of each water level reading. Note whether 12- or 24-hour clock was used.

17. ELAPSED TIME: Time since test was begun.

18. DEPTH TO WATER: Measured depth to the groundwater table.

19. WATER ELEVATION: Elevation of the top of the groundwater table (use datum listed above).

20. MEAS. METH.: Method used to measure the water level in the well (see abbreviation key at the bottom of the data sheet).

21. TAPE NO.: The unique identification number of the traceable standard tape used to calibrate the measuring device.

22. WELL STATUS: Condition of the well at the time of measuring (see abbreviation key at the bottom of the data sheet).

23. REMARKS: Any additional pertinent comments not specifically required above.

24. INITIALS: Initials of person completing this data entry.

25. ABBREVIATION KEYS: Self explanatory.

26. SIGNATURE: The person completing this form must sign the form at the end of the test.

27. DATE: Date the form was signed.

3.5.3 Groundwater Levels – Single Well (Items on Figure SOP016-8)

1. CONTRACTOR: Organization performing the test.

2. SEQ. #: Enter page number of this set of forms (page # of #).

3. PROJECT NO.: Record the contractor assigned project number or the contract number.

4. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.

5. PROJECT NAME: Record the name assigned by the contractor's organization to the project.

6. LOCATION: Specific location.

7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.

8. CLIENT: Agency with the contract under which the work is being performed.

WELL DATA

9. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.

10. MEASURED UP(+)/DOWN(-) FROM: Describe the starting point for the previous measurement.

11. MP ELEVATION: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.

12. DATUM = MSL OR: Is the datum for the previous elevation Mean Sea Level? If not, what? Also tell whether it was derived from a map elevation (write "MAP") or survey data (write "SURVEY").

13. MEASURING POINT DESCRIPTION: Describe the point used as the origin for all down-hole (water table) measurements. NOTE: All Rhode Island wells are required to have a permanently marked reference (measuring) point (refer to SOP No. 019).

14. REMARKS: Record any pertinent observations about the site/well conditions not specifically required in the preceding.

15. DATALOGGER: This section is record of pertinent datalogger information.

16. MANUFACTURER: Record the manufacturer/brand name as stated on the datalogger.

17. MODEL: Enter the model number of the datalogger.

18. S/N: Enter the serial number of this datalogger.

19. TAG PROGRAMMED IN LOGGER: What is the identifier used in the datalogger's program to indicate that this unit was used to record a given data set?

20. TRANSDUCER: This section is a listing of pertinent information about the transducer used.

21. MANUFACTURER: Record the manufacturer/brand name as stated on the transducer.

22. MODEL: Enter the model number of the transducer.

23. S/N: Enter the serial number of this transducer.

24. INPUT/UNITS: What are the units this transducer uses?

25. RANGE: Record the pressure or depth range over which this transducer is certified.

CALIBRATION

26. PRESSURE RATING: This is taken from the manufacturer's specifications for a given transducer. (Usually in psi, or kpa).

27. "SUBMERGENCE = ___ (V) / (MV)": Record the voltage returned by the transducer at a given depth of submergence. Indicate whether the reading is in volts (v), or millivolts (mv).

28. VOLUME WATER ADDED/REMOVED: (Applicable if inert object insertion/removal method was not employed.) Record the volume of water added to or removed from the well.

29. DISCHARGE RATE: If z (above) is filled, enter the rate at which this water was added or removed.

30. INITIAL WATER LEVEL (ft): Enter the water level in the well at the beginning of the test.

31. PRESSURE TRANSDUCER SUBMERGENCE: Record the depth to which the transducer is submerged at the beginning of the test and the depth to the transducer at the end if the test. All depths will be recorded to the nearest 0.01 ft.

32. TIME: Record the time the test is begun and ended. Note whether 12- or 24-hour clock was used.

33. OBSERVED CHANGES IN ADJACENT WELLS: Note any changes in water levels in nearby wells.

34. RESULTS RECORDED ON DISKETTE #: Tracking number of the diskette on which these data are archived.

35. DISKETTE FILE NAME: Name of the file(s).

36. SIGNATURE: The person completing this form must sign the form at the end of the test

37. DATE: Date the form was signed.

3.6 GROUNDWATER LEVELS – MULTIPLE WELLS (Items on Figure SOP016-9)

1. CONTRACTOR: Organization performing the test.

2. SEQ. #: Enter page number of this set of forms (page # of #).

3. PROJECT NO.: Record the contractor assigned project number or the contract number.

4. PROJECT NAME: Record the name assigned by the contractor's organization to the project.

5. LOCATION: Specific location.

6. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.

7. CLIENT: Agency with the contract under which the work is being performed.

8. REMARKS: Any pertinent observations not specifically required above.

9. WELL: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.

10. DATE: Date this measurement was made.

11. TIME: Time this measurement was made. Note whether 12- or 24-hour clock was used.

12. DEPTH TO WATER: Depth from MP to top of groundwater table.

13. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.

14. MP ELEV.: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.

15. MEAS. METH.: Method used to measure the water level in the well (see abbreviation key at the bottom of the data sheet).

16. REMARKS/MP: Describe the location and nature of the measuring point.

17. INITIALS: Initials of the person completing this form.

18. ABBREVIATION KEYS: Self explanatory.

19. SIGNATURE: The person completing this form must sign the form at the end of the test.

20. DATE: Date the form was signed.

3.7 GROUNDWATER LEVELS – DATALOGGERS (Items on Figure SOP016-10)

1. CONTRACTOR: Organization performing the test.

2. SEQ. #: Enter page number of this set of forms (page # of #).

3. PROJECT NO.: Record the contractor assigned project number or the contract number.

4. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.

5. PROJECT NAME: Record the name assigned by the contractor's organization to the project.

6. LOCATION: Specific location.

7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.

8. CLIENT: Agency with the contract under which the work is being performed.

WELL DATA

9. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.

10. MEASURED UP(+)/DOWN(-) FROM: Describe the starting point for the previous measurement.

11. MP ELEVATION: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.

12. DATUM = MSL OR: Is the datum for the previous elevation Mean Sea Level? If not, what? Also tell whether it was derived from a map elevation (write "MAP") or survey data (write "SURVEY").

13. MEASURING POINT DESCRIPTION: Describe the point used as the origin for all down-hole (water table) measurements. NOTE: All Rhode Island wells are required to have a permanently marked reference (measuring) point (refer to SOP No. 019, Section 3.4).

14. REMARKS: Record any pertinent observations about the site/well conditions not specifically required in the preceding.

DATALOGGER (This section is a record of pertinent datalogger information)

15. MANUFACTURER: Record the manufacturer/brand name as stated on the datalogger.

16. MODEL: Enter the model number of the datalogger.

17. S/N: Enter the serial number of this datalogger.

18. TAG PROGRAMMED IN LOGGER: What is the identifier used in the datalogger's program to indicate that this unit was used to record a given data set?

TRANSDUCER (This section is a listing of pertinent information about the transducer used)

19. MANUFACTURER: Record the manufacturer/brand name as stated on the transducer.

20. MODEL: Enter the model number of the transducer.

21. S/N: Enter the serial number of this transducer.

22. INPUT/UNITS: What are the units this transducer uses?

23. RANGE: Record the pressure or depth range over which this transducer is certified.

CALIBRATION

24. PRESSURE RATING: This is taken from the manufacturer's specifications for a given transducer (usually in psi, or kpa).

25. "SUBMERGENCE = ___ (V) / (MV)": Record the voltage returned by the transducer at a given depth of submergence. Indicate whether the reading is in volts (v), or millivolts (mv).

26. DATE: Date of each water level reading

27. TIME: Time of each water level reading. Note whether 12- or 24-hour clock was used.

28. LOGGING TIME INTERVAL: Time since test was begun.

29. WL FEET BELOW MP: Measured depth to the groundwater table from measuring point.

30. SUBMERGENCE: Depth of water above the transducer.

31. MEAS.METHOD: What device/method was used to measure the water level.

32. TAPE NO.: Record the tape identification number.

33. TRANSDUCER MOVED?: Was the transducer moved since the last water level reading?

34. REMARKS: Any pertinent remarks not otherwise specified.

35. INITIALS:

DATA TRANSFER TO DISKETTE:

36. DATE: Date data were archived onto diskette.

37. TIME: Time stamp the computer assigns the data file.

38. FILE NAME: Name assigned the data file.

39. SOFTWARE USED FOR TRANSFER: Any special software, or computer operating system used to write the files to diskette. NOTE: If a "shareware" archiver which compresses files was used, and the archived file is not self-extracting, a copy of the unarchive program should be copied onto the diskette also.

40. OUTPUT FORMAT: What is the format of the output file? (DOS, UNIX, Binary, Compressed?)

41. INITIALS: Initials of the person who copied the data to diskette.

42. ABBREVIATION KEY: Self-explanatory.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

None.

6. REFERENCES

U.S. Environmental Protection Agency. 1984. User's Guide to the Contract Laboratory Program. July.

FIGURE SOP016-1
FIELD PARAMETER LOGBOOK
SOIL AND SEDIMENT SAMPLES

HIGH CONCENTRATION EXPECTED? HIGH HAZARD?

INSTALLATION/SITE _____ AREA _____

INST CODE FILE NAME _____

SITE TYPE SITE ID
FIELD SAMPLE NUMBER

DATE (MM/DD/YY) / / TIME AM PM SAMPLE PROG.

DEPTH (TOP) DEPTH INTERVAL UNIT _____

SAMPLING METHOD:

SPLIT SPOON AUGER SHELBY TUBE SCOOP OTHER

CHK ANALYSIS SAMPLE CONTAINER NO. REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE

DESCRIPTION OF SITE AND SAMPLE CONDITIONS
SITE DESCRIPTION:_____
SAMPLE FORM _____ COLOR _____ ODOR _____
PID (HNu) _____ UNUSUAL FEATURES _____
_____
WEATHER/TEMPERATURE
SAMPLER

HIGH CONCENTRATION EXPECTED? HIGH HAZARD?

FIGURE SOP016-2
FIELD PARAMETER LOGBOOK
GROUNDWATER AND SURFACE WATER SAMPLES

INSTALLATION/SITE AREA
INST CODE FILE NAME SITE TYPE
SITE ID FIELD SAMPLE NUMBER
DATE (MM/DD/YY) / / TIME AM PM SAMPLE PROG.
DEPTH (TOP) DEPTH INTERVAL UNITS

SAMPLING MEASUREMENTS

CAL REF.	pH	TEMPERATURE C	CONDUCTIVITY	OTHER

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE

DESCRIPTION OF SITE AND SAMPLE CONDITIONS
SITE DESCRIPTION
SAMPLING METHOD
SAMPLE FORM COLOR ODOR
PID (HNu)
UNUSUAL FEATURES
WEATHER/TEMPERATURE _____ SAMPLER _____

FIGURE SOP016-3
MAP FILE LOGBOOK

SITE ID POINTER _____
DESCRIPTION/MEASUREMENTS
SKETCH/DIMENSIONS:

MAP REFERENCE
COORDINATE DEFINITION (X is Y is)
COORDINATE SYSTEM SOURCE ACCURACY
X-COORDINATE Y-COORDINATE UNITS
ELEVATION REFERENCE
ELEVATION SOURCE ACCURACY ELEVATION
UNITS

SAMPLER

FIGURE SOP016-4
MAP FILE AND PURGING LOGBOOK
GROUNDWATER SAMPLES

WELL COORD. OR ID SAMPLE NO._____
WELL/SITE
DESCRIPTION_____
_____
X-COORD. Y-COORD. _____ ELEV. UNITS
DATE ____/____/____ TIME AIR TEMP.

WELL DEPTH _____ ft _____ in. CASING HT. _____ ft _____ in.
WATER DEPTH _____ ft _____ in. WELL DIAMETER _____ in.
WATER COLUMN HEIGHT _____ ft _____ in. SANDPACK DIAM. _____ in.
EQUIVALENT VOLUME OF STANDING WATER _____ (gal) (L)
VOLUME OF BAILER _____ (gal) (L) or PUMP RATE _____ (gpm) (lpm)
TOTAL NO. OF BAILERS (5 EV)_____ or PUMP TIME _____ MIN.
WELL WENT DRY? [Yes] [No] NUM. OF BAILERS _____ or PUMP TIME_____MIN
VOL. REMOVED _____ (gal) (L) RECOVERY TIME _____ MIN
PURGE AGAIN? [Yes] [No] TOTAL VOL. REMOVED _____ (gal) (L)

Date and Time	Quantity Removed	Time Required	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/ clarity/odor/partic.)
(before)									
(during)									
(during)									
(during									
(after)									

COMMENTS:_____
_____
_____
_____

_____
SIGNATURE

FIGURE SOP016-5
FIELD CALIBRATION: pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY, OXIDATION-REDUCTION POTENTIAL, AND DISSOLVED OXYGEN METERS

INITIAL CALIBRATION	FINAL CALIBRATION
DATE:	DATE:
TIME:	TIME:

pH METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

pH STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
7.0			
10.0			
4.0			

CONDUCTIVITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

COND. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

TEMPERATURE METER CALIBRATION

METER ID _____

TEMP. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
ICE WATER			
BOILING WATER			
OTHER			

FIGURE SOP016-5 *(continued)*

TURBIDITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

ORD METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

DISSOLVED OXYGEN METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

COMMENTS:_____
_____
_____
_____

_____
SIGNATURE

FIGURE SOP016-6
FIELD PERMEABILITY TEST DATA SHEET

Contractor: **Seq. #** /

Project Name:				Project #:						
Location:				Client:						
Party Chief:				Contractor:						
Observation Well:										
Test Type: Rising/Falling Head w/Slug				Rising/Falling Head w/out Slug						
Start Date:								Discharge Rate		
Clock Time	Elapsed Time (min)	Depth to GWL (ft)	Rec (ft)	Clock Time	Elapsed Time	Depth to GWL (ft)	Rec (ft)	Time	Flow Meter	Discharge Rate

Signature: _____ **Date:** _____

FIGURE SOP016-7
GROUNDWATER LEVELS – SINGLE WELL

Contractor: **Seq. #** /

Project No.:
Project Name:
Field Party Chief:

WELL DATA:

Stickup: (ft)
MP Elevation:
Well No.: Site: Area:
Site: Area:
Area:

up (+)/down (-) from: Datum = MSL or:
Datum = MSL or:

Measuring Point Description:

Datalogger:
Manufacturer: Model: S/N:
Tag No. Programmed in Logger:

Transducer: Manufacturer: Model: S/N:
Input/Units: Range:

Calibration:
Pressure Rating:
0 ft submergence = (v) / (mv) ft submergence = (v) / (mv)

Volume Water Added/Removed:
Discharge Rate:
Initial Water Level (ft):

Pressure Transducer Submergence
Initial (ft): Final(ft): Time:Start: End:
Observed Changes in Adjacent Wells:

Results Recorded on Diskette #:
Diskette File Name:

Signature: _____ Date: _____

FIGURE SOP016-8
GROUNDWATER LEVELS – MULTIPLE WELLS

Contractor: **Seq. #** /

Project No.:
Project Name:
Field Party Chief:

WELL DATA:

Stickup: (ft)
MP Elevation:

Measuring Point Description:
Remarks:
Well No.:
Site: Area: up (+)/down (-) from:
up (+)/down (-) from:
up (+)/down (-) from:
Datum = MSL or:

Date	Time	Elapsed Time	Depth to Water	Water Elevation	Meas. Meth.	Tape No.	Well Status	Remarks	Initials

Measurement Method:
A = Airline
C = Chalk and tape
E = Electric tape
T = Tape with popper
X = Other (describe in remarks)

Well Status:
D = Dry
F = Flowing
P = Pumping
RP = Recently pumped
NP = Nearby well pumping
NRP = Nearby well recently
X = Obstructed

Signature: _____ Date: _____

FIGURE SOP016-8 *(continued)*

Contractor: **Seq. #** /

Project No.:
Project Name: Location:
Field Party Chief: Client:

Well	Date	Time	Depth to Water	Stickup	MP Elev.	Meas. Meth.	Tape No.	Remarks/MP	Initials

Measurement Method:
A = Airline
C = Chalk and tape
E = Electric tape
T = Tape with popper
X = Other (describe in remarks)

Well Status:
D = Dry
F = Flowing
P = Pumping
RP = Recently pumped
NP = Nearby well pumping
NRP = Nearby well recently
X = Obstructed

FIGURE SOP016-9
GROUNDWATER LEVELS DATALOGGERS

Contractor
Project No.: **Well No.:**
Project Name: **Site:**
Field Party Chief: **Area:**

WELL DATA: Stickup: (**ft**) **up (+)/down (-) from:**
MP Elevation: **Datum = MSL or:**

Measuring Point Description:
Remarks:

Datalogger:
Manufacturer: Model: S/N:
Tag No. Programmed in Logger:
Transducer: Manufacturer: Model: S/N:
Input/Units: Range:
Calibration: Pressure Rating:
0 ft submergence = (v) / (mv) ft submergence = (v)

Logging	Date	Time	Logging Time Interval	WL, ft Below MP	Submergence (logger reading)	Meas. Method	Tape No.	Well Status	Transducer Moved	Remarks	Initials
Start											
Stop											
Start											
Stop											

Data Transfer to Disk

Date	Time	File Name	Software Used for Transfer	Output Format	Initials

Measurement Method:
A = Airline
C = Chalk and tape
E = Electric tape
T = Tape with popper
X = Other (describe in remarks)

Well Status:
D = Dry
F = Flowing
P = Pumping
RP = Recently
NP = Nearby well pumping
NRP = Nearby well recently pumped
X = Obstructed

Signature **Date**

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Standard Operating Procedure No. 020
for
Active Soil Gas Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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December 2014

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to provide guidelines for soil gas sampling. A soil gas survey is an effective screening tool in locating areas contaminated with volatile organic compounds.

2. MATERIALS

The following materials may be required:

1-L Tedlar bags	Probe set, including probe jack
3/16-in. outer diameter polyethylene tubing	Rotary hammer with 1 × 36-in. drill bit
Clean sand	Sample labels
Disposable shield points	Tools: vise grips, 0.75-in. wrench, scissors
Extension cord	Two measuring cups
Portable generator or other power source	Tygon tubing for vacuum box
Powdered bentonite	Vacuum box and vacuum pump

3. PROCEDURES

3.1 SOIL GAS POINT INSTALLATION

Installation of soil gas points includes the following steps:

1. Assemble clean probe sections to the desired sampling depth.

2. Cut polyethylene tubing to at least 1 ft longer than the depth of the hole.

3. Insert one end of the tubing approximately 0.25-in. inside of aluminum shield point. Crimp the shield point tightly around the tubing with vise grips and insert the tube and shield point inside of the clean KV probe.

4. Using rotary drill and 36-in. drill bit, bore down 30 in. at the desired depth for sampling. Be sure to clear the hole well so that soil does not fall back into hole.

5. Drive stainless steel probe and attached shield point and polyethylene tubing down the hole with a rotary hammer to approximately 4 ft, or above the saturation zone. (It is desired to obtain a sample of the soil gas, not the groundwater.) If samples are needed from greater than 4 ft, drive the steel probe with a solid tip to the desired depth, extract, and insert a probe fitted with a disposable shield point and tubing.

6. Extract the probe by hand or with the jack. Be sure that shield point and tubing stays in the ground and attached to the shield point.

7. Pour 0.5 cup of sand down sampling hole. Gently shake the tubing to ensure that the sand settles and no bridged spaces remain.

8. Pour 0.5 cup bentonite down sampling hole, add 0.25 cup distilled water, add another 0.5 cup bentonite down hole, and another 0.25 cup water. Continue until bentonite seal reaches the surface.

9. Allow at least 20 minutes before extracting sample.

10. Collect sample (Section 3.2).

11. Remove probe and backfill hole with bentonite.

3.2 SOIL GAS SAMPLE COLLECTION USING TEDLAR BAGS[1]

The following steps summarize the collection of a soil gas sample using Tedlar bags:

1. Cut at least 1 in. off the end of the tubing to ensure a clean sample.

2. Attach tubing to the vacuum box and pump.

3. Open valve on a clean, dry Tedlar bag, and attach inside the vacuum box.

4. Close the vacuum box, close stopcock (3-way valve) between vacuum box and pump, and then turn the pump on.

5. Allow Tedlar bag to fill 90 percent (do not overfill bag), shut off, crimp Tygon tubing (to prevent release of sample back down hole), open stopcock, and remove Tedlar bag from box.

   — If the bag is filled with air only, squeeze the air out completely to purge air that was in the tubing and sand and reattach inside the box. Repeat Bullets 4 and 5. Close the valve on the Tedlar bag upon removal, label it accordingly, and put it in a cool, dark area. NOTE: Not so cool as to cause condensation.

   — If Tedlar bag is filled with water and air, be sure to close valve on Tedlar bag before removing it, label the bag accordingly, and put it in a cool, dark area. NOTE: Not so cool as to cause condensation.

   — If water is pulled into the Tedlar bag, Tygon tubing inside the vacuum box must be replaced.

1. Summa canisters are also acceptable and are generally used for projects requiring analytical data with a lower detection limit. An equivalent standard operating procedure for Summa canisters and offsite analysis will be submitted prior to sampling.

6. Remove and decontaminate probes.

7. Repeat the above procedures for each additional soil gas point.

4. MAINTENANCE

No maintenance required.

5. FIELD QUALITY CONTROL MEASURES

To ensure that the equipment is free of volatile contaminants, collect at least two quality control samples per day by drawing uncontaminated air through an unused representative sampling apparatus (assembled shield point and tubing). One sample should be taken at the beginning of the day, prior to collecting any samples, the other at the end of the day, after decontaminating the equipment. Ambient air may usually be assumed to be uncontaminated. If site ambient air is assumed to be contaminated, it should be sampled for contaminant levels.

To ensure that the analyzed samples are representative of the collected samples, and that he Tedlar bags are not losing volatile samples, spiked samples of known volatile concentration will be prepared. These samples will be stored and handled in the same manner as other field samples. Spiked samples will be the first collected and last analyzed. Selected low level samples should also be duplicated at a different time and analyzed immediately to verify that analyte loss is not occurring. Alternatively, samples may be analyzed in the field, using either Tedlar bags or syringe samplers to collect and transport the samples to the gas chromatograph.

Note sampling times for each sample in field notebook and on sample bag (if bags are used). No more that 4 hours should elapse between sampling and analysis; 15 minutes is preferable.

6. REFERENCES

American Society for Testing and Materials. D5314-93 Standard for Soil Gas Monitoring in the Vadose Zone.

Posner, J.C. and J. Woodfin. 1986. Sampling with Gas Bags I: Losses of Analyte with Time; Applied Industrial Hygene. November. pp. 163-168.

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Standard Operating Procedure No. 021
for
Sediment Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) delineates protocols for sampling sediments from streams, rivers, ditches, lakes, ponds, lagoons, and marine and estuarine systems.

EA recognizes that other protocols have been developed that meet the criteria of quality and reproducibility. Clients may have their own sediment sampling protocols which may contain methodologies and procedures that address unique or unusual site-specific conditions or may be in response to local regulatory agency requirements. In such cases, EA will compare its and the client's protocols. The goal is to provide the client with the most quality; therefore, if the client's protocols provide as much or more quality assurance than EA's protocols for the particular site or project, EA will adopt those particular protocols and this SOP will be superseded in those respects. If EA is required to implement the client's protocols in lieu of EA's protocols, EA will make the client formally aware of any concerns regarding differences in protocols that might affect data quality and will document such concerns in the project file.

2. PROCEDURES

The water content of sediment varies. Sediments range from soft to dense and fine to rocky. A variety of equipment may be necessary to obtain representative samples, even at a single site. Factors to consider in selecting the appropriate sampling equipment include sample location (edge or middle of the waterbody), depth of water and sediment, grain size, water velocity, and analytes of interest.

3. GENERAL PROCEDURES

1. Surface water and sediment samples are to be collected at the same location (if both are required in the project-specific Sampling and Analysis Plan).

2. Collect the surface water sample first. Sediment sampling usually results in disturbance of the sediments, which may influence the analytical results of the surface water samples.

3. Wear gloves when collecting samples. Comply with the Health and Safety Plan specifications for proper personal protective equipment.

4. If sampling from a boat or near waterbodies with depths of 4 ft or more, the sampling team will wear life jackets.

5. Wading into a waterbody disturbs the sediment. Move slowly and cautiously, approach the sample location from downstream. If flow is not strong enough to move entrained particles away from the sample location, wait for the sediment to resettle before sampling.

6. Collect samples first from areas suspected of being the least contaminated, thus minimizing the risk of cross-contamination.

7. Collecting samples directly into sample containers is not recommended. Sediment samples should be placed in Teflon®, stainless steel, or glass trays, pans, or bowls for sample preparation.

8. Use the proper equipment and material construction for the analytes of interest. For example, for volatile organic compound analysis, the sampling material in direct contact with the sediment or surface water must consist of Teflon, polyethylene, or stainless steel.

9. Refer to EA SOP No. 005 (Field Decontamination) for proper decontamination methods before and after sampling and between samples.

10. Collect samples for volatile organic compound analysis first. Do not mix such samples before placing them in the sample containers. For composite volatile organic compound samples, place equal aliquots of each subsample in the sample container.

11. Sediment that will be analyzed for other than volatile organic compounds should be prepared as follows:

    - Place the sediment in a mixing container.
    - Divide the sediment into quarters.
    - Mix each quarter separately and thoroughly.
    - Combine the quarters and mix thoroughly.
    - For composite samples, mix each subsample as described above. Place equal aliquots of each subsample in a mixing container and follow the procedure described above.

12. Mark the sampling location on a site map. Record sampling location coordinates with a Global Positioning System unit, photograph (optional, recommended) and describe each location, and place a numbered stake above the visible high water mark on the bank closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at a future date.

13. Dispose of investigation-derived wastes according to applicable rules and regulations.

4. CORERS

A corer provides a vertical profile of the sediment, which may be useful in tracing historical contaminant trends. Because displacement is minimal, a corer is particularly useful when sampling for trace metals and organics. Corers can be constructed out of a variety of materials.

For example, a 2-in. diameter polyvinyl chloride pipe with a Teflon or polyethylene liner can be lowered into the sediment; a 2-in. diameter well cap can be used to form an airtight seal and negative pressure as the pipe is withdrawn.

- Ensure that the corer and (optional) liner are properly cleaned.
- Stand downstream of the sample location.
- Force the corer into the sediment with a smooth continuous motion. Rotate (not rock) the corer if necessary to penetrate the sediment.
- Twist the corer to detach the sample; then withdraw the corer in a single smooth motion. If the corer does not have a nosepiece, place a cap on the bottom to keep the sediment in place.
- Remove the top of the corer and decant the water (into appropriate sample containers for surface water analysis, if required).
- Remove the nosepiece or cap and deposit the sample into a stainless steel, Teflon, or glass tray.
- Transfer the sample into sample containers using a stainless steel spoon (or equivalent device).

5. SCOOPS AND SPOONS

When sampling at the margins of a waterbody or in shallow water, scoops and spoons may be the most appropriate sampling equipment. For collecting samples several feet from shore or in deeper water, the scoop or spoon may be attached to a pole or conduit.

- Stand downstream of the sample location.
- Collect the sample slowly and gradually to minimize disturbing the fine particles.
- Decant the water slowly to minimize loss of fine particles.
- Transfer the sediment to sample containers or mixing trays, as appropriate.

6. DREDGES

Three types of dredges are most frequently used: Peterson, Ponar, and Eckman. Many other dredge types are available; their applicability will depend upon site-specific factors.

6.1 PETERSON AND PONAR DREDGES

These dredges are suitable for hard, rocky substrates, deep waterbodies, and streams with fast currents. Ponars have top screens and side plates to prevent sample loss during retrieval.

- Open the jaws and place the cross bar into the proper notch.
- Lower the dredge to the bottom, making sure it settles flat.
- When tension is removed from the line, the cross bar will drop, enabling the dredge to close as the line is pulled upward during retrieval.
- Pull the dredge to the surface. Make sure the jaws are closed and that no sample was lost during retrieval.
- Open the jaws and transfer the sediment to sample containers or to a mixing tray.

6.2 ECKMAN DREDGE

The Eckman dredge works best in soft substrates in waterbodies with slow or no flow.

- Open the spring-loaded jaws and attach the chains to the pegs at the top of the sampler.
- Lower the dredge to the bottom, making sure it settles flat.
- Holding the line taut, send down the message to close the jaws.
- Pull the dredge to the surface. Make sure the jaws are closed and that no sample was lost during retrieval.
- Open the jaws and transfer the sediment to sample containers or a mixing tray.

7. REFERENCES

None.

Standard Operating Procedure No. 022
for
Sediment and Benthic Macroinvertebrate Sampling with Eckman Grab

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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December 2014

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1. SCOPE AND APPLICATION

This Standard Operating Procedure covers the protocol for obtaining qualitative or quantitative samples of soft sediments and macroinvertebrates inhabiting soft sediments in lakes, reservoirs, and other waterbodies. The Eckman grab sampler is well suited to collecting samples in deeper (up to 100 ft) waterbodies.

Use of brand names in this Standard Operating Procedure is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable standard operating procedures for the maintenance and calibration of same.

2. MATERIAL

The following materials may be required:

Eckman grab sampler: a box-shaped device with two scoop-like jaws	Sample containers
Boat	Sieve – 500 µ (U.S. Standard No. 30)
Personal protective equipment	Stainless steel spoon or trowel
Personal flotation devices	

3. PROCEDURES

The following is a summary of procedures on use of the Eckman grab sampler:

- Cock the sampler by raising each jaw upward into the cocked position using the attached able and secure the cable to the catch pin located at the top of the sampler.
- Once cocked, lift the sampler overboard and lower slowly but steadily to the bottom.
- Once on the bottom, indicated by a slack line, the weighted messenger is sent down the line tripping the catch mechanism, causing the spring loaded jaws to close the bottom of the sampler, containing the sediment.
- Raise the sample at a slow but steady rate to prevent sample loss or washout.
- Once the sample is on board, empty the sample into a stainless steel, polytetrafluoroethelyne, or polytetrafluoroethelyne-lined bowl or tray for processing.
  - If the sediment will be analyzed for volatile organic compounds, transfer the sample into the appropriate sample containers immediately.

- If the sediment will not be analyzed for volatile organic compounds, use Stainless steel spoon to thoroughly homogenize sample, then transfer sample into appropriate containers. Add preservative (if required) and place in ice-filled chest.

  — If benthic macroinvertebrates are to be collected, sieve sample and transfer macroinvertebrates into appropriate container.

- Thoroughly decontaminate the device.

4. MAINTENANCE

Maintain according to manufacturer's suggestions.

5. PRECAUTIONS

The following precautions should be taken while using an Eckman grab sampler:

- Inspect the device for mechanical deficiencies prior to its use.
- This sampler is inefficient in waters deeper than approximately 75-100 ft, under adverse weather conditions, and in waters of moderate to strong currents or wave action.
- Exercise caution at all times once the grab is loaded or cocked because a safety lock is not part of the standard design.
- Operate the sampler from a boat with a winch and cable.
- Wear gloves when collecting sediment samples. Be sure to consult the health and safety plan for the proper dermal and respiratory protection prior to collecting any samples.
- Higher levels of personal protective equipment may be required by the Health and Safety Plan.
- While sampling from a boat in waterbodies with a depth of 5 ft or more, the sampling team will wear personal flotation devices (life jackets).
- Collect samples first from those areas that are suspected of being the least contaminated, thus minimizing the risk of cross-contamination.

6. REFERENCES

American Society for Testing and Materials. Standard 2.1. D4387 Guide for Selecting Grab Sampling Devices for Collecting Benthic Macroinvertebrates.

U.S. Environmental Protection Agency. 1990. Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters. Office of Research and Development. EPA/600/4-90/030. November.

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Standard Operating Procedure No. 024
for
Photoionization Detector (Microtip HL-200)

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for field operations with a photoionization detector (PID). PIDs use an ultraviolet emitting lamp designed to detect, measure, and display the total concentration of airborne ionizable gases and vapors. This information is used to determine control measures such as protection and action levels.

Use of brand names in this Standard Operating Procedure is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable standard operating procedure for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Battery back	Regulator
Calibration gas (100ppm Isobutylene)	Tedlar bag
PID (i.e., Microtip HL-200)	Tygon tubing

3. STARTUP/CALIBRATION PROCEDURE

The following describes startup and calibration procedures:

- Turn the instrument on by pressing the back of the power switch located on the handle of the Microtip.
- The message “Warming up now, please wait” will be displayed for up to 3 minutes. After normal display appears, the Microtip is ready for calibration.
- Fill a Tedlar bag with the desired calibration gas (usually 100 ppm isobutylene).
- Press SETUP button and select the desired Cal Memory using the arrow keys (normally set to 200 ppm). Press EXIT button to leave setup function.
- Press CAL button and expose Microtip to Zero Gas. (Usually clean outdoor air will be suitable. If any doubt exists as to the cleanliness of the background air, a commercial source of zero gas should be used.).
- The Microtip then asks for the Span Gas concentration. Enter the known span gas concentration and then connect the Tedlar bag containing the Span Gas.

NOTE: THE SPAN GAS CONCENTRATION IS DEPENDENT UPON BOTH THE CONCENTRATION OF THE SPAN GAS USED AND THE RATING OF THE ULTRAVIOLET LAMP IN THE MICROTIP AT TIME OF CALIBRATION. IF USING 100 ppm ISOBUTYLENE AND THE STANDARD 10.6 eV LAMP, THE SPAN GAS CONCENTRATION WILL BE 56 ppm.

- Press enter and the Microtip sets its sensitivity. Once the display reverts to normal, the Microtip is calibrated and ready for use. Remove the Span Gas from the inlet probe. The instrument should be calibrated at least once a day.

4. BATTERY CHARGING

The following is a summary of battery charging procedures:

- Ensure Microtip is off.
- Set the voltage selector switch on the bottom of the battery charger to the appropriate AC line voltage.
- Press the release button on the bottom of the Microtip and remove the battery pack by sliding it backwards.
- Plug charger into the battery pack and then into an AC outlet and allow the battery to charge for at least 8 hours.
- After charging, remove the charger, first from the outlet then from the battery pack, and slide the battery pack back onto the Microtip.

5. PRECAUTIONS

The following is a summary of precautions while using the Microtip:

- Microtip does not carry an Intrinsic Safety Rating and must not be used in a hazardous location where flammable concentrations of gases or vapors are constantly present.
- All calibration, maintenance, and servicing of this device, including battery charging, must be performed in a safe area away from hazardous locations.
- Do not open or mutilate battery cells.
- Do not defeat proper polarity orientation between the battery pack and battery charger.
- Substitution of components may affect safety rating.

6. REFERENCES

Microtip HL-200 User's Manual. 1990. February.

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Standard Operating Procedure No. 025
for
Soil Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for sampling surface and subsurface soils. Soil samples give an indication of the area and depth of site contamination, so a representative sample is very important.

2. MATERIALS

The following materials may be required:

Bucket auger or push tube sampler	Split-spoon, Shelby tube, or core barrel sampler
Drill rig and associated equipment	Stainless steel bowl
Personal protective equipment as required by the Health and Safety Plan	Stainless steel spoon, trowel, knife, spatula (as needed)

3. PROCEDURE

3.1 SUBSURFACE SAMPLES

Don personal protective equipment. Collect split-spoon, core barrel, or Shelby Tube samples during drilling. Upon opening sampler, or extruding sample, immediately screen soil for volatile organic compounds using either a photoionization detector or flame ionization detector. If sampling for volatile organic compounds, determining the area of highest concentration, use a stainless steel knife, trowel, or laboratory spatula to peel and sample this area. Log the sample in the Field Logbook while it is still in the sampler. Peel and transfer the remaining sample in a decontaminated stainless steel bowl. Mix thoroughly with a decontaminated stainless steel spoon or trowel. Place the sample into the required number of sample jars. Preserve samples as required. Discard any remaining sample into the drums being used for collection of cuttings. Decon sampling implements. All borings will be abandoned.

NOTE: If sample recoveries are poor, it may be necessary to composite samples before placing them in jars. In this case, the procedure will be the same, except that two split-spoon samples will be mixed together. The Field Logbook should clearly state that the samples have been composited, which samples were composited, and why the compositing was done.

Samples taken for geotechnical analysis will be undisturbed samples, collected using a thin-walled (Shelby tube) sampler.

3.2 SURFICIAL SOIL SAMPLES

Don personal protective equipment. Remove vegetative mat. Collect a sample from under the vegetative mat with a stainless steel trowel, push tube sampler, or bucket auger. If a representative sample is desired over the depth of a shallow hole or if several shallow samples are to be taken to represent an area, composite as follows:

- As each sample is collected, place a standard volume in a stainless steel bowl.
- After all samples from each hole or area are in the bucket, homogenize the sample thoroughly with a decontaminated stainless steel spoon or spatula.

If no compositing is to occur, place sample directly into the sample jars. Place the leftover soil in the auger borings and holes left by sampling. If necessary, add clean sand to bring the subsampling areas back to original grade. Replace the vegetative mat over the disturbed areas. Samples for volatile organic compounds will not be composited. A separate sample will be taken from a central location of the area being composited and transferred directly from the sampler to the sample container. Preserve samples as required. Decon sampling implements.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Refer to the Health and Safety Plan.

Soil samples will not include vegetative matter, rocks, or pebbles, unless the latter are part of the overall soil matrix.

6. REFERENCES

ASTM International. Method D1586-84, Penetration Test and Split-Barrel Sampling of Soils.

———. Method D1587-83, Thin Walled Sampling of Soils.

Department of the Army, Office of the Chief of Engineers. 1972. Engineer Manual 1110-2-1907 Soil Sampling. 31 March.

Standard Operating Procedure No. 027A
for
Passive Soil Gas Surveys
– Gore Sorbers

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The steps and information herein are the Standard Operating Procedures (SOPs) for conducting a GORE-SORBER Screening Survey. GORE-SORBER® Screening Modules and organic analyses will be supplied/conducted by:

W.L. Gore & Associates, Inc.
101 Lewisville Road
P.O. Box 1100
Elkton, Maryland 21922-1100
(410) 392-3300

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. COLLECTOR DESCRIPTION

The sorbent containers and insertion/retrieval cords are constructed solely of inert, hydrophobic, microporous GORE-TEX® expanded polytetrafluoroethylene (ePFTE, similar to Teflon) with no fillers or plasticizer introduced during manufacturing. The unique feature of this construction is that the entire sorbent container surface area, as well as the surrounding insertion/retrieval "cord," facilitates vapor transfer. Sorbent containers (sorbers) are typically filled with TENAX®.

3. FIELD OPERATIONS

3.1 MATERIALS

The following materials may be required for field operations:

Cooler(s) with chilled ice packs or ice	Knife, scissors, and needle nose pliers
Corks with screw eyes	Latex surgical gloves or equivalent
Correctly scaled site map	Measuring tape, transit, or other distance measuring device
Electric power source (AC power outlet or generator)	Paper towels and American Society for Testing and Materials Type II water or equivalent
Electric rotary, hammer-action, or combination hammer with 1-in. carbide-tipped bit (31-36 in. long)	Patching compound for concrete and/or asphalt holes (if required)
Extension cord	Pen, clipboard, field notebook, chain-of-custody (COC) form, and SOP
Fiberglass staff flags or some other means of location marking	Slide hammer/tile probe
GORE-SORBER® Screening Modules and Vials	Small shovel
Insertion rod	Trash bags

3.2 LOCATING SAMPLE SITES

Lay out sampling grid using point spacing specified in Work Plan. From a known survey point, locate and mark all screening module location sites to the nearest inch using fiberglass staff flags.

Note on field maps and/or field log any deviations to the sample grid as presented in the Work Plan.

Drill Hole—A 9/16- to 1-in. hole is cored to a depth of 2-3 ft below ground surface (installation depth is held constant for a given survey). This depth has been selected to keep the modules below the daily effects of atmospheric temperature changes. Coring is accomplished using a variety of tools depending on the nature of the material being cored. The holes should be vertical and as free from debris as possible.

Prepare Sorber Unit and Note the Unique Serial Number—Immediately after the hole is cored, a GORE-SORBER® Screening Module is removed from its sealed container. Note that each module has a unique serial number recorded on top of the module vial and a metal tag attached to the module. Each vial is also individually numbered. **Record this number on the site map and/or field notebook immediately**.

Insert Sorber Unit—Insert the stainless steel insertion rod into the pocket in the bottom of the module, and lower it into the hole. Ensure that the module goes the entire way down the hole. If a large resistance is felt during insertion, remove the module and re-drill the hole. Re-insert the module. When the module is completely inserted in the hole, press the insertion rod against the side of the hole. Twist the rod and pull the rod out.

Seal Hole—Attach the end of the module to the screw eye in the cord. **Do not remove the metal ID tag**. Coil the excess retrieval cord and push it with the metal tag into the hole. Cork the hole to prevent the intrusion of rain and atmospheric gasses during exposure. If the cork does not fit snugly into the hole, and wrap a short length of the module retrieval cord around the cork and re-insert the cork into the hole.

Decontaminate the auger and insertion rod. After each use, decontaminate all intrusive equipment using decontamination procedures specified in Section 3.3.2 of SOP No. 005.

3.3 EXPOSURE TIME

Exposure times, typically 14 days, are defined in the site Work Plan. Exposure times should be sufficient to allow equilibration of the modules with subsurface conditions. Actual subsurface exposure time and conditions will be measured and recorded.

3.4 FIELD QUALITY CONTROL BLANKS

3.4.1 Temperature Control Blank

Water temperature control blanks are normally supplied by Gore with one blank supplied with each cooler of shipped modules. Temperature control blanks consist of a small vial of American Society for Testing and Materials Type I water that is used to determine the temperature of the modules upon arrival at the laboratory. One temperature control blank must be included with each cooler shipped to Gore for analysis.

3.4.2 Trip Blanks

The trip blank is a set of sorbent modules used to detect volatile organic compound (VOC) contamination during sample shipping and handling. Trip blanks travel to the site with the sampling modules and are returned to the laboratory with the sampling modules. The trip blank will not be exposed to field conditions. The trip blank will be used to assess whether or not any chemical detected by the sorbers are the result of sources other than the study sites. One trip blank is to accompany each cooler containing VOCs. Trip blanks will be kept in sample refrigerators during the course of field work.

3.4.3 Field Duplicates

The collection of field duplicate samples provides for evaluation of overall sampling and laboratory precision by comparing analytical results of two samples of the same matrix from the same location. Two sorber units will be installed into one hole for a duplicate sample. The additional modules will allow for duplicate analysis of several modules from the same hole. If there is a wide difference in analytical results between duplicate samples, it can indicate poor precision of analytical technique and suggest increased evaluation of the data may be warranted. Field duplicates will be collected at a frequency of 10 percent of the samples collected per event.

3.5 SORBER RETRIEVAL

Evaluate the Sample Site—Note any site disturbance that may have occurred since the sorber module was installed. Note any stains on the ground, cork removal, or other such features that might indicate tampering. Remove cork.

Remove Sorber Unit from Hole—Wearing surgical gloves, and wrap retrieval cord once or twice around your hand. Using slow, steady tension, pull the cord straight out of the ground. **Double check the Module ID number on the sample module, sample vial, and COC/Field Logbook to ensure that the correct module is retrieved from the correct grid position**. Cut off the cork and discard.

Place Sorber Unit in Vial—Put the entire retrieval cord, including the metal tag, back into the correctly labeled vial. Tightly reseal the vial. Immediately place the vial in a cooler with blue ice. Sorbers will be stored onsite in a freezer until shipped to the laboratory.

3.6 SORBER SHIPMENT

Sample packing procedures will follow the steps outlined in SOP No. 004. The sorbers should be packed in the blue ice certified by W.L. Gore to be volatile free. Do not use Styrofoam "peanuts" or any other packing material which may contain volatiles or out-gas and contaminate sorbers during shipment. Bubble packing is acceptable. Receive clearance from SciTech to ship samples.

Carefully cut three modules from each sorber unit, one sorber at a time. Care must be taken at this point to ensure that the serial number for each sorber unit is transposed to the sample vial and COC. Do not start a new sorber unit until the transfer of modules from the previous sorber unit is completed in full. Place these three modules in a clean bottle supplied by the contract laboratory.

Note the serial number of the sorber unit tag on the bottle label. Place this number on the contract laboratory COC. Seal the bottle. Place bottle in cooler and pack the samples following the steps in SOP No. 004.

Using the vial racks, coolers, and ice substitutes supplied by the contract laboratory, return the exposed vials and COC document to the contract laboratory via overnight carrier service. Return the remaining sorber module to the GORE vial and seal. Place vials in cooler and pack the samples following steps in SOP No. 004.

Using the vial racks, coolers, and ice substitutes supplied by Gore, return the exposed vials and COC document to Gore's analytical laboratory via overnight carrier service.

4. ANALYTICAL AND DATA PRESENTATION

4.1 SAMPLE RECEIVING

Upon receipt at the W.L. Gore and contract laboratories, all soil gas samplers are inspected and sample labels are cross-referenced against the COC form. Any anomalies observed during the inspection are noted on the COC. When all anomalies, if any, are resolved, the samplers are ready for analysis.

4.2 VOLATILE ORGANIC COMPOUND ANALYSIS

W.L. Gore will analyze for VOCs and report the results of this work directly to the organization conducting the soil gas survey.

4.3 SAMPLE HOLDING

There are no holding time limitations.

4.4 INSTRUMENTATION

Instrumentation at W.L. Gore consists of a Hewlett-Packard 5890-II gas chromatograph, 5971A mass selective detector, and 7673 liquid autosampler. A 25-m, 0.2-mm bore, 0.5 μm "HP-5" 95 percent dimethyl, 5 percent diphenyl polysiloxane capillary column is normally used. A typical temperature program developed for analyzing the sorbers is: initial temperature 40°C for 4 minutes, ramp 20 C/minute to 320°C, final temperature 2 minutes. Injection port temperature (for method extraction) is 250°C, detector transfer line is 380°C. A Perkin-Elmer ATD-400 Automated Thermal Desorption unit is the extraction device used by Gore for sites with low concentrations of gasoline and solvent contamination. By cryofocusing the sample extract prior to sample injection into the gas chromatograph column, Gore has achieved greatly increased sensitivity to all compounds, and superior separation of VOCs compared to solvent or headspace extraction methods.

4.5 ANALYTICAL PARAMETERS

Table SOP027A-1 includes proposed analytical parameters. The soil gas contractor will also conduct a library search to identify and report up to 100 organic chemical constituents present in each module if requested.

4.6 LABORATORY QUALITY ASSURANCE PROCEDURES

W.L. Gore will conform to its Quality Assurance Plan (1994) to be appended to the project-specific Quality Assurance Project Plan with regard to quality control sample type, frequency, handling, preparation, and analytical procedure.

4.7 MAPPING/REPORTING

Graphic presentation of the data extracted from the GORE-SORBER® Screening Modules is presented by overlaying the contamination patterns detected during the analysis onto computer-aided design maps supplied by the field investigator.

5. REFERENCES

W.L. Gore. 1994. Quality Assurance Plan.

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TABLE SOP027A-1 PROPOSED ANALYTICAL PARAMETERS PASSIVE SOIL GAS SURVEY

Analytes	Limit (µg/sorber)
Acetone	(a)
Benzene	0.04
2-Butanone	(a)
Carbon Tetrachloride	0.06
Chlorobenzene	0.03
Chloroform	0.03
Chloromethane	(a)
1,4-Dichlorobenzene	0.04
1,1-Dichloroethane	(a)
1,2-Dichloroethane	(a)
1,1-Dichloroethylene	(a)
trans-1,3-Dichloroethylene	(a)
1,2-Dichloropropane	(a)
cis-1,3-Dichloropropene	(a)
trans-1,3-Dichloropropene	(a)
Ethylbenzene	0.03
Methyl tert-Butyl Ether	0.07
Methylene Chloride	0.23
2-Methylnapthalene	0.03
2-Methylphenol	0.04
Naphthalene	0.03
Octane	0.02
Pentadecane	0.06
Phenanthrene	0.015
Phenol	0.05
Styrene	(a)
1,1,2,2-Tetrachloroethane	(a)
Tetrachloroethylene	0.07
1,2,4,5-Tetramethylbenzene	0.02
Toluene	0.03
1,1,1-Trichloroethane	0.06
1,1,2-Trichloroethane	(a)
Trichloroethylene	0.04
Tridecane	0.04
1,2,4-Trimethylbenzene	0.03
1,3,5-Trimethylbenzene	0.03
Undecane	0.04
Vinyl Chloride	(a)
m-Xylene	0.02
o-Xylene	0.03
Total Xylenes	(a)

(a) Method detection limit studies currently being conducted.

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Standard Operating Procedure No. 028
for
Well and Boring Abandonment

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to establish the protocols by which all wells and borings will be safely abandoned. The primary objective of well abandonment is to ensure that the abandoned well or boring does not provide a conduit for the vertical migration of contamination between aquifers.

2. MATERIALS

The following materials may be required:

Drill rig	Bentonite pellets (seal)
Filter pack material	Cement (Portland Type II)
Pure sodium bentonite with no additives (bentonite) powder (grout)	Approved water

3. PROCEDURE

The procedures used in boring abandonment will ideally accomplish two objectives: (1) protect aquifers from cross-contamination by sealing the borehole, and (2) restore the strata in the borehole to nearly original conditions by selective placement of fill material.

Any casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, grout will be placed from the bottom of the hole to within 3 ft of the ground surface, and allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with "ABD," for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site or cluster.

If the hole is within 10 ft of a monitoring well in the same aquifer, or a replacement well is to be installed within 10 ft of the well, any temporary casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, the hole will then be backfilled with filter pack material opposite sand strata and bentonite or grout opposite substantial (2 ft or thicker) clay and silt strata. Where sand as backfill approaches the ground surface, 2 ft of bentonite will be placed above the sand and a 3-ft concrete plug will be placed at the surface. Otherwise, backfill materials will be placed from the bottom of the hole to within 3 ft of the ground surface. These materials will be allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with "ABD," for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site cluster.

If the well is not within 10 ft of another monitoring well, or if there are no substantial, continuous sand bodies, and no replacement well is planned within 10 ft of the original well location, then the hole may be grouted from the bottom to the top.

3.1 GROUT

Grout used in construction will be composed by weight of:

- 20 parts cement (Portland cement, Type II or V)
- 0.4-1 part (maximum) (2-5 percent) bentonite
- 8 gal (maximum) approved water per 94-lb bag of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump prior to placement.

Grout placement will be performed using a commercially available grout pump and a rigid tremie pipe removal and grouting will be accomplished in stages, aquifer by aquifer, sealing the boring from the bottom to ground surface. This will be accomplished by placing a grout pipe to the bottom and pumping grout through the pipe until undiluted grout reaches the bottom of the next higher section of casing or, for the top-most section, until grout flows from the boring at ground surface. Efforts will be made to grout incrementally as the temporary casing is removed.

After 24 hours, the abandoned drilling site will be checked for grout settlement. On that day, any settlement depression will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at the ground surface.

3.2 BORINGS

The term “Borings” as used in this Standard Operating Procedure applies to any drilled hole made during the course of a remedial investigation which is not completed as a well. This includes soil test borings, soil sampling borings, and deep stratigraphic borings. Whether completed to the planned depth or aborted for any reason prior to reaching that depth, borings will be grouted and normally closed within 4 hours, or within 4 hours or completion of logging of completion of logging.

3.2.1 Shallow Borings not Penetrating Water Table

Shallow borings made for the collection of subsurface soil samples will be abandoned by backfilling the hole with cuttings from the hole, **if and only if the boring does not penetrate the water table.** Clean sand will be used to make up any volume not filled by the cuttings.

3.2.2 Borings Penetrating the Water Table

Shallow borings made for the collection of subsurface soil samples **which penetrate the water table** will be abandoned by grouting the hole from the bottom to the top.

3.2.3 Deep Stratigraphic Borings

Deep stratigraphic borings will normally be located in areas which, by virtue of the historical record, are presumed relatively uncontaminated. Therefore, these borings are usually over 100 ft from any sampling well locations. Any boring located within 10 ft of a proposed well location, or located directly upgradient or downgradient (on anticipated flow line) of a proposed well location, will be abandoned by placing clean sand in the aquifer intervals and bentonite or grout in aquitard intervals as described above. If the boring is over 10 ft from and/or not upgradient of a proposed well location, the boring will be completely filled with grout.

3.3 WELLS

The following procedure applies to wells aborted prior to completion and existing wells determined to be ineffective or otherwise in need of closure.

Prior to abandoning any developed well, the proper well licensing body will be provided written notification along with an abandonment plan for that well.

If the well is within 10 ft of another monitoring well in the same aquifer, or a replacement well is to be installed within 10 ft of the well, casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, the hole will then be backfilled with filter pack material opposite sand strata and bentonite or grout opposite substantial (2 ft or thicker) clay and silt strata. Where sand as backfill approaches the ground surface, 2 ft of bentonite will be placed above the sand and below the concrete plug near the surface. Backfill materials will be placed from the bottom of the hole to within 3 ft of the ground surface. These materials will be allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with “ABD,” for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site cluster.

If the well is not within 10 ft of another monitoring well, and is not to be replaced by another well within 10 ft of the original location, casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, grout will be placed from the bottom of the hole to within 3 ft of the ground surface, and allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with “ABD,” for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site cluster.

4. REPLACEMENT WELLS

Replacement wells (if any) will normally be offset at least 10 ft from any abandoned well in a presumed upgradient or crossgradient groundwater direction. Site-specific conditions may necessitate variation to this placement.

5. PRECAUTIONS

None.

Standard Operating Procedure No. 030
for
Radioactive Surveys

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) is developed to serve as guidance to personnel performing radiological environmental surveys of surface soil, water bodies, or other environmental media which may be potentially contaminated with alpha, beta, and beta-gamma radioisotopes.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

The following assumptions will be made:

- Radiological contamination is present at the site.
- All radioisotopes are present, unless historical documentation is available to help identify the specific radioisotope(s) present.
- A potential health hazard exists from external and internal radiation exposure until instrumentation survey data and appropriate environmental samples indicate otherwise.

2. MATERIALS

The following materials may be required:

Eberline Model PAC-1SAG survey meter mated with an alpha scintillation detector (or equivalent)
Eberline Model E-520 survey meter (or equivalent), mated with a HP-210 handheld detector (or equivalent)
Eberline Smart Portable (ESP-2) survey meter (or equivalent) mated with a SPA-3 low energy gamma scintillation detector (or equivalent)

3. SURVEY PROCEDURES

3.1 SURVEY SITE PREPARATION

Survey instrumentation and sampling equipment will remain outside the potentially contaminated area until the boundaries of the contaminated site can be established. Upon establishing the contaminated boundaries, entry and exit routes will be designated for ingress and egress into the area. Cold and hot lines should be established to control the spread of potential radiological contamination from hot to cold areas.

A cartesian grid (X-Y) of the survey site will be developed. The Project Officer in charge of the survey will develop a specific methodology to accomplish this framework. The grid pattern

should also be usable in locating sampling points for cleanup and in reproducing the sampling data. The grid of the survey site should be used in planning for the collection of other environmental samples from the site. Universal Transverse Mercator coordinates are preferred but not mandated.

The Project Officer in charge should note the following observations:

- Any standing water on the survey site.
- Water run-off areas and where the run-off water is leading to, i.e., streams, lakes, marshes, etc. These areas must be considered during the pathway analysis.
- A pathway analysis will be performed to assist in determining the number and type of environmental samples needed to assess the potential health hazard.

3.2 INSTRUMENTATION SURVEY

3.2.1 Calibration and Operational Checks

All portable survey meters will be calibrated at quarterly intervals. All instruments will be properly labeled with the calibration date posted on the label.

All portable survey meters will be checked for operability prior to packing and shipping the instruments to the survey site. The operability check will consist of checking the operation of the survey meter with an appropriate radiation check source at a known distance from the instrument detector. The reading will be documented on the quality control form for each instrument and will be included in the instrumentation shipping kit.

The operability check will be repeated at the survey site prior to starting the instrumentation survey, and periodically during the survey. The instrument readings will be recorded on the quality control form for each instrument.

Background radiation levels will be determined prior to entering the survey site.

An alpha instrumentation survey will be performed with an Eberline Model PAC-1SAG survey meter mated with an alpha scintillation detector (or equivalent). All alpha instrumentation readings will be taken at approximately 1 cm from the surface of the test media. All results will be recorded in disintegrations per minute.

A beta instrumentation survey will be performed with an Eberline Model E-520 survey meter (or equivalent), mated with a HP-210 handheld detector (or equivalent). All results will be recorded in millirad per hour. Readings will be taken approximately 1 cm from the surface of the test media.

A beta-gamma instrumentation survey will be performed with an ESP-2 survey meter (or equivalent) mated with a SPA-3 low energy gamma scintillation detector (or equivalent). All beta-gamma measurements will be taken at approximately 1 m from the surface of the test media. The results will be recorded in microrads per hour and the distance at which the measurement was taken will be documented.

3.3 SURFACE SOIL SAMPLE SURVEY

The Project Officer will evaluate the need to collect soil samples. Soil samples may be needed to assess projected airborne contamination during remedial cleanup or when vehicles and personnel transverse the contaminated site. The Project Officer will design a soil sampling plan to adequately assess potential health risks from low level contamination in soil. The grid developed for the instrumentation survey could be used to assist in determining the soil sample collection points.

Background soil samples should be collected from areas outside of the potentially contaminated area. Background sample data could be used to compare natural occurring radioisotopes in the natural surroundings versus what is present in the contaminated site.

Soil samples will be collected, labeled, and preserved as detailed in SOP No. 025 (Soil Sampling). Soil sample numbers will incorporate grid coordinates so that each can be readily identified and tracked back to the collection point.

3.4 WATER SAMPLES SURVEYS

The Project Officer will evaluate the need to assess the potential contamination in the waterbodies surrounding the contaminated survey site.

A water sampling plan will be designed to accomplish this task. Sampling will be accomplished according to protocols established in SOP No. 007 (Surface Water Sampling Procedures).

Background water samples should be collected from tap water sources in the nearby areas, and any other waterbodies that could provide background data comparison to the potentially contaminated water site.

Water samples may be treated with nitric acid to prevent the plating of radiological materials to walls of the sample containers. Use of preservative is dictated specifically by the method and/or laboratory used for analysis (refer to Work Plan or Quality Assurance Project Plan).

Sample containers should be labeled and packaged to assist in tracking management and to prevent leaking and spills.

3.5 OTHER ENVIRONMENTAL SURVEYS

The Project Officer will evaluate the need to assess the potential contamination in other environmental media such as air samples, vegetation samples, animal samples, etc.

A sampling plan and assessment methodologies will be developed for site-specific environmental assessment.

Refer to SOP Nos. 003 and 016.

4. MAINTENANCE

Refer to manufacturer's manuals for calibration and maintenance of instruments.

5. PRECAUTIONS

NOTE: For purpose of this protocol, the soil surface is defined as the top 1-15 cm of soil.

6. REFERENCES

Krey, P.W. (Acting Director) and H.L. Beck (Acting Deputy Director). 1990. EML Procedures Manual 27th Edition, Volume 1 (HASL-300). Chieco, N.A. et al. (eds.), Environmental Measurements Laboratory, U.S. Department of Energy.

Standard Operating Procedure No. 032
for
Piezometer Installation

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to define acceptable piezometer types and installation techniques. For the purposes of this SOP, a piezometer is defined as a well installation designed to determine and/or monitor groundwater level rather than to acquire environmental samples. The objective of the selected installation technique is to ensure that the piezometer provides representative data while minimizing subsurface contamination, cross-contamination, and installation costs.

A piezometer may typically consist of a 2-in. diameter casing with attached screen. This installation may differ from a typical monitoring well installation in one of several ways. The screen may be stainless-steel, a stainless steel drive-point, slotted polyvinylchloride, or continuously wire-wrapped slotted polyvinylchloride. The piezometer screen may either be driven into place or set in a drilled, open hole. If the screen is driven into place, an engineered filter pack is omitted.

Regardless of the screen and casing material, and the method in which the piezometer is installed, proper care will be taken to avoid providing a vertical conduit for contaminants between aquifers. This will be accomplished by the use of bentonite and/or grout seals as appropriate.

Piezometers may be installed singly or in clusters to monitor one or more piezometric surface(s). Piezometers may not be located within 15 ft of an existing monitoring well. Piezometers should not be installed upgradient of monitoring wells. It is recommended that multiple (nested or clustered) piezometers be located 10-15 ft apart.

2. MATERIALS

The following materials may be required:

Casing		Bentonite pellets (SOP No. 019)
Large stand-mounted hammer with attached leveling device		Cement (SOP No. 019)
Large wooden mallet		Drill rig
Hand-held level		
Personal protective equipment as required by contractor's Health and Safety Plan	**— OR —**	
Stainless steel piezometer drive-points — or — stainless steel or slotted polyvinyl chloride well screens[1]		
Steel measuring tape		

1. Piezometer screen and casing should be inert with respect to the groundwater; therefore, the selection of screen and casing material will be based on select field tests of aquifer chemistry and potential contaminants.

3. INSTALLATION

Three options for the installation of piezometers are discussed in the following sections: installation of a well screen in an open hole (Section 3.1), installation of a driven sampling point (e.g., Geoprobe, Hydropunch, etc.) below a drilled hole (Section 3.2), and shallow installation of a driven point from the surface (Section 3.3).

Driven screens/sampling points are, by their design, point source samplers and their placement must be determined by a qualified geologist or geotechnical engineer onsite. Estimated depths of placement should be included in the work plans for piezometer installation. The maximum depth to which a given point can be driven is a function of a number of parameters, such as the degree of induration and friction coefficient of the material(s) through which it is being advanced, the rigidity of the rod(s), and the driving force available.

3.1 WELL SCREEN IN OPEN HOLE

If the piezometer is to be installed in a drilled, open hole, refer to SOP No. 019 for appropriate drilling and installation protocol. In this case, the piezometer will differ from a monitoring well only in the diameter of the casing. All other provisions for preventing vertical migration of contaminants will be observed.

3.2 DRIVEN POINT BELOW OPEN HOLE

If the piezometer will employ a drive-point screen driven through a hole which is pre-drilled to the top of the target aquifer, follow the drilling procedures detailed in SOP No. 019, set the drive point according to the procedures below, and grout the hole according to SOP No. 019.

3.3 DRIVEN POINT FROM SURFACE

If the piezometer is to be driven from the surface, the installation should be considered as temporary. The contractor's work plan must include a timetable for, and details of the abandonment plan (refer to SOP No. 028 [Well and Boring Abandonment] for details) for these piezometers. Follow the installation steps below:

- Drill or hand auger small hole to a maximum depth of 2 ft to serve as a guide for the drive point.

- Assemble and set the drive point, screen (typically a 2-ft length), and an appropriate number of threaded stainless steel casing extensions into this pilot hole.

- If a drill rig is used, the hydraulic system may be used to press the drive point downward or the drop hammer may be used to drive the point downward. If the piezometer site is inaccessible by drill rig, a tripod-mounted drop hammer may be used to drive the point. Threaded stainless steel casing (typically 2-ft lengths) extensions may be added as needed until the piezometers are driven to the desired depth.

- At sites where the sediment is relatively soft and the desired screen depth is no greater than 2 ft, a large mallet may be used to pound the piezometer to the desired depth directly from the surface.

- Add additional threaded casing onto the top of piezometer if needed so that piezometer extends 2-3 ft above ground surface. Place protective cap on top of piezometer.

- Measure height of the piezometer casing above ground surface. Record site number, screen depth, and height above ground surface.

- If a shallow pilot hole was used, fill the hole to ground surface with bentonite pellets.

- Decontaminate soil augers before moving onto another site.

- Complete drilled holes according to procedures detailed in SOP No. 019.

- Develop piezometers according to procedures in SOP No. 019.

Refer to SOP Nos. 003 (Field Logbook), 005 (Field Decontamination), 010 (Water Level and Well Depth Measurements), and applicable parts of 019 (Monitoring Well Installation).

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Water, soil, and vapors at the sites may be contaminated with solvents, petroleum, chemical agents, explosives, and heavy metals or their respective byproducts. Therefore, extreme care will be taken to avoid skin contact with potentially contaminated material.

Refer to the site-specific Health and Safety Plan for discussion of hazards, preventive measures, and personal protective equipment to be used during piezometer installation and development activities.

If piezometers are being installed from boats or piers over bodies of open water, personal flotation devices (life jackets) will be required as part of the personal protective equipment.

6. REFERENCES

Aller, L., et al. 1989. Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells, National Water Well Association.

ASTM International. D5092-90 Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers.

COMAR 26.04.04 Well Construction.

Nielsen, D.M. 1993. Correct Well Design Improves Monitoring, in *Environmental Protection*, Vol. 4, No. 7. July.

U.S. Environmental Protection Agency. 1989. Groundwater Handbook.

Standard Operating Procedure No. 036
for
Turbidity Measurements (DRT 100)

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the turbidity of all types of aqueous solutions, including drinking water, saline water, and industrial and domestic wastes. Turbidity is an indication of the optical properties that cause light to be scattered or absorbed through an aqueous sample. Turbidity is largely a function of the refractive index and the size and shape of the particles suspended or dissolved in the solution. Turbidity meters do not produce an "absolute" measurement, but one that is "relative" to the optical nature of the solids in solution.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Turbidity meter (DRT 100 or equivalent)
Lint free laboratory wipes (Kimwipes or equivalent)
Formazin standards (from manufacturer)
Sample bottle
Cuvettes

3. PROCEDURE

Calibration of the turbidity meter will be checked on a daily basis as follows:

- Set the range switch to 1000 range before turning the turbidity meter on and whenever the light shield is not in place over the sample well.
- Allow the turbidity meter 15-60 minutes to warmup.
- Clean the reference standard with kimwipes.
- Place the formazin suspension or reference standard in the turbidity meter sample well.
- Place the light shield over the reference standard.
- Rotate the front panel range switch counterclockwise to the appropriate nephelometric turbidity unit range.

- Adjust the reference adjust knob counterclockwise to read the same value as the reference standard value. This value is stamped on top of the reference standard.
- The turbidity meter is now standardized on all ranges to the factory formazin calibration and unknown samples may be read directly in nephelometric turbidity unit, feeder terminal unit, or Jackson turbidity unit.
- Rotate the range switch clockwise to the 1000 range before removing the reference standard.
- Record reading in field logbook (Refer to SOP Nos. 003 and 016).
- Do not leave the reference standard in the sample well for long periods.

Turbidity will be measured as follows:

- Pour aqueous sample into a new cuvette assuring no air bubbles.
- Place the cuvette into the sample well.
- Place the light shield over the sample.
- Rotate the range switch counterclockwise to the range which provides best readability and sensitivity for the sample being measured.
- Allow the turbidity meter to stabilize before recording the nephelometric turbidity unit value.
- Turn the range switch clockwise to the 1000 range and then remove the sample.
- Do not leave the filled cuvette in the sample well for long periods.
- Repeat above steps for additional samples.

Cuvette cleaning procedure is as follows:

- Cuvette must be clean and free of rubs or scratches.
- Wash the cuvette in a detergent solution.
- Rinse thoroughly 8-10 times, preferably with distilled water to remove all streaks.
- Polish with kimwipes.
- Cuvettes must be stored in a clean dust-free environment.

4. MAINTENANCE

Source lamp may be replaced as follows:

- Remove the instrument case per manufacturer instruction.
- Remove the bulb by loosening a screw and removing the electrical leads.
- Insert the new bulb and reconnect the electrical leads.
- Before tightening the screw, be sure to position the filament so that it will be parallel to the axis of the sample well.
- Insert the lamp alignment tool in the sample well to focus the new bulb.
- Move the lamp bracket assembly in or out until a focused image of the filament is within the rectangular box on the lamp alignment tool.
- Once the filament image has been aligned and focused within the rectangular box on the lamp adjustment tool, tighten all screws snugly.
- Replace the instrument case.

5. PRECAUTIONS

Handle the reference standard or sample cuvettes by the top to prevent surface scratches or finger smudges which will cause analysis errors.

Check the mechanical meter zero when the instrument is in a vertical position and the power switch is off. Adjust to zero only if necessary by means of the black screw on the meter face.

The turbidity meter should be left on for the entire work shift to minimize warm-up and recalibration delays.

Do not leave the reference standard or filled curvette in the sample well for long periods.

Leave the light shield in place on the instrument when it is not in use in order to protect the sample well for long periods.

Always set the range switch to 1000 range before turning the instrument on and whenever the light shield is not in place over the well.

6. REFERENCES

Manufacturer's Manual.

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Standard Operating Procedure No. 037
for
Dissolved Oxygen Measurements
(YSI Model 57)

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the dissolved oxygen (DO) of all types of aqueous solutions, including drinking water, saline water, and industrial and domestic wastes. DO is a measurement of the amount of soluble oxygen in an aqueous solution. It is a general indication of an aerobic/anaerobic condition of a water sample.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

DO meter (YSI Model 57 or equivalent)
Self-stirring biological oxygen demand bottle probe
Membrane standards
Biological oxygen demand bottle

3. PROCEDURE

3.1 SETUP

It is important that before the meter is prepared for use and calibrated, it should be placed in the intended operating position, i.e., vertical, tilted, or horizontal. The instrument may need readjustment if the operating position is altered. The setup procedures should be as follows:

- With the switch set to **OFF**, adjust the meter pointer to zero with the screw in the center of the meter panel.
- Switch to **RED LINE** and adjust the **RED LINE** knob until the meter needle aligns with the red mark if necessary.
- Switch to **ZERO** and adjust to 0 mg/L scale with the **ZERO** control knob.
- Attach the prepared probe to the **PROBE** connector of the instrument and adjust the retaining ring finger tight.
- Before calibrating, allow 15 minutes for optimum probe stabilization. Repolarize whenever the instrument has been **OFF** or the probe has been disconnected.

3.2 CALIBRATION

Calibration is accomplished by exposing the probe to a known oxygen concentration, such as water-saturated air (%), or water of a known oxygen content (mg/L), and then adjusting the calibration controls so the display shows a reading matching the oxygen concentration of the known sample. Calibration can be disturbed by physical shock, touching the membrane, and fouling of the membrane or drying out of the electrolyte. Calibration will be checked after each series of measurements. Calibration of the DO meter will be performed on a daily basis as follows:

1. Place the probe in moist air. Biological oxygen demand probes can be placed in partially filled (50 ml) biological oxygen demand bottles. Wait 10 minutes for temperature to stabilize ± 2°C.

2. Switch to **TEMPERATURE** and read. Refer to Table SOP037-1 for solubility of oxygen in fresh water (calibration value).

3. Determine altitude or atmospheric correction factor from Table SOP037-2.

4. Multiply the calibration value from Table SOP037-1 by the correction factor from Table SOP037-2 to obtain the correct calibration value.

   EXAMPLE: Assume a temperature of 20°C and an altitude of 1,100 ft. From Table SOP037-1, the calibration value of 20°C is 9.09 mg/L. From Table SOP037-2, the correction factor for 1,100 ft is 0.96. Therefore, the corrected calibration value is 9.09 mg/L × 0.96 = 8.73 mg/L.

5. Switch to the appropriate mg/L range, set the **SALINITY** knob to zero and adjust the **CALIBRATE** knob until the meter reads the calibration value from Step 4. Wait 2 minutes to verify calibration stability. Readjust if necessary.

3.3 DISSOLVED OXYGEN MEASUREMENT

- With the instrument prepared for use and the probe calibrated, place the probe in the sample.

- Turn the **STIRRER** knob **ON**.

- Adjust the **SALINITY** knob to the salinity of the sample if appropriate.

- Allow sufficient time for the probe to equilibrate to the sample temperature and DO.

- Read DO on appropriate scale.

- Before measuring the DO of the next sample, rinse probe and sample bottle with distilled water and then with next water sample.

Follow steps above for the next sample(s).

The DO meter should normally be left on during the working day to avoid the delay of waiting for probe repolarization.

4. MAINTENANCE

The following steps will be taken to maintain the DO meter:

- Replace the batteries when the **RED LINE** knob is at its extreme adjustment or at least annually.

- In the **BATT CHECK** position on the **STIRRER** knob, the voltage of the stirrer batteries is displayed on the red **0-10** scale. Do not permit them to discharge below 6 volts.

- Replace membrane every 2 weeks depending on application. Probes will be stored in a humid environment to prevent drying out.

5. PRECAUTIONS

The DO meter case is water resistant when properly closed. As a precaution against damaged gaskets or loose fittings, the instrument case will be opened and inspected for moisture whenever the instrument has been subjected to immersion or heavy spray. The case is opened by removing the screws on the rear cover an lifting the cover off.

6. REFERENCES

Manufacturer's handbook.

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TABLE SOP037-1 SOLUBILITY OF OXYGEN IN WATER EXPOSED TO WATER SATURATED AIR AT 760 mm Hg PRESSURE

Temperature (°C)	Solubility (mg/L)	Temperature (°C)	Solubility (mg/L)	Temperature (°C)	Solubility (mg/L)
0	14.62	17	9.67	34	7.07
1	14.22	18	9.47	35	7.95
2	13.83	19	9.28	36	7.84
3	13.46	20	9.09	37	6.73
4	13.11	21	8.92	38	6.62
5	12.77	22	8.74	39	6.52
6	12.45	23	8.58	40	6.41
7	12.14	24	8.42	41	6.31
8	11.84	25	8.26	42	6.21
9	11.56	26	8.11	43	6.12
10	11.29	27	7.97	44	6.02
11	11.03	28	7.83	45	5.95
12	10.78	29	7.69	46	5.84
13	10.54	30	7.56	47	5.74
14	10.31	31	7.43	48	5.65
15	10.08	32	7.31	49	5.56
16	9.87	33	7.18	50	5.47

NOTE: Derived from 17th Edition, Standard Methods for the Examination of Water and Wastewater.
°C = Degree Celsius.
mg/L = Milligram per liter.

TABLE SOP037-2 CALIBRATION VALUES FOR VARIOUS ATMOSPHERIC PRESSURES AND ALTITUDES

Pressure			Altitude		Calibration Value (Percent)
Inches Mercury	Millimeter Mercury	Kilopascal	Feet	Meter	
30.23	768	102.3	-276	-84	101
29.92	760	101.3	0	0	100
29.61	752	100.3	278	85	99
29.33	745	99.3	558	170	98
29.02	737	98.3	841	256	97
28.74	730	97.3	1126	343	96
28.43	722	96.3	1413	431	95
28.11	714	95.3	1703	519	94
27.83	707	94.2	1995	608	93
27.52	699	93.2	2290	698	92
27.24	692	92.2	2587	789	91
26.93	684	91.2	2887	880	90
26.61	676	90.2	3190	972	89
26.34	669	89.2	3496	1066	88
26.02	661	88.2	3804	1160	87
25.75	654	87.1	4115	1254	86
25.43	646	86.1	4430	1350	85
25.12	638	85.1	4747	1447	84
24.84	631	84.1	5067	1544	83
24.53	623	83.1	5391	1643	82
24.25	616	82.1	5717	1743	81
23.94	608	81.1	6047	1843	80
23.62	600	80.0	6381	1945	79
23.35	593	79.0	6717	2047	78
23.03	585	78.0	7058	2151	77
22.76	578	77.0	7401	2256	76
22.44	570	76.0	7749	2362	75
22.13	562	75.0	8100	2469	74
21.85	555	74.0	8455	2577	73
21.54	547	73.0	8815	2687	72
21.26	540	71.9	9178	2797	71
20.94	532	70.9	9545	2909	70
20.63	524	69.9	9917	3023	69
20.35	517	68.9	10293	3137	68
20.04	509	67.9	10673	3253	67
19.76	502	66.9	11058	3371	66

NOTE: Derived from 17th Edition, Standard Methods for the Examination of Water and Wastewater.

Standard Operating Procedure No. 038
for
Redox Potential Measurements

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for measuring the redox of flooded sediment and soil. Redox is an indication of the reduction of oxidation intensity of an anaerobic system. Redox will be expressed in mV. A complete anaerobic system redox potential is -150 Mv. A positive value indicates an aerobic system.

Redox measurement in a natural system is difficult to obtain due to the absence of true equilibria, heterogeneity of media, and pH effects deprived redox measurements in natural media of precise thermodynamic significance (Ponnamperuma 1972). Despite the difficulties involved in the redox measurements in natural media, it is widely accepted that redox readings in natural anaerobic systems can provide valuable environmental information. Whitfield found redox useful as a semi-quantitative indicator of the degree of stagnation of a particular aquatic environment as did Ponnamperuma for flooded soils and sediments. The redox measurements of natural waters are not representative of that median, since natural waters are in a highly dynamic state rather than in or near equilibrium, according to Stumm and Morgan 1970. It is generally recognized that redox measurements in oxygenated natural waters are invalid.

2. MATERIALS

The following materials may be required:

pH meter	Sample bottle
Combination pH electrode	Standard solution (pH 4 and 7 buffers saturated with quinhydrone)
Lint-free laboratory wipes (Kimwipes, or equivalent)	Wash bottle
Distilled water	

3. PROCEDURE

Calibration of the pH meter will be calibrated on a daily basis as follows.

- Prepare beaker of standard solution with known voltage(s)
- Connect electrodes to instrument
- Turn on and clear
- Rinse electrode with distilled water blot excess with laboratory wipes
- Immerse probe in beaker of standard solution
- Press mV key
- After the reading stabilizes, the absolute mV of solution is displayed.
- Rinse electrode and blot excess.

Redox will be measured after calibration as follows:

- Prepare sample in a beaker
- Rinse electrode and blot excess water
- Immerse electrode in sample and stir briefly
- Press mV switch
- Record the reading after it stabilizes
- For next sample(s), follow above steps.

4. MAINTENANCE

Check the batteries each time the meter is used.

Keep the probe stored in a 0.1 M KCL solution when not in use. Alternatively, the electrode may be rinsed with deionized water and trapping any residual water inside the protective cap.

5. PRECAUTION

Remove coatings of oil material or particulate matter that can impair electrode response by gentle wiping or detergent washing, followed by distilled water rinsing.

6. REFERENCES

Beckman Instruments, Inc. User Manual for 10, 11, and 12 pH/ISE meter.

Ponnamperuma, F.N. 1972. The Chemistry of Submerged Soils, Advances in Agronomy. Vol. 24.

Stumm, W. and J.J. Morgan. 1970. Aquatic Chemistry, Wiley, New York.

Whitfield, M. 1969. Eh as an Operational Parameter in Estuarine Studies. *Limnol. Oceanogr*., Vol. 14.

Standard Operating Procedure No. 039
for
Sample Preservation and Container Requirements

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. PURPOSE AND SCOPE

The purpose of this Standard Operating Procedure (SOP) is to define the preservatives and techniques to be employed in preserving environmental samples between collection and analysis.

2. MATERIALS

The following materials may be required:

Containers (see Section 3 for description)	NaOH
HNO_3	Ice chests
H_2SO_4	Ice

3. DEFINITION OF CONTAINER TYPES

Listed below are the definitions of various container types.

Type	Container	Closure	Septum
A	80-ounce (oz) amber glass, ring handle bottle/jug, 38-millimeter (mm) neck finish	White polypropylene or black phenolic, baked polyethylene cap, 38-430 size, 0.015-mm polytetrafluoroethelyne (PTFE) liner	
B	40-mililiter (mL) glass vial, 24-mm neck finish	White polypropylene or black phenolic, open top, screw cap, 15-mm opening, 24-400 size	24-mm disc of 0.005-inch (in.) PTFE bonded to 0.120-in. silicon for total thickness of 0.125 in.
C	1-L high density polyethylene, cylinder-round bottle, 28-mm neck finish	White polyethylene cap, white ribbed, 28-410 size; F217 polyethylene liner	
D	120-mL wide mouth glass vial, 48-mm neck finish	White polyethylene cap, 40-480 size; 0.015-mm PTFE liner	
E	250-mL Boston round glass bottle	White polypropylene or black phenolic, open top, screw cap	Disc of 0.005-in. PTFE bonded to 0.120-in. silicon for total thickness of 0.125 in.
F	8-oz short, wide mouth, straight-sided, flint glass jar, 70-mm neck finish	White polypropylene or black phenolic, baked polyethylene cap, 48-400 size; 0.030-mm PTFE liner	
G	4-oz tall, wide mouth, straight - sided, flint glass jar, 48-mm neck finish	White polypropylene or black phenolic, baked polyethylene cap, 48-400 size; 0.015-mm PTFE liner	

Type	Container	Closure	Septum
H	1-L amber, Boston round, glass bottle, 33-mm pour-out neck finish	White polypropylene or black phenolic, baked polyethylene cap, 33-430 size; 0.015-mm PTFE liner	
K	4-L amber glass ring handle bottle/jug, 38-mm neck finish.	White polypropylene or black phenolic, baked polyethylene cap, 38-430 size; 0.015-mm PTFE liner	
L	500-mL high-density polyethylene, cylinder bottle, 28-mm neck finish	White polypropylene, white ribbed, 28-410 size; F217 polyethylene liner	

4. PROCEDURE

All containers described in Section 3 must be certified clean, with copies of laboratory certification furnished upon request. There may be circumstances when alternative containers will be used (e.g., aluminum foil around tissue samples placed in plastic bags, plastic buckets for large soil/sediment samples, etc.) for which laboratory certification may not be available. Such containering should be appropriately decontaminated or verified appropriately clean prior to using.

Water samples will be collected into pre-preserved containers appropriate to the intended analyte as given in Quality Assurance Project Plan. Samples taken for volatile organic compounds will be collected in accordance with SOP No. 003, Section 3.3.8. Samples taken for metals analysis will be verified in the field to a pH <2. The container should be tightly capped, then swirled to thoroughly mix the sample. The cap will then be loosened to release any excess pressure this operation may have generated. Samples taken for total phosphorous content will be verified in the field to a pH <2. The container should be tightly capped and swirled to thoroughly mix the sample. The cap will then be loosened to release any excess pressure this operation may have generated. Samples taken for cyanide will be verified for a pH >12. Most other samples do not require added preservation; however, there are analytes that may require special preservation, i.e., sulfide which requires a zinc acetate preservation. Preservation must be performed as documented in the project-specific Quality Assurance Project Plan. These samples will be immediately placed on ice and cooled to 4±2°C.

Soil and sediment samples will be collected into containers appropriate to the intended analyte as given in the Quality Assurance Project Plan. Samples taken for volatile organic compound analysis will collected in accordance with the site-specific SOP. Samples taken for metals analysis will be tightly capped, placed on ice, and maintained at a temperature of 4°C. Samples taken for total phosphorous content will be tightly capped, placed on ice, and maintained at a temperature of 4°C. Under most circumstances, no preservatives will be added to any other soil samples; follow project-specific requirements as documented in the Quality Assurance Project Plan. These samples will be immediately placed on ice and cooled to 4±2°C.

5. MAINTENANCE

Not applicable.

6. PRECAUTIONS

Note that acidifying a sample containing cyanide may liberate HCN gas.

- Avoid breathing any fumes emanating from acidified samples.
- Acidify samples only in the open, rather than in closed spaces, i.e., a vehicle.
- Hold suspected HCN-generating sample away from body and downwind while manipulating it.
- See the Health and Safety Plan for other safety measures.

7. REFERENCES

U.S. Environmental Protection Agency (EPA). 1986. Test Methods for Evaluating Solid Waste, SW-846.

———. 1987. A Compendium of Superfund Field Operations Methods, EPA 540-P87-001.

———. 1991. A Compendium of ERT Soil Sampling and Surface Geophysics Procedures.

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Standard Operating Procedure No. 041
for
Sludge/Lagoon Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for sampling sludges. Sludges include solid matter derived from waste materials that are suspended in or settled from a liquid. This procedure can be applied to the collection of sludge samples from areas of deposition such as: tanks, sumps, landfills, ditches, ponds, and lagoons. It is important to collect a representative sample of the waste material.

EA recognizes that other protocols have been developed that meet the criteria of quality and reproductivity. Clients may have their own sludge/lagoon sampling protocols which may contain methodologies and procedures that address unique or unusual site-specific conditions or may be in response to local regulatory agency requirements. In such cases, EA will compare its and the client's protocols. The goal is to provide the client with the most quality; therefore, if the client's protocols provide as much or more quality assurance than EA's protocols for the particular site or project, EA will adopt those particular protocols and this SOP will be superseded in those respects. If EA is required to implement the client's protocols in lieu of EA's protocols, EA will make the client formally aware of any concerns regarding differences in protocols that might affect data quality and will document such concerns in the project file.

2. MATERIALS

The following materials may be required:

Plastic sheeting	Stainless steel hand core sludge sampler and extensions
Polypropylene rope	Stainless steel dip sampler, scoops, trowels, spoons, and ladles
Sample bottles	Utility knife
Stainless steel or Teflon® tray	

3. PROCEDURES

The liquid content of the sludge sample may vary from nearly all liquid to a dense, nearly liquid-free material. It may be necessary to use a variety of equipment to obtain the required samples, even at a single site.

3.1 GENERAL

1. Upon arrival at the site, immediately set up and organize the equipment.

2. Establish background levels of airborne organic compounds using a photoionization detector or a flame ionization detector.

3. Cut a section of 6-mil plastic sheeting of approximately 6 ft × 6 ft. Place the sheeting on the upgradient side of the sample area.

4. Arrange the sample containers, sampler(s), and decontamination equipment on the plastic sheeting.

5. Don personal protective equipment in accordance with the Site Safety and Health Plan.

6. Collect the sample(s). The preferred method of collecting sludge samples will be by hand corer; refer to Section 3.2. If using a scoop, trowel, spoon, or ladle, refer to Section 3.3.

3.2 HAND CORER

1. Ensure that the corers and liners are properly decontaminated prior to use.

2. Force the corer into the sludge with a smooth, continuous motion to a depth of 9-12 in.

3. Twist the corer to detach the sample, then withdraw the corer in a single smooth motion.

4. Remove the top of the corer and, if excess liquid is present, decant the liquid into a sample bottle. This liquid will be labeled and analyzed.

5. Remove the nosepiece of the corer and deposit the sample into a stainless steel or Teflon tray.

6. Transfer the sample into sample bottles using a stainless steel laboratory spoon or equivalent object.

7. If possible, the top 6 in. of the core will be sampled into three separate sample bottles, 2 in. per bottle, to ensure that an accurate chronology of contamination can be determined.

8. Ensure that each sample bottle is properly labeled, noted on the chain-of-custody form, and placed in the sample cooler with ice packs.

9. Decontaminate sampling equipment according to SOP No. 005.

10. Dispose of all sampling wastes in properly labeled containers.

3.3 SCOOP, TROWEL, SPOON, OR LADLE

1. Ensure that the sampling equipment is properly decontaminated prior to use.

2. Insert the sampling device into the material at the selected point and slowly remove the sample. Care should be taken to retain as much of the solid component as possible.

3. Transfer the sample into the appropriate sample bottles.

4. Ensure that each sample bottle is properly labeled, noted on the chain-of-custody form, and placed in the sample cooler with ice packs.

5. Decontaminate sampling equipment according to SOP No. 005.

6. Dispose of all sampling wastes in properly labeled containers.

3.4 SAMPLING LOCATION

For all samples, mark the sampling location on a site map. Photograph (optional, recommended) the sampling site. Describe each sampling location in the Field Logbook. Establish the sampling coordinates using a Global Positioning System or other 3-D System. Record the coordinates for each sample in the Field Logbook.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

The following precautions should be noted:

1. Sludges may contain high levels of contaminants.

2. It is extremely important to continually monitor the levels of contaminants, using the appropriate survey instruments (e.g., photoionization detector, indicator tubes) in the breathing zone of the sampler(s) and other field team members.

3. Refer to the Site Safety and Health Plan for appropriate personal protective equipment.

4. Field team members should consult with the Site Safety and Health Coordinator for all safety and health questions or concerns relating to sampling activities.

6. REFERENCES

U.S. Environmental Protection Agency. 1987. A Compendium of Superfund Field Operations Methods. EPA/54/P-87/001.

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Standard Operating Procedure No. 042
for
Disposal of
Investigation-Derived Material

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to define the required steps for disposing of investigation-derived material (IDM) generated during field activities.

IDM, as used herein, includes soil cuttings, drilling muds, extraneous sediment, purged groundwater, decontamination fluids, and disposable personal protective equipment. For the sake of clarity and ease in use, this Standard Operating Procedure is subdivided into procedures for disposal of liquid IDM and solid IDM as follows:

- Liquid IDM (Section 3.2) includes the following materials:
  - Water from initial development of new wells and the redevelopment of existing wells
  - Purge water from groundwater sampling
  - Decontamination fluids (Section 3.4)
- Solid IDM (Section 3.3) consists of the following materials:
  - Soil drill cuttings from monitoring well installation
  - Sediment remaining after collection of the required sample volume
  - Grout, a mixture of cement and bentonite, generated during installation of monitoring wells
  - Disposable personal protective equipment (Section 3.4).

2. MATERIALS

The following materials may be required:

Any additional equipment that may be dictated by project or site-specific plans	Hazardous waste labels
Bar codes	Permanent marker
Chain-of-custody forms	Field logbook (bound)
Department of Transportation 17C specification metal containers	Waste identification labels

3. PROCEDURE

3.1 GENERAL

No container will be labeled as a “Hazardous Waste” unless the contents are in fact known to be hazardous as defined by 40 Code of Federal Regulation 261.

IDM may be disposed onsite if it is: (1) initially screened, or evaluated to determine whether it is contaminated; (2) not abandoned in an environmentally unsound manner; and (3) not inherently waste-like.

IDM is to be considered contaminated if: (1) it is visually or grossly contaminated; (2) it has activated any field monitoring device that indicates that the level exceeds standard Level 1; (3) it has previously been found to exhibit levels of contamination above environmental quality standards; and (4) the responsible party and/or appropriate regulator deem(s) that records of historical uses indicate that additional testing of the IDM is needed, or additional caution is warranted handling IDM from a given site.

3.2 PROCEDURES FOR LIQUID INVESTIGATION-DERIVED MATERIAL DISPOSAL

Listed below are the procedures for the disposal of liquid IDM:

1. All water from the initial development of new wells, and purge water generated during the first round of groundwater sampling, will be containerized in Department of Transportation approved 55-gallon drums. Decontamination fluids may be bulk-containerized until completion of the field task.

2. Label all containers as to type of media, date the container was sealed, point-of-generation, and points-of-contact. The well number and container number will be identified on the container.

3. The contractor/support personnel will log all media generated onsite into a bound Field Logbook. Media information should include the following: date of generation, contents of containers, number of containers with the same contents (if applicable), location of containers, well number the media is associated with, personnel sampling the media, sampling dates, and sampling results.

4. Containers of well development water and purge water may be stored at the well site pending the first round analytical results.

5. Laboratory turnaround time must be no greater than 30 days. Upon receipt of the analytical results, a copy will be furnished to the client within 3 working days. Both the client and contractor will evaluate the data to determine disposal requirements, per state and local regulations. A disposal decision is required within 10 days of receipt of sampling results. Appropriate disposal must be performed no later than 50 days from the

1. This value is defined as two times background, where "background" values are to be determined as follows: (1) regional background values will be used where they are available; and (2) if regional values are not available, background may be empirically determined at uncontaminated sampling sites using onsite sensors such as organic vapor analyzers (photoionization detector or flame ionization detector), scintillometers, etc.

decision date unless prevented by inclement weather (e.g., rain and muddy conditions may preclude site access, freezing weather may freeze media).

Dispose of media in accordance with Steps 6 and 7 of this procedure, as appropriate.

6. If the first round analytical data of the liquid media are below the Maximum Contaminant Levels established by the Federal Safe Drinking Water Act, the water may be gradually infiltrated into the ground at least 50 feet downgradient of the well.

   If the well location has no downgradient area, the water will be infiltrated into the ground in an area deemed appropriate by the client and the contractor/support personnel.

   Disposal locations must allow percolation of the water and prohibit "ponding."

   Upon completion of water discharge to ground, enter type of media, amount of media, date of disposal, and discharge point(s) in a bound Field Logbook and provide this information to the client.

   Empty containers are to be properly decontaminated, stored, and reused by the appropriate personnel.

   If the liquid media sampling results do not meet the required Maximum Contaminant Levels and cannot be discharged to the ground, then determine if the waste meets the sanitary sewer discharge criteria (National Pollutant Discharge Elimination System standards).

7. If, at any time, visual contamination of purge/development water is observed, or if organic vapor monitor readings (HNu, photoionization detector) register more than 5 parts per million above background and/or radiological meters register more than twice the background mrems, then the liquid will be drummed and a composite sample will be taken that day. A disposal decision will be based on the analytical results of this sample rather than the first round of analytical results.

3.3 PROCEDURES FOR SOLID INVESTIGATION-DERIVED MATERIAL DISPOSAL

Listed below are the procedures for the disposal of solid IDM:

1. If the conditions outlined in Section 3.1 are met, proceed to Section 3.3, Step 2; otherwise, proceed to Section 3.3, Step 7.

2. During soil drilling operations or sediment sampling, the resulting cuttings, mud, and/or extraneous sediment will be discharged onto the ground (or waterbody for sediment) near the well (or sample location for sediment) if the following conditions are met: (1) no visual contamination is observed, (2) organic vapors are less than 5 parts per million

above background, (3) radiological meter readings (if applicable) are under two times background, and (4) the medium has been screened and found to be less than two times background if the potential for contamination exists.

Proper sediment and erosion control measures will be implemented as follows:

- Soil drill cuttings will be uniformly spread and contoured to blend with the surroundings of the site.
- If amount of solid IDM exceeds 5,000 square feet or 100 cubic yards of material, a sediment and erosion control plan is required.
- If the amount of solid IDM is under 5,000 square feet or 100 cubic yards, the site will be stabilized as soon as possible. Stabilization includes mulch, seed, and tack.
- Critical areas require stabilization within 7 days from the date of well completion. Critical areas include swales, water sources, drainage ditches, etc.
- All other disturbed areas require stabilization within 14 days from the date of well completion.

3. If the well location is in or near a wetland, the soil drill cuttings will be drummed and transported away from the site for spreading.

4. Label all IDM containers that will not be spread on the day of generation. Each container should be labeled with the type of media, date the container was sealed, point-of-generation, and name of the contact person. The well number or sample location and container number should be identified on the container.

5. The contractor/support personnel will log all media generated onsite into a bound Field Logbook. Media information should include: date of generation, contents in containers, number of containers with the same contents, location of containers, and well number or sample location the media is associated with.

6. Containers will be staged at the well site until contractor/support personnel spread the cuttings in the appropriate locations, using proper sediment and erosion control measures per Section 3.3.

7. If soil drilling mud, cuttings, or sediment show visible contamination, or organic vapor readings are more than 5 parts per million above background levels, or radiological meter readings (if applicable) show greater than two times background levels, or if the potential for contamination exists (levels greater than two times background), media will immediately be containerized, labeled appropriately (Section 3.2), and sampled on the same day.

8. The solid IDM should be sampled and appropriate Toxicity Characteristic Leaching Procedure analyses conducted prior to determining disposition. Laboratory turn-around time must be no greater than 30 days. Upon receipt of analytical results, a copy will be furnished to the client within 3 working days. The contractor will evaluate the data to determine disposal requirements within 10 days. Appropriate disposal must be performed no later than 50 days after the decision date if weather permits (Section 3.2).

    - If the solid IDM is determined to be non-hazardous and uncontaminated, proceed to Section 3.3.

    - If the solid IDM is determined to be non-hazardous but contaminated, proceed to Section 3.3.

    - If the solid IDM is found to be hazardous wastes, proceed to Section 3.3.

9. If the solid IDM is not a hazardous waste **and** analytical data show contaminant concentrations below the U.S. Environmental Protection Agency Region 3 (or applicable Region where work is being performed) Risk-Based Concentrations, contact the appropriate federal, state, or local agency for approval to discharge onto the ground or back to the waterbody near the site of generation.

    - Follow steps detailed in Section 3.3, Step 2 (above) pertaining to sediment and erosion control.

    - Upon completion of the solid IDM discharge to the ground or waterbody (for sediment), enter type of media, amount of media, date of disposal, and discharge point(s) in a bound Field Logbook. This information must be provided to the client.

    - Empty containers are to be properly decontaminated, stored, and reused by appropriate personnel.

10. If the intrusive media is not a hazardous waste but analytical data show concentrations above the screening criteria, dispose of the IDM according to state and local regulations.

    - Ensure that the waste containers are properly labeled as applicable in accordance with Section 3.3, Step 4.

    - Inform the client of the type and amount of waste, and location of the waste.

    - When the waste is removed, enter the type of waste, amount of waste, date of pickup, and destination of the waste in a bound Field Logbook. This information must be provided to the client.

3.4 PROCEDURES FOR DECONTAMINATION SOLUTION AND PERSONAL PROTECTIVE EQUIPMENT DISPOSAL

Decontamination solutions include catch water from steam-cleaning operations performed on large sampling equipment, drill rigs, and drums, as well as smaller quantities of soapy water and rinse solutions used in decontaminating field sampling equipment. At the completion of the field event, a composite sample of the decontamination solution will be taken. The decontamination solution will be treated as liquid IDM pending results (Section 3.2).

Personal protective equipment will be containerized onsite, appropriately labeled, and disposed in a designated trash receptacle.

4. MAINTENANCE

The waste manifest document and bill of lading should be uploaded to the project file as soon as possible in either hard copy or electronic format. Refer to EA's Records Retention Policy for archiving information.

5. REFERENCES

Environment Article Section 7-201(t).

U.S. Environmental Protection Agency. 1991. Management of Investigation-Derived Wastes during Site Inspections PB91-921331, OERR Directive 9345.3-02. Office of Emergency and Remedial Response U.S. Environmental Protection Agency, Washington, D.C. May.

Standard Operating Procedure No. 043 for Multi-Probe Water Quality Monitoring Instruments

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. PURPOSE AND SCOPE

The purpose of this Standard Operating Procedure is to delineate protocols for field operation of multi-probe water quality instruments. The instrument can monitor a variety of basic parameters including dissolved oxygen, percent saturation, temperature, pH, specific conductance, resistivity, salinity, total dissolved solids, oxidation reduction potential (ORP), level, and depth.

Use of brand names in this Standard Operating Procedure is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable standard operating procedures for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

- Multi-probe instrument
- Probe/sonde with appropriate cables
- Appropriate standards
- Accessories (batteries, charger, case, etc.)
- Instrument logbook
- Manufacturer's Operations Manual.

3. CALIBRATION PROCEDURE

Calibration must be performed daily at a minimum before using the instrument. Calibration may be performed in the laboratory or in the field. Detailed step-by-step calibration procedures for the equipment described below are provided in the most recent version of the manufacturer's Operations Manual. Documentation includes at a minimum: time, date, analyst, standard, primary standard lot number, secondary standard lot number, and expiration dates of standards.

Fill the calibration cup with the appropriate standard as follows:

- Temperature: None required
- Specific Conductance: Conductivity standards
- pH: pH 7 buffer plus pH 4 and/or pH 10 buffer
- Dissolved Oxygen: Saturated air or saturated water
- ORP: Quinhydrone (Zobell's Solution)
- Turbidity: Nephelometric turbidity unit (NTU) standards
- Salinity: Calibration for specific conductance
- Depth/Level: Set zero in air.

3.1 CONDUCTIVITY CALIBRATION

Conductivity meters are calibrated at least once per day to at least one standard. The standard should be selected in accordance with the range expected to be measured (e.g., 1.0 µS/cm standard should not be used to calibrate meters being used in saltwater). See manufacturer's recommendations in the Operations Manual for additional information on calibration standard selection. Calibration information is recorded in conjunction with the data collected for that sampling event.

3.2 pH CALIBRATION

The pH meters are calibrated at least once per day to a minimum of two standard buffers (pH 4 and 7, or pH 7 and 10) in accordance with the range expected to be measured. The calibration is verified using a fresh solution of pH 7 buffer post-calibration. Calibration information is recorded in conjunction with the data collected for that sampling event.

3.3 DISSOLVED OXYGEN CALIBRATION

Dissolved oxygen meters are air calibrated at least once per day. Calibration information is recorded in conjunction with the data collected for that sampling event.

3.4 OXIDATION REDUCTION POTENTIAL CALIBRATION

ORP meters are calibrated at least once per day to at least one standard. It is recommended that Zobell's Solution is used; however, another solution can be used as long as it meets the manufacturer's specifications for calibration. Calibration information is recorded in conjunction with the data collected for that sampling event.

3.5 TURBIDITY CALIBRATION

The turbidity meters are calibrated at least once per day to a minimum of two standards (0 NTU and 100 or 126 NTUs recommended) in accordance with the range expected to be measured. Calibration information is recorded in conjunction with the data collected for that sampling event.

3.6 DEPTH/LEVEL CALIBRATION

The depth and level calibration is performed with the depth sensor module in the air and not immersed in any solution. The appropriate correction for height above the water surface is inputted into the meter. Calibration information is recorded in conjunction with the data collected for that sampling event.

3.7 ADDITIONAL CALIBRATIONS

Additional measurements may be taken with the multi-probe water quality instruments. For any of these measurements, the calibration procedures will be conducted in accordance with the manufacturer's specifications. Calibration information is recorded in conjunction with the data collected for that sampling event.

4. FIELD OPERATION

4.1 SETUP OF MULTI-PROBE WATER QUALITY INSTRUMENT

Post-calibration and prior to sampling, the multi-probe water quality instrument will be set up for data collection. If the cables have been unattached, they will be reconnected to the transmitter (if applicable) and the display. Once all cables are attached, the meter will be turned on and allowed to warm up for a few seconds in order to allow the display screen to load.

4.2 SURFACE WATER

Prior to sampling, check the condition of the probes before each deployment. When sampling in surface water, the sensor must be in an amount of water sufficient for all probes to be submerged. Data values displayed on the display screen are recorded in the field logbook and accepted into the instrument's data logger. Post-data collection, the sensor will be retrieved and rinsed for use at the next sample location. If travel time between sample locations is great, the display is to be turned off. When all sampling is completed, disconnect all equipment and return it to its proper storage location.

4.3 GROUNDWATER

Prior to sampling, check the condition of the probes before each deployment. When sampling groundwater, mount sampler on a flow-through sampler cup. Start sampler pump and allow pump/hose system to be purged of air bubbles. Sampling rate should be set to record all parameters each time 1-3 liters (unless otherwise specified in the sampling plan) have been removed from the well. Record all the monitored values in the appropriate field logbook to ensure against inadvertent data loss.

5. MAINTENANCE

All maintenance should be performed in accordance with the manufacturer's Operations Manual.

6. PRECAUTIONS

Check the condition of the probes frequently between sampling. Do not force pins into connections, note keying sequence. If field readings are outside the expected range, check for bubbles on, or damage to, the probes. If there are no bubbles or damage, recalibrate the sensor.

7. REFERENCES

Manufacturer's Operations Manual.

Standard Operating Procedure No. 047
Direct-Push Technology Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) establishes the protocol for using direct-push technology (DPT) in media sampling and performing subsurface characterization. This SOP includes the following DPT methods: Geoprobe®, Hydropunch®, Cone Penetrometer Testing (CPT), and Site Characterization and Analysis Penetrometer System (SCAPS).

2. MATERIALS

The following materials may be required:

Appropriately sized, all-terrain vehicle-skid-or track-mounted; DPT equipment; and supplies (i.e., hydraulic derrick and hammer assembly)	Personal protective equipment
Bentonite grout and clean sand for DPT hole abandonment	Phosphate-free, laboratory-grade detergent (e.g., Liquinox, Alconox, etc.)
DPT stainless steel rods	Source of approved water
Heavy plastic sheeting	Steam cleaner/sprayer and water obtained from approved source for decontaminating DPT equipment
Logbook	Steel drums for intrusion derived wastes (e.g., contaminated personal protective equipment, decon solutions, etc.)
Long-handled bristle brushes	Wash and rinse tubs
Mini-bailer or tubing and peristaltic pump (groundwater sampling only)	

3. GEOPROBE® AND HYDROPUNCH®

3.1 MATERIALS

Water sources for Geoprobe® and Hydropunch® activities, grouting, sealing, filter placement, well installation, and equipment decontamination must be approved by the Project Manager prior to arrival of the Geoprobe® and Hydropunch® equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analysis over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives will be the only additive allowed, and its use must be approved by the Project Manager prior to the arrival of the Geoprobe® and Hydropunch® equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product number, product description, and intended use for the product.

Portland Type II cement will be used for grout (refer to SOP No. 019).

3.2 GROUNDWATER – HYDRAULIC PUSHING AND SAMPLING

The objective of the selected DPT sampling technique is to allow grab samples to be taken at a selected site to facilitate aquifer characterization and analysis of potential contaminants. The analytical results from sampling can also be used to determine the placement of monitoring wells.

A site geologist will be present during all sampling and installation procedures, and will fully document all procedures and soil characteristics in the Field Logbook (refer to SOP No. 016).

The site geologist will have on hand, at a minimum, a copy of the approved Health and Safety Plan, this SOP, the Field Investigation Work Plan, a hand lens (10X), a standard color chart, and a grain size chart.

Only solid vegetable shortening (e.g., Crisco®) without flavoring or additives may be used on downhole Geoprobe® and Hydropunch® equipment.

Surface runoff or other fluids will not be allowed to enter any DPT location or well during or after DPT activities.

The subcontractor will use the equipment specific guidelines for installation of the Geoprobe® DPT equipment. Probe rods will be forced into the ground by hydraulic means.

- Drive the sampler to the desired groundwater sampling interval. At the desired depth, insert extension rods down the inside diameter of the probe rods until the extension reaches the bottom of the screen. Remove the probe rods and sampler sheath while holding the screen in place.

- Collect the groundwater sample in the screen interval with a mini-bailer, peristaltic or vacuum pump, or other acceptable small diameter sampling device.

- The head of the rod may be equipped with a sensing device for characterization of soil properties or the contaminant content.

The subcontractor will use the equipment-specific guidelines for installation of the Hydropunch® equipment. Rods will be forced into the ground by hydraulic means.

- The Hydropunch® tool is a double cylinder, designed to be sealed until the desired sampling depth is reached. Upon reaching the desired sampling depth, the outer cylinder is pulled back, exposing a perforated, stainless steel sampling barrel covered with filter material.

- The water sample enters the barrel and the sample is retrieved by pulling the probe rods from the hole with the hydraulic derrick and hammer assembly. Groundwater is the only media that is sampled by Hydropunch® equipment.

- The head of the rod may be equipped with a sensing device for characterization of the soil properties or the contaminant content.

- The sample volume collected with this technique is approximately 500-1,000 ml. Larger sample volumes can be collected by inserting tubing attached to a peristaltic pump into the rods to obtain water samples.

If desired, a small diameter monitoring well may be installed at this point. Refer to SOP No. 019 (Monitoring Well Installation).

If a well will not be installed, the rods will be removed as the borehole is simultaneously filled with a bentonite/grout mixture. A polyvinyl chloride (PVC) tube fed into the rod casing will allow the addition of grout.

3.3 SUBSURFACE SOIL – HYDRAULIC PUSHING AND SAMPLING

The objective of the selected DPT sampling technique is to allow grab samples to be taken at a selected site for characterization of the stratigraphy and for analysis of potential contaminants. The analytical results from sampling can also be used to determine the placement of monitoring wells.

A site geologist will be present during all DPT sampling and soil characterization. All procedures and soil characteristics will be fully documented in the Field Logbook (refer to SOP No. 016).

The site geologist will have on hand, at a minimum, a copy of the approved Health and Safety Plan, this SOP, the Field Investigation Plan, a hand lens (10X), a standard color chart, and a grain-size chart.

Only solid vegetable shortening (e.g., Crisco®) without flavoring or additives may be used on downhole Geoprobe® equipment.

Surface runoff or other fluids will not be allowed to enter any DPT location or well during or after DPT activities.

The subcontractor will use the equipment specific guidelines for installation of the Geoprobe® DPT equipment. Probe rods will be forced into the ground by hydraulic means. Additional rods will be added in 3- to 4-ft increments until the leading edge of the sampler reaches the top of the desired sampling interval.

Once the desired sampling depth has been reached, insert extension rods down the inside diameter of the probe rods until it reaches the top of the sampler assembly. Attach the extension rod handle to the top extension rod. Turn the handle clockwise until the stop-pin detaches from the drive head. Remove the extension rods and the stop-pin. Attach a drive cap to the probe and drive the sampler approximately 2 ft using hydraulic derrick.

The DPT sampler can be retrieved by pulling the probe rods from the hole with the hydraulic derrick and hammer assembly.

The liner will be capped with Teflon® tape and vinyl end caps. The liners can be split open to remove samples for composition analysis or for transfer to other containers for shipment to the laboratory for analysis.

The head of the rod may be equipped with a sensing device for characterization of the soil properties or the contaminant content.

3.4 DECONTAMINATION

All Geoprobe® and Hydropunch® DPT equipment must be thoroughly cleaned before and after each use to allow retrieval of representative groundwater samples. Geoprobe® soil sample liners are disposed of after each use. Scrub all metal parts with a stiff, long bristle brush and a non-phosphate soap solution. Steam cleaning may be substituted where available. Rinse with distilled water and allow to air-dry before assembly.

After decontamination, a new clean liner will be installed and all parts will be inspected for wear or damage.

Refer to SOP No. 005 (Field Decontamination).

3.5 ABANDONMENT

Pure bentonite or a bentonite/grout mixture (20:1) will be used to fill the resulting borehole if the water table is penetrated. Boreholes that do not penetrate the water table will be backfilled with cuttings from the hole and topped with a bentonite seal. Clean sand will be used to fill any remaining volume in the borehole.

Abandonment of Geoprobe® and Hydropunch® generated DPT boreholes will meet the standards established under SOP No. 028 (Well and Boring Abandonment).

4. CONE PENETROMETER TESTING

4.1 MATERIALS

A CPT rig typically consists of an enclosed 20- to 40-ton truck equipped with vertical hydraulic rams that are used to force a sensor probe into the ground. The weight of the CPT rig is dependent upon the thrust required at the site. The majority of CPT rigs are mounted in heavy-duty trucks that are ballasted to a total dead weight of approximately 15 tons. Screw anchors are utilized to develop the extra reaction to reach the maximum thrust of 20 tons. The rig is separated into two separate workspaces: data acquisition and hydraulic push areas.

Water sources for CPT activities and decontamination must be approved by the Project Manager prior to arrival of the CPT equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analysis over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives will be the only additive allowed, and its use must be approved by the Project Manager prior to the arrival of the DPT equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product number, product description, and intended use for the product.

Portland Type II cement will be used for grout (refer to SOP No. 019).

4.2 SUBSURFACE CHARACTERIZATION

The objective of this technology is to collect stratigraphic information using CPT equipment to determine subsurface stratigraphy and geotechnical properties at a particular site. CPT activities will be in accordance with American Society for Testing and Materials D 3441-86 and American Society for Testing and Materials D 5778-95. The stratigraphic information gathered can be used to facilitate the selection of DPT sampling screen intervals. At the same time, it is possible to install a 0.25-in. diameter pre-packed PVC monitoring well.

CPT rods are used to hydraulically push the CPT probe into the subsurface. Probes cannot be pushed into hard rock, and significant gravel or cobble content in the formation may impede or preclude penetration of the probe. The depth of penetration achievable depends on the type of formation, type of sampling probe, and size of the hydraulic equipment used.

The CPT probe includes the following components:

- A conical tip to measure vertical resistance beneath the tip.
- A friction sleeve to measure frictional resistance on the side of the probe, as a function of depth.

- Two internal strain gauge-type load cells, which independently measure the vertical resistance and side friction.

- A cone pressure gauge to measure the water pressure as the probe is pushed into the ground.

- Inclinometer to determine potential drifting of the probe (optional).

- Seismic transducers to perform downhole seismic surveys (optional). Therefore, stratigraphic data collected with the CPT include: tip resistance, local friction, friction ratio, pore pressure, and resistivity.

Data will be transferred from the probe to the data acquisition system or logger through an electrical cable. The hole will be advanced continuously at a rate of 0.6-1.0 in. per second. The data will be logged at every 0.4-0.8 in. of penetration. Monitor the probe's stratigraphic position will be monitored as it advances downward. Perform pore water pressure dissipation tests in representative hydrostratigraphic intervals. Record dissipated pore water pressures to represent hydraulic head values.

Once the confining unit underlying the surficial aquifer or the required depth has been reached, the CPT is pulled from the ground. Target interval samples can be collected during CPT hole advancement using direct push sampling techniques, i.e., Geoprobe® or Hydropunch® (Section 3).

4.3 DECONTAMINATION

All CPT equipment must be thoroughly cleaned before arrival at the work site, between test holes, and prior to being moved out of a work area. Scrub all metal parts with a stiff, long bristle brush and a non-phosphate soap solution. Steam cleaning may be substituted where available. Rinse with distilled water and allow to air-dry before assembly.

Refer to SOP No. 005 (Decontamination).

4 .4 ABANDONMENT

If the push hole was developed for the stratigraphic test only, once the testing is completed, grout the hole from bottom to top. If the hole has not collapsed after removing the CPT, PVC piping will be used to grout the hole. If the hole has collapsed after removing the CPT, then hollow CPT rods and a sacrificial tip will be used to grout the hole. The PVC pipe or CPT rods will be pushed to the bottom of the hole. Grout will then be pumped to the bottom of the hole as the PVC pipe or CPT rods are withdrawn.

Refer to SOP No. 028 (Well and Boring Abandonment).

5. SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM

5.1 MATERIALS

SCAPS cone penetrometer and laser induced fluorescence (LIF) technology requires the use of a specialized 20-ton truck. The truck has two separate enclosed compartments. Each compartment is temperature controlled and monitored for air quality. The two rooms are the data acquisition and processing room, and the hydraulic ram/rod handling room. Approximately 20 ft of overhead clearance is required to fully extend the hydraulic ram and allow for leveling jack movement.

All materials required to complete SCAPS analysis are provided by the subcontractor to include cone penetrometer equipment. All hydraulic equipment, SCAPS rods, nitrogen lasers, etc. are included within the vehicle. A decontamination water source and a source of water for mixing the grout are required.

Water sources for equipment decontamination must be approved by the Project Manager prior to arrival of the SCAPS equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analysis over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives will be the only additive allowed, and its use must be approved by the Project Manager prior to the arrival of the SCAPS equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product number, product description, and intended use for the product.

Portland Type II cement will be used for grout (refer to SOP No. 019).

5.2 HYDRAULIC PUSHING AND SAMPLING

The objective of the SCAPS technique is to allow grab samples and stratigraphic information to be collected at a selected site to facilitate subsurface characterization and for analysis of potential contaminants. The analytical results obtained can also be used to determine the placement of monitoring wells. At the same time, it is possible to install a small diameter well for sampling purposes. Refer to SOP No. 019 (Monitoring Well Installation). If a well will not be installed, the borehole can be grouted as the equipment is removed.

A site geologist will be present during all installation and sampling procedures and will fully document all procedures and soil characteristics in the Field Logbook (refer to SOP No. 016).

The site geologist will have on hand, at a minimum, a copy of the approved Health and Safety Plan, this SOP, the Field Investigation Work Plan, a hand lens (10X), a standard color chart, and a grain-size chart.

Only solid vegetable shortening (e.g., Crisco®) without flavoring or additives may be used on downhole SCAPS equipment.

Surface runoff or other fluids will not be allowed to enter any DPT location or well during or after direct-push activities.

The subcontractor will use the equipment specific guidelines for installation of the SCAPS DPT equipment. Prior to SCAPS field activities, calibration soil samples will be collected and analyzed in order to determine the LIF sensor fluorescence threshold and detection limits for the site.

SCAPS LIF technology uses a pulsed nitrogen laser coupled with an optical detector to make fluorescence measurements via optical fibers. The LIF sensor is mounted on a cone penetrometer probe so that soil classification data and fluorescence data are collected simultaneously. The laser consumes nitrogen gas, which is supplied from cylinders stored on the accompanying trailer.

The SCAPS CPT sensors are used to gather stratigraphic information. See Section 4 for CPT operating procedures.

Target interval samples can be collected during SCAPS hole advancement using direct push sampling techniques such as Geoprobe® or Hydropunch® (Section 3).

5.3 DECONTAMINATION

Decontamination of SCAPS equipment is automated after initialization by a field team member. A pressurized hot water system is used to decontaminate the push rods as they are retracted from the ground. The SCAPS vehicle is equipped with a decontamination collar mounted to the bottom that cleans the rods. The decontamination water is removed by vacuum and transferred to a storage drum prior to disposal or treatment. A trailer attached to the back of the vehicle contains the water pump, heater for decontamination, and decontamination water containment drum.

Worker exposure is reduced by minimizing contact with contaminated media.

Refer to SOP No. 005 (Decontamination).

5.4 ABANDONMENT

SCAPS automatically grouts the penetrometer cavity as the rods are removed. The grout is pumped at high pressure through a 0.25-in. diameter tube in the center of the penetrometer rods. The tip is sacrificed at the bottom of the cavity to allow release of the grout.

A trailer attached to the back of the vehicle contains the 300-gal grout mixing bin and pump.

If the automatic grout feed does not work, the cavity will be manually filled with grout.

Abandonment of SCAPS generated borehole will meet the standards established under SOP No. 028 (Well and Boring Abandonment).

6. MAINTENANCE

Not applicable.

7. PRECAUTIONS

Refer to the site-specific Health and Safety Plan for discussion of hazards and preventive measures during intrusive activities.

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Standard Operating Procedure No. 048
for
Low-Flow Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. GROUNDWATER SAMPLING BY LOW-FLOW PURGE AND SAMPLING METHOD USING DEDICATED PUMPS

1.1 SCOPE OF APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to establish the protocol for collecting groundwater samples using dedicated pump systems. The procedure is designed to permit the collection of groundwater samples with minimum turbidity.

1.2 EQUIPMENT/MATERIALS

- Work Plan.
- Well construction data, location map, and field data from last sampling event.
- Field logbook and Field Record of Well Gauging, Purging, and Sampling forms (Figure SOP048-1).
- Electric water level measuring device, 0.01 ft accuracy for monitoring water level during pumping operations.
- Pumps: adjustable rate, submersible pumps constructed of stainless steel and Teflon®.
- Tubing: Teflon or Teflon-lined polyethylene must be used to collect samples for organic analysis. For samples collected for inorganics analysis, Teflon or Teflon-lined polyethylene tubing will be used.
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Power source (generator, etc.).
- Water quality indicator parameter monitoring instruments—pH, turbidity, specific conductance, and temperature. Optional indicators—Eh and dissolved oxygen.
- Flow-through cell (preferred) or clean container for water quality probes.
- Decontamination supplies (for monitoring instrumentation).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.
- Drum for purge water containment.

1.3 PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing well purging and groundwater sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, well identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.

- Check well for damage or evidence of tampering, record pertinent observations in field logbook and sampling form.

- Lay out sheet of polyethylene for monitoring and sampling equipment.

- Unlock well and remove well cap (if applicable).

- Measure VOCs with an ionization detector (flame or photo) instrument at the rim of the well and in the breathing zone, and record the readings in the field logbook and the sampling form.

- Measure and record the height of protective casing above the concrete pad or ground surface, as appropriate. This reading is compared to that recorded during well installation as an indication of possible well damage or settling that may have occurred.

- Dedicated sampling pumps should be positioned with the pump intake mid-point in the screened interval. If non-dedicated equipment is used, care will be taken to position pump or sampling hose intake at the screen mid-point.

- Measure and record the depth to water (to 0.01 ft) in the well to be sampled before purging begins. If the well casing does not have a reference point (usually a v-cut or indelible mark in the well casing), make one. If a reference point is made, it will be noted in the field logbook. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well. The depth to well bottom will be measured following the completion of sampling because of the potential to stir up sediment at the bottom of the well.

- Prepare the pump by checking electrical connections, discharge tubing, and motor (Grundfos Redi-Flo2). Locate the generator (if applicable) downwind of the well; connect the power converter to the generator and to the pump.

1.4 WELL PURGING AND SAMPLING PROCEDURE

The following general procedure should be followed to obtain representative groundwater samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to purging: purge date and time, purge method, and total well depth.

- Connect the flow-through cell or clean container containing the instrumentation header to the pump discharge and begin purging the well at 0.2-0.5 L/min, unless a different purge rate has been previously established for that well. Fill the flow cell completely. Care should be taken not to cause entrapment of air in the system. Record the purge start time and purge rate.

- Establish that the water level has not dropped significantly such that the pump is dry (bubbles in discharge) or water is heard cascading down the inside of the well. Ideally, the pump rate should cause little or no water level drawdown in the well (>0.5 ft and the water level should stabilize). The water level should be monitored every 3-5 minutes (or as appropriate) during pumping. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 L/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If water levels continue to drop with the pump on the lowest flow rate, the pump will be shut off and the well will be allowed to recharge to prevent the well from going dry. **The well will not be purged to dryness prior to sampling to prevent erroneous field parameters and groundwater samples.** Sampling will commence as soon as the well has recharged to a sufficient level to collect the appropriate volume of samples with the pump.

- During purging of the well, monitor the water quality indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every 3-5 minutes (or as appropriate). Record purge rate, volume purged, depth to water, water quality indicator parameters values, and clock time at 3- to 5-minute intervals in field logbook and sampling record. Purging of the standing well water is considered complete when three consecutive readings of the water quality indicator parameters agree within approximately 10 percent. Turbidity readings consistently below 10 nephelometric turbidity units (NTU) are considered to represent stabilization of discharge water for this parameter. If the parameters have stabilized, but the turbidity is not in the range of the 10 NTU goal, the pump flow rate should be decreased and measurement of the parameters should continue every 3-5 minutes.

- Purge water at a well will be containerized if a well has exceeded the MEG or MCL in previous sampling events. Any purge water that is collected will be treated at the groundwater treatment plant.

- Prior to sampling, disconnect the discharge tubing from the flow-through cell. If the water discharged by the pump is silty, wait for the water to clear before sampling. Ensure that bubbles are not observed in the discharge tubing. Record pertinent observations in field logbook and sampling records.

- Begin filling sample containers by allowing the pump discharge to flow gently down the inside of the container with as little agitation or aeration as possible. Collect the samples in the order below, as applicable:

  — VOCs
  — Inorganics.

- VOC samples requiring pH adjustment will have their pH checked to assure that the proper pH has been obtained. This will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling. Details on sample preservation are discussed in Section 1.5.

- Label each sample as collected. Those samples (VOCs, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Inorganic samples, after preservation, do not need to be cooled.

- After collection of the samples, restore the dedicated pumping assembly to the well by hanging the tube, electric line, and support cable inside the well by the specially-designed PVC well cap assembly. Lock well.

- Complete remaining portions of Field Record of Well Gauging, Purging, and Sampling form (Figure SOP048-1) after each well is sampled, including sample date and time, total quantity of water removed, well sampling sequence, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

1.5 SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Pre-preserved bottles will be used if possible. Minimum sample preservation requirements for each parameter group are summarized below:

- **VOCs—**Aqueous VOC samples must be collected as specified below. Each VOC sample is taken in duplicate:

  — Uncap the sample bottle, taking care not to touch the Teflon-faced septum. If the septum is contaminated in any way, it should be replaced.

  — Fill a sample bottle, preserve with HC1, and check the pH. Adjust the volume of HC1 to assure pH<2.

— Add the amount of HC1 determined in the above step, and fill the sample vial slowly from the tubing, minimizing air entrainment, until the vial slightly overflows.

— Place the Teflon-faced silicon rubber septum on the convex meniscus, Teflon side (shiny side) down and screw cap on.

— Invert the bottle, tap lightly, and check for air bubbles.

— If air bubbles are present, open the bottle, add sample to eliminate air bubbles, and reseal. Repeat this procedure until the bottle is filled and no air bubbles are detected.

— Place samples on ice until shipment.

- **Inorganics—**Fill the sample bottle, preserve the sample to pH<2 with nitric acid (HNO_3), seal container, and place sample on ice for shipment.

Disposable pipettes should be used to introduce chemicals into the samples if necessary. Chemicals used for preserving should be poured into a 150-ml beaker. They should not be drawn directly from the preservative bottles because the bottle may become contaminated. Measurements for pH and temperature should not be taken from the sample containers. When preserving samples to a required pH, pH paper should be used to check the resultant pH. The sample should be poured across the pH paper. Never place pH paper directly into sample.

NOTE: Shipping regulations limit the amount of preservative which can be added. For a 1-L sample, this is generally 1.5 ml of acid preservative.

1.6 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the groundwater samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each sample delivery group (SDG) (an SDG may not exceed 20 samples) at the frequency noted:

- Field Duplicate—Required at a frequency of 10 percent per SDG.

- Matrix Spike/Matrix Spike Duplicate—Required at a frequency of 5 percent.

- Equipment Rinsate Blank—Required once prior to installation of dedicated pump systems.

- Source Water Blank—Required at a frequency of once per source per sampling event when equipment (rinsate) blank is required.

- Trip Blank—Required for VOC samples at a frequency of one per sample shipment.

1.7 DECONTAMINATION

Non-dedicated sampling equipment and field monitoring equipment will be decontaminated prior to use and following sampling of each well. This equipment will be decontaminated by the procedure listed below. Alternative procedures must be approved by the Project Manager prior to sampling event. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

2. GROUNDWATER SAMPLING BY LOW-FLOW PURGE AND SAMPLING METHOD USING PERISTALTIC PUMPS

2.1 SCOPE OF APPLICATION

The purpose of this SOP is to establish the protocol for collecting groundwater samples using peristaltic pump systems. The procedure is designed to permit the collection of groundwater samples with minimum turbidity, and is intended to be used in conjunction with the analyses for the most common types of groundwater contaminants (VOCs and inorganic compounds).

2.2 EQUIPMENT/MATERIALS

- Work Plan.
- Well construction data, location map, field data from last sampling event.
- Field logbook and Field Record of Well Gauging, Purging, and Sampling forms (Figure SOP048-1).
- Water level measuring device, 0.01 ft accuracy (electronic preferred) for monitoring water level drawdown during pumping operations.
- Peristaltic pump.

- In-well tubing: Teflon or Teflon-lined polyethylene must be used to collect samples for organic analysis. For samples collected for inorganics analysis, Teflon or Teflon-lined polyethylene, PVC, Tygon, or polyethylene tubing may be used.
- Pump head tubing: Silicon tubing must be used to in the pump head assembly.
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Power source (battery, etc.).
- Water quality indicator parameter monitoring instruments – pH, turbidity, specific conductance, and temperature. Optional indicators – Eh and dissolved oxygen.
- Flow-through cell (preferred) or clean container for water quality probe.
- Decontamination supplies (for monitoring instrumentation).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.
- Drum for purge water containment.

2.3 PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing well purging and groundwater sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, well identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.
- Check well for damage or evidence of tampering, record pertinent observations in field logbook and sampling form.
- Unlock well and remove well cap (if applicable).
- Measure VOCs with an ionization detector (photo or flame) instrument at the rim of the well and in the breathing zone and record the readings in the field logbook and the sampling form.

- Measure and record the height of protective casing above the concrete pad, or ground surface, as appropriate. This reading is compared to that recorded during well installation as an indication of possible well damage or settling that may have occurred.

- Measure and record the depth to water (to 0.01 ft) in the well to be sampled before purging begins. If the well casing does not have a reference point (usually a v-cut or indelible mark in the well casing), make one. If a reference point is made, it will be noted in the field logbook. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well. The depth to well bottom will not be measured following the completion of sampling because of the potential to stir up sediment at the bottom of the well.

- Position the intake of the sampling hose at the mid-point of the screened interval.

- Prepare the pump by checking electrical connections and discharge tubing. Locate the battery downwind of the well; connect the peristaltic pump to the battery.

2.4 WELL PURGING AND SAMPLING PROCEDURES

The following general procedure should be followed to obtain representative groundwater samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to purging: purge date and time, purge method, and total well depth.

- Measure the water level with the pump in well before starting the pump. Begin purging the well at 0.3-0.5 L/min, unless a different purge rate has been previously established for that well.

- If well diameter permits, establish that the water level has not dropped significantly such that the pump is dry (air in discharge) or tubing suction is broken. Ideally, the pump rate should cause little or no water level drawdown in the well (>0.5 ft and the water level should stabilize). The water level should be monitored every 3-5 minutes (or as appropriate) during pumping. Care should be taken not to cause pump suction to be broken, or entrainment of air in the pump system. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.3 L/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If water levels continue to drop with the pump on the lowest flow rate, the pump will be shut off and the well will be allowed to recharge to prevent the well from going dry. **The well will not be purged to dryness prior to sampling to prevent erroneous field parameters and groundwater samples.** Sampling will commence as soon as the well has recharged to a sufficient level to collected the appropriate volume of samples with the pump.

- During purging of the well, monitor the field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every 3-5 minutes (or as appropriate). Purging of the standing well water is considered complete when three consecutive readings of the water quality indicator parameters agree within approximately 10 percent. Turbidity readings consistently below 10 NTU are considered to represent stabilization of discharge water for this parameter. If the parameters have stabilized, but the turbidity is not in the range of the 10 NTU goal, the pump flow rate should be decreased and measurement of the parameters should continue every 3-5 minutes.

- Purge water at a well will be containerized if a well has exceeded the MEG or MCL in previous sampling events. Any purge water that is collected will be treated at the groundwater treatment plant.

- Prior to sampling, disconnect the sample discharge tubing from the flow-through cell. If the water discharged by the pump is silty, wait for the water to clear before sampling. Ensure that bubbles are not observed in the discharge tubing.

- Collect groundwater samples directly from the silicon tubing into preserved (when appropriate) sample containers. Begin filling sample containers from the pump discharge, allowing the water to fill the containers by allowing the pump discharge to flow gently down the inside of the container with as little agitation or aeration as possible. Collect the samples in the order below, as applicable:

  — VOCs
  — Inorganics.

- VOC samples requiring pH adjustment will have their pH checked to assure that the proper pH has been obtained. This will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling. Detail on sample preservation are discussed in Section 2.5.

- Label each sample as collected. Those samples (VOCs, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Inorganic samples, after preservation, do not need to be cooled.

- After collection of the samples, restore the dedicated tubing assembly to the well by hanging the tube inside the well by the specially-designed PVC well cap assembly. Lock well.

- Complete remaining portions of Field Record of Well Gauging, Purging, and Sampling form (Figure SOP048-1) after each well is sampled, including: sample date and time, total quantity of water removed, well sampling sequence, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

- The silicon tubing used in the peristaltic pump will be changed after use at each well.

2.5 SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Pre-preserved bottles will be used if possible. Minimum sample preservation requirements for each parameter group are summarized below:

- **VOCs—**Aqueous VOC samples must be collected as specified below. Each VOC sample is taken in duplicate:

  — Uncap the sample bottle, taking care not to touch the Teflon-faced septum. If the septum is contaminated in any way, it should be replaced.

  — Fill a sample bottle, preserve with HCL, and check the pH. Adjust the volume of HCL to assure pH<2.

  — Add the amount of HCL determined in the above step, and fill the sample vial slowly from the tubing, minimizing air entrainment, until the vial slightly overflows.

  — Place the Teflon-faced silicon rubber septum on the convex meniscus, Teflon side (shiny side) down, and screw cap on.

  — Invert the bottle, tap lightly, and check for air bubbles.

  — If air bubbles are present, open the bottle, add sample to eliminate air bubbles, and reseal. Repeat this procedure until the bottle is filled and no air bubbles are detected.

  — Place samples on ice until shipment.

- **Inorganics—**Fill the sample bottle, preserve the sample to pH<2 with nitric acid (HNO_3), seal container, and place sample on ice for shipment.

Disposable pipettes should be used to introduce chemicals into the samples if necessary. Chemicals used for preserving should be poured into a 150-ml beaker. They should not be drawn directly from the preservative bottles because the bottle may become contaminated. Measurements for pH and temperature should not be taken from the sample containers. When preserving samples to a required pH, pH paper should be used to check the resultant pH. The sample should be poured across the pH paper. Never place pH paper directly into sample.

NOTE: Shipping regulations limit the amount of preservative which can be added. For a 1-L sample, this is generally 1.5 ml of acid preservative.

2.6 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the groundwater samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each SDG (an SDG may not exceed 20 samples) at the frequency noted:

- Field Duplicate—Required at a frequency of 10 percent per SDG
- Matrix Spike/Matrix Spike Duplicate—Required at a frequency of 5 percent
- Equipment (Rinsate) Blank—Required once prior to installation of dedicated sample tubing
- Source Water Blank—Required at a frequency of one per source per sampling event
- Trip Blank—Required for VOC samples at a frequency of one per sample shipment.
- Temperature Blank—Required at a frequency of once per sample shipment container.

2.7 DECONTAMINATION

Non-dedicated sampling and field monitoring equipment will be decontaminated prior to use and following sampling of each well. This equipment will be decontaminated by the procedure listed below. Alternate procedures must be approved by the Project Manager prior to the sampling event. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

3. SURFACE WATER AND LEACHATE SEEP SAMPLING PROCEDURE

3.1 SCOPE OF APPLICATION

The purpose of this SOP is to establish the protocol for collecting surface water and leachate seep samples. The procedure is designed to permit the collection of representative surface water and leachate seep samples, and has been adapted from the procedure outlined in the Work Plan. This SOP is suitable for collecting surface water and seep samples requiring analyses for the most common types of surface water contaminants (VOCs and inorganic compounds).

3.2 EQUIPMENT/MATERIALS

- Work Plan.
- Location map, field data from last sampling event.
- Field logbook and Field Record of Surface Water and Sediment Sampling forms (Figure SOP048-2).
- Water quality indicator parameter monitoring instruments – pH, turbidity, specific conductance, and temperature. Optional indicators – Eh and dissolved oxygen.
- Decontamination supplies (for monitoring instrumentation).
- Dedicated, pre-cleaned 1-L wide-mouth or volatile organic analyte sample container (for sample collection).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.

3.3 PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing surface water or leachate seep sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, sample station identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.

- Visually inspect sample station for evidence of changes in physical condition; record pertinent observations in field logbook and sampling form.

- Measure VOCs with a flame ionization detector instrument in the breathing zone and record the reading in the field logbook and sampling form.

3.4 SAMPLING PROCEDURE

The technique for surface water and leachate seep sampling must be selected after addressing such items as:

- Depth of waterbody
- Depth of sample
- Stratification
- Seasonal variations
- Analytical parameters of interest.

The following general procedure should be used to obtain representative surface water and leachate seep samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to sampling: date and time, sample method, and sample depth.

- Collect the sample from the surface water, within several tenths of a foot of the streambed, by immersing a new, dedicated 1-L glass or volatile organic analyte sample container into the waterbody. If a stream is being sampled, collect the sample upstream of the sampler with the opening of the sampling device oriented upstream but avoiding floating debris.

- Directly fill the appropriate sample containers from the 1-L or volatile organic analyte sampling device.

- Collect the samples in the order below, as applicable:

  — VOCs
  — Inorganics.

- Water sample containers are generally filled directly from the source or sampler without special considerations. The exception is the collection of aqueous VOC samples requiring pH adjustment. VOC samples will have their pH checked to assure that the proper pH has been obtained. This will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling. Details on sample preservation methods are discussed in Section 3.6.

- Label each sample as collected. Those samples (VOCs, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Inorganic samples, after preservation, do not need to be cooled.

- Measure water quality indicator parameters, if possible, by direct immersion of instrument probes into the waterbody immediately following sample collection. If direct measurement is not possible, measure these parameters from water remaining in the sampling device or another sample bottle. Record this information in the field logbook and sample data record.

- Complete remaining portions of the Field Record of Surface Water and Sediment Sampling form (Figure SOP048-2) after each station is sampled, including: time of sample collection, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

3.5 SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Minimum sample preservation requirements for each parameter group are summarized below:

- **VOCs—**Aqueous VOC samples must be collected as specified below. Each sample is taken in duplicate:

  — Uncap the sample bottle, taking care not to touch the Teflon-faced septum. If the septum is contaminated in any way, it should be replaced.

  — Fill a sample bottle, preserve with HC1, and check the pH. Adjust the volume of HC1 to assure pH<2.

  — Add the amount of HC1 determined in the above step, and fill the sample vial slowly from the 1-L container, minimizing air entrainment, until the vial slightly overflows.

  — Place the Teflon-faced silicon rubber septum on the convex meniscus, Teflon side (shiny side) down and screw cap on.

  — Invert the bottle, tap lightly, and check for air bubbles.

  — If air bubbles are present, open the bottle, add sample to eliminate air bubbles, and reseal. Repeat this procedure until the bottle is filled and no air bubbles are detected.

  — Place samples on ice until shipment.

- **Inorganics—**Fill the sample bottle, preserve the sample to pH<2 with nitric acid (HNO_3), seal container, and place sample on ice for shipment.

Disposable pipettes should be used to introduce chemicals into the samples. Chemicals used for preserving should be poured into a 150-ml beaker. They should not be drawn directly from the preservative bottles because the bottle may become contaminated. Measurements for pH and temperature should not be taken from the sample containers. When preserving samples to a required pH, pH paper should be used to check the resultant pH. The sample should be poured across the pH paper. Never place pH paper directly into sample.

NOTE: Shipping regulations limit the amount of preservative which can be added. For a 1-L sample, this is generally 1.5 ml of acid preservative.

3.6 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the surface water and leachate seep samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each SDG (an SDG may not exceed 20 samples) at the frequency noted:

- Field Duplicate—Required at a frequency of 10 percent per SDG.
- Matrix Spike/Matrix Spike Duplicate—Required at a frequency of 5 percent.
- Equipment (Rinsate) Blank—Required at a frequency of once per day per media sampled.
- Source Water Blank—Required at a frequency of once per source per sampling event when equipment (rinsate) blank is required.
- Trip Blank—Required for VOC samples at a frequency of one per sample shipment.

3.7 DECONTAMINATION

Field monitoring equipment will be decontaminated prior to use and following sampling of each station by the procedure listed below. Laboratory pre-cleaned, dedicated 1-L glass sample collection containers are used once and discarded and, therefore, do not undergo any decontamination. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

4. REFERENCES

U.S. Environmental Protection Agency. 1996. Groundwater Issue-Low Flow Sampling (Minimal Drawdown) Groundwater Sampling Procedures. April.

FIELD RECORD OF WELL GAUGING, PURGING, AND SAMPLING

Site Name:		Project Number:	
Well ID:		Well Lock Status:	
Well Condition:		Weather:	

Gauge Date:		Gauge Time:	
Sounding Method:		Measurement Ref:	
Stick Up/Down (ft):		Well Diameter (in.):	

Purge Date:		Purge Time:	
Purge Method:		Field Personnel:	
Ambient Air VOCs (ppm):		Well Mouth VOCs (ppm):	

WELL VOLUME

A. Well Depth (ft):		D. Well Volume/ft (L):	
B. Depth to Water (ft):		E. Well Volume (L) (C*D):	
C. Liquid Depth (ft) (A-B)		F. Three Well Volumes (L) (E*3):	

G. Measurable LNAPL? Yes _____ /ft No _____

Parameter	Beginning	1	2	3	4	5
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Total Quantity of Water Removed (L):			
Samplers:		Sampling Time (Start/End):	
Sampling Date:		Decontamination Fluids Used:	
Sample Type:		Sample Preservatives:	
Sample Bottle IDs:			
Sample Parameters:			

Figure SOP048-1.

FIELD RECORD OF WELL GAUGING, PURGING, AND SAMPLING

Site Name:	Project Number:	Date:
Well ID:	Field Personnel:	

Parameter	6	7	8	9	10	11
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Parameter	12	13	14	15	16	17
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Comments and Observations:

Figure SOP048-1.

FIELD RECORD OF SURFACE WATER AND SEDIMENT SAMPLING

Site Name:			Project Number:
Sample Location ID:			Date:
Time:	Start:	End:	Sample Team Members:

SURFACE WATER INFORMATION

Type of Surface Water:
( ) Stream ( ) River
( ) Pond/Lake ( ) Seep

Water Depth and Sample Location _____ (ft)

Depth of Sample from Top of Water _____ (ft)

Equipment Used for Collection:
( ) None, Grab into Bottle
( ) Bomb Sampler
( ) Pump _____

Decontamination Fluids Used:
( ) Isopropyl Alcohol
( ) ASTM Type II Water
( ) Deionized Water
( ) Liquinox Solution
( ) Hexane
( ) HNO_3 Solution
( ) Potable Water
( ) None

Water Quality Parameters
( ) Temperature ____
( ) Conductivity ___ µmhs/cm
( ) pH ____ units
( ) Dissolved oxygen ____ mg/L
( ) Turbidity ____ NTU
( ) Eh ____ mv

Velocity Measurements Obtained? ( ) No ( ) Yes, See Flow Measurement Data Record
_____

Field QC Data: ( ) Used:
Duplicate ID _____
( ) MS/MSD

Field Duplicate Collected
( ) Yes
( ) No

Sample Location Sketch:

Method
( ) Winkler
( ) Probe

SEDIMENT INFORMATION

Type of Sample Collected:
( ) Discrete
( ) Composite

Sediment Type:
( ) Clay
( ) Sand
( ) Organic
( ) Gravel

Equipment Used for Collection:
( ) Gravity Corer
( ) Stainless Steel Split Spoon
( ) Dredge
( ) Hand Spoon/Trowel
( ) Aluminum Pans
( ) Stainless Steel Bucket
( ) _____

Decontamination Fluids Used:
( ) Isopropyl Alcohol
( ) ASTM Type II Water
( ) Deionized Water
( ) Liquinox Solution
( ) Hexane
( ) HNO_3 Solution
( ) Potable Water
( ) None

Sample Observations:
( ) Odor _____
( ) Color

Field QC Data: ( ) Field Duplicate Collected ( ) MS/MSD
Duplicate ID _____

SAMPLES COLLECTED

Check if Required at this Location	Matrix: Surface Water	Matrix: Sediment	Check if Preserved with Acid/Base	Volume Required	Check if Sample Collected	Sample Bottle IDs			

NOTES/SKETCH

Figure SOP048-2.

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Standard Operating Procedure No. 051
for
Low Flow Purge and
Sampling with Dedicated Pumps

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

Revision: 1
December 2014

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1. SCOPE OF APPLICATION

The purpose of this Standard Operating Procedure is to establish the protocol for collecting groundwater samples using dedicated pump systems. The procedure is designed to permit the collection of groundwater samples with minimum turbidity, and is intended to be used in conjunction with the analyses for the most common types of groundwater contaminants (volatile organic compounds and semivolatile organic compounds, pesticides, polychlorinated biphenyls, metals, and inorganic compounds). This Standard Operating Procedure was prepared based on draft guidance prepared by the U.S. Environmental Protection Agency Region 1 and conforms to the procedures described in the Long-Term Monitoring Plan.

2. EQUIPMENT/MATERIALS

- Long-Term Monitoring Plan.
- Well construction data, location map, and field data from last sampling event.
- Field logbook, Field Record of Well Gauging Form (Figure SOP051-1), and Field Record of Well Gauging, Purging, and Sampling Form (Figure SOP051-2).
- Electronic water level measuring device, 0.01 ft accuracy for monitoring water level during pumping operations.
- Pumps: adjustable rate, submersible pumps constructed of stainless steel and Teflon.
- Tubing: Teflon or Teflon-lined polyethylene must be used to collect samples for organic and inorganic analyses.
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Power source (generator, etc.).
- Water quality indicator parameter monitoring instruments—pH, turbidity, specific conductances, and temperature. Optional indicators—Eh and dissolved oxygen. Water quality indicator parameters will be measured in the field in accordance with EPA-600/4-79-020 (1983) using the following methods: temperature (Method 170.1), pH (Method 150.1), turbidity (Method 180.1), specific conductance (Method 120.1), and dissolved oxygen (Method 360.1).

- Flow-through cell for water quality parameters.
- Decontamination supplies (for monitoring instrumentation).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.

3. PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing well purging and groundwater sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, well identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.
- Check well for damage or evidence of tampering; record pertinent observations in the field logbook and sampling form.
- Lay out sheet of polyethylene for monitoring and sampling equipment.
- Unlock well and remove well cap (if applicable).
- Measure volatile organic compounds with a photoionization detector instrument at the rim of the well and in the breathing zone, and record the readings in the field logbook and the sampling form.
- Measure and record the height of protective casing above the concrete pad or ground surface, as appropriate. This reading is compared to that recorded during well installation as an indication of possible well damage or settling that may have occurred.
- Measure and record the depth to water (to 0.01 ft) in the well to be sampled before purging begins. If the well casing does not have a reference point (usually a v-cut or indelible mark in the well casing), make one. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well. The depth to well bottom will be measured following completion of the sampling because of the potential to stir up sediment at the bottom of the well.

- Prepare the pump by checking electrical connections, discharge tubing, and motor (Grundfos Redi-Flo2). Locate the generator (if applicable) downwind of the well; connect the power converter to the generator and the pump.

4. SAMPLING PROCEDURE

The following general procedure should be followed to obtain representative groundwater samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to purging: purge date and time, purge method, and total well depth.

- Connect the flow-through cell containing the instrumentation header to the pump discharge and begin purging the well at 0.2-0.5 L/min, unless a different purge rate has been previously established for that well. Fill the flow-through cell completely. Care should be taken not to cause entrapment of air in the system. Record the purge start time and purge rate.

- Establish that the water level has not dropped significantly such that the pump is dry (bubbles in discharge) or water is heard cascading down the inside of the well. Ideally, the pump rate should cause little or no water level drawdown in the well (<0.5 ft and the water level should stabilize). The water level should be monitored every 3-5 minutes (or as appropriate) during pumping. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 L/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If the water level continues to drop with the pump on the lowest flow rate, the pump will be shut off and the well allowed to recharge to prevent it from going dry. **The well will not be purged to dryness prior to sampling to prevent erroneous field parameters and groundwater samples.** Sampling will commence as soon as the well has recharged to a sufficient level to collect the appropriate volume of samples with the pump.

- During purging of the well, monitor the water quality indicator parameters, including pH, temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity, every 3-5 minutes (or as appropriate). Record purge rate, volume purged, depth to water, water quality indicator parameters values, and clock time at 3- to 5-minute intervals in the field logbook and sampling record. Purging of the standing well water is considered complete when three consecutive readings of the water quality indicator parameters agree within the following: $\pm$ 0.1 for pH, $\pm$ 3 percent for conductivity, $\pm$ 10 mV for redox potential, and $\pm$ 10 percent for turbidity and dissolved oxygen. Temperature readings should also be recorded along with the aforementioned water quality indicators. Although it is not critical in determining the stabilization of the discharge water, it is important for data interpretation and should also be measured.

Additionally, turbidity readings consistently below 10 nephelometric turbidity units (NTUs) are considered to represent stabilization of discharge water for this parameter. If the parameters have stabilized but the turbidity is not in the range of the goal of 10 NTUs, the pump flow rate should be decreased and measurement of the parameters should continue every 3-5 minutes; however, it is important to note that natural turbidity levels in groundwater at some sites may exceed 10 NTUs.

- Prior to sampling, disconnect the discharge tubing from the flow-through cell. If the water discharged by the pump is silty, wait for the water to clear before sampling. Ensure that bubbles are not observed in the discharge tubing. Record pertinent observations in the field logbook and sampling records.

- The purging rate will be controlled so that the well is not purged dry before sampling. If necessary, purging will be temporarily halted to permit recharge rather than allowing the well to be purged dry.

- Begin filling sample containers from the pump discharge, allowing the water to fill the containers by allowing the pump discharge to flow gently down the inside of the container with as little agitation or aeration as possible.

- Label each sample as collected. Those samples requiring cooling will be placed into an ice cooler for delivery to the laboratory.

- After collection of the samples, restore the dedicated pumping assembly to the well by hanging the tube, electric line, and support cable inside the well by the specially-designed PVC well cap assembly. Lock well.

- Complete remaining portions of Field Record of Well Gauging, Purging, and Sampling form (Figure SOP051-2) after each well is sampled, including sample date and time, total quantity of water removed, well sampling sequence, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

5. SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Minimum sample preservation requirements for each parameter group are summarized below and in Table 3-1 of the Quality Assurance Project Plan:

- **Pesticides and Herbicides**—Fill the sample bottle, seal with a Teflon-lined cap, and place on ice for shipment.

6. FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the groundwater samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each sample delivery group (a sample delivery group may not exceed 20 samples) at the frequency noted:

- ***Field Duplicate***—Required at a frequency of 10 percent per sample delivery group
- ***Matrix Spike/Matrix Spike Duplicate***—Required at a frequency of 5 percent
- ***Equipment Rinsate Blank***—Required once prior to installation of dedicated pump systems
- ***Source Water Blank***—Required at a frequency of once per sampling event when equipment rinsate blank is required.
- ***Trip Blank***—Required for volatile organic compound samples at a frequency of one per sample shipment.

NOTE: The dedicated pumps remain in the wells between sampling events.

7. DECONTAMINATION

Non-dedicated sampling equipment and field monitoring equipment will be decontaminated prior to use and following sampling of each well. This equipment will be decontaminated by the procedure listed below. Alternative procedures must be approved by the Project Manager prior to sampling event. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

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Project Name:			Project No:		Date:
Weather/Temperature:					
EA Personnel:			Equipment:		
Well Number	Well Elevation	Depth to Water	Depth to LNAPL	LNAPL Thickness	Corrected Water Table Elevation[(a)]

(a) Based on an assumed specific gravity of 0.80 for LNAPL.

NOTE: All measurements in feet.
LNAPL = Light, non-aqueous phase liquid.

Figure SOP051-1. Field record of well gauging.

Site Name:		Project Number:	
Well ID:		Well Lock Status:	
Well Condition:		Weather:	

Gauge Date:		Gauge Time:	
Sounding Method:		Measurement Ref:	
Stick Up/Down (ft):		Well Diameter (in.):	

Purge Date:		Purge Time:	
Purge Method:		Field Personnel:	
Ambient Air VOCs (ppm):		Well Mouth VOCs (ppm):	

WELL VOLUME			
A. Well Depth (ft):		D. Well Volume/ft (L):	
B. Depth to Water (ft):		E. Well Volume (L) (C*D):	
C. Liquid Depth (ft) (A-B)		F. Three Well Volumes (L) (E*3):	
G. Measurable LNAPL? Yes _____ /ft No _____			

Parameter	Beginning	1	2	3	4	5
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Total Quantity of Water Removed (L):			
Samplers:		Sampling Time (Start/End):	
Sampling Date:		Decontamination Fluids Used:	
Sample Type:		Sample Preservatives:	
Sample Bottle IDs:			
Sample Parameters:			

Figure SOP051-2. Field record of well gauging, purging, and sampling.

Standard Operating Procedure No. 057
for
Multi-Incremental Sampling

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. INTRODUCTION

1.1 SCOPE AND APPLICATION

Multi-incremental (MI) sampling (sometimes designated by the acronym MIS), originally utilized by the mining industry, was initially proposed for environmental sampling at explosives-related sites (U.S. Environmental Protection Agency Solid Waste 846 Method 8330B, Appendix A Collecting and Processing of Representative Samples for Energetic Residues in Solid Matrices from Military Training Ranges [2006]). MI sampling is particularly effective at such sites because explosives residue is found in surface soil as opposed to at depth, and the potentially impacted areas are relatively easy to delineate because the area of the firing ranges is, in most cases, well defined.

Although MI sampling was initially implemented for the assessment of impacts from explosives, there has been recent movement to extend the list of acceptable contaminants to include metals, semivolatile organic compounds, and even volatile organic compounds (State of Alaska Department of Environmental Conservation [2009] and State of Hawai'i Department of Health [2009]). However, the adequacy of MI sampling is evaluated on a case-by case basis at the time the planning documents are prepared to ensure that the resulting analytical data are appropriate to make the decisions required by the project. This evaluation process considers:

1. Planning elements based on the decisions to be made for each potentially complete pathway (based on the conceptual site model), including contaminants distribution, hot spot size, future land use scenarios, contaminant fate and transport, etc.

2. Sample preparation procedures to be employed by the analytical laboratory (limitations and impacts on the analytical data due to the various preparation methods that can be employed)

3. Data evaluation requirements (i.e., the data needing to meet a certain level of confidence). In addition to technical considerations, stakeholders' input is also folded into the planning stages. Consequently, specific field requirements may be outlined in the planning documents for the sampling program implementation to supplement this Standard Operating Procedure (SOP).

This SOP focuses on the actual collection of MI samples, not project planning or data evaluation to follow, and assumes that successful project planning and scoping have been performed, documented, and agreed to by all stakeholders. Because Sampling Units (SUs) are defined so that the mean concentration value obtained is relevant to an explicitly articulated end use of the data, it is imperative that any changes to the SUs or sampling strategy deemed necessary by actual field conditions unanticipated at the time the sampling plan was designed should be made by the project technical lead rather than by field personnel. This way, field deviations from the approved plan during sample collection will not negatively impact the adequacy of the data for the planned purpose.

1.2 GLOSSARY OF TERMS

1.2.1 Sampling Units

An SU (sometimes termed Decision Unit [DU]) is the area and depth of soil (the sampled population) to be characterized by the average concentration of the MI sample. A DU may contain several SUs that are sampled using MI techniques or may consist of just one SU. SUs are restricted to actual source zones and must incorporate only areas that are similar as far as impact (i.e., not to "dilute" contamination) as well as future use. SUs/DUs selected based on future land use scenarios may be called Exposure Units. SUs must be delineated so that the mean analyte concentrations obtained are directly relevant to well defined project objectives. They are the smallest volume of soil for which a concentration value will be obtained, and the basic unit about which a decision or conclusion based on an analytical result can be made.

1.2.2 Decision Units

A DU is a specific area (or volume of soil) about which a decision is to be made. In the ideal and most direct case, the DU and SU are the same volume of soil. As noted above, a DU may be composed of a single SU, or may include multiple SUs, if the DU is very large in size. The important thing is that the entire area of a DU is consistent as far as contamination distribution and future use/exposure scenario, just like an SU. Either all or a percent of the SUs composing the DU may be sampled in an MI fashion, the number of SUs sampled depending on the confidence of the data that are extended from the SUs to the DU.

1.2.3 Grid Cell

A grid cell is a sub-division of the SU. SUs are divided into uniform-size grid cells, and one increment is collected from each cell, from the same relative location within each grid cell. The shape of the cells is not specified—the only criterion for cell shape selection is that the cells should be of equal size (they can be triangular, square, rectangular, etc.) so the increments collected from each cell are equally weighted over the SU.

1.3 GENERAL CONCEPTS

The use of standard discrete samples to characterize soil contamination has two significant sources of error:

1. Field sampling error is at least 10 times greater than analytical (laboratory-associated) error.

2. A source of analytical error was found to be that in sample processing and sub-sampling (a single subsample from the 4- or 8-ounce soil jar is taken at the laboratory).

Depending on the areal and vertical contaminant distribution profile, MI sampling and processing are designed to minimize these sources of error, resulting in an average concentration that is a much more precise and accurate estimate for the SU.

It is also important to note that the horizon characterized by MI sampling is usually superficial, although MI can be implemented at greater depth, this resulting in much higher associated sampling costs.

The purpose of this SOP is to delineate protocols for the application of MI field sampling of surface soil. The procedure, which can be adapted to allow for MI sampling in other environments, i.e., in an excavation trench, has been adapted from U.S. Army Corps of Engineers sampling guidance (2009).

2. EQUIPMENT AND MATERIALS

The following equipment and materials may be required:

- Spray paint[1], pin flags, or rope to mark either grid corners or outline the sampling grid
- Incremental sampling tool (i.e., the MI tool developed by the Cold Regions Research and Engineering Laboratory or alternative[2] coring device); stainless steel spoons or scoops may be used but only in conjunction with scales, so that aliquots of equal mass are collected from each location
- Clean Zip-lock® bags, 5-gallon plastic containers, or other appropriate large container for placing the increments; the size of the container should be adequate to hold the sample volume, which is approximately 1-2 kilograms
- If MI sampling is used for volatile organic compound analysis, the increments of equal mass are collected with tools such as En Core® sampler and placed in a container obtained from the analytical laboratory that is partially filled with methanol
- Coolers and ice for cold storage of samples after collection
- Field logbook and pen with waterproof black ink for field documentation
- Global Positioning System instrument or other survey equipment to document locations of DU or SUs

[1] Avoid if spray paint is likely to affect MI sample quality.

[2] A source for the MI sampling tool shown in this SOP is Ike Loukos, LES Engineering, Inc. Telephone No. 301-471-3393, email i.loukos@att.net.

- Personal protective equipment should be worn during sample collection as required by the Health and Safety Plan for the project.

3. MULTI-INCREMENTAL SAMPLING PROCEDURE

Increments of soil will be collected within each cell of the SU. Increments should be approximately of the same weight. For surface soil sampling, a coring tool may be used to facilitate the rapid collection of uniform, representative increments from a consistent depth interval. This way, equal volumes are collected for each increment and equal mass is obtained under the assumption that the density of the sampled medium is uniform across the cell of the SU. The size of the coring tool will be selected based on the volume of the increments, which is in turn calculated based on number and depth of the increments and the fact that an adequate total sample mass is typically 1-2 kilograms dry weight (to overcome effects of compositional heterogeneity due to the inherent particulate nature of soil and sediment). It is not necessary to determine by the Global Positioning System location of every increment collected, as long as the SU has been properly identified and the relative position of the increment location within each cell is recorded.

The SU or DU will be demarcated in the field using pin flags, spray paint, or rope and fixed with a Global Positioning System. Increments will be selected as defined in the sampling plan.

Prior to MI sampling activities, the field team will don the personal protective equipment. The increments will be collected from the depth specified in the planning documents (usually up to 6 inches deep) using a coring tool or other method that ensures equal volume is collected for each increment. Unless specified in the sampling plan, the vegetative mat will be included in the sampled interval. Of note is that some plans may require only sampling native soil; the horizontal limits of sampling will be dependent on past disposal practices and the decision to be made. If used, the stainless-steel sampler will be pushed into the soil until the sampler is full and will not penetrate further. The sampler is then removed carefully, and the soil is pushed out of the sampler with the lever on the side of the instrument (see photos below).







Place the sample (increment or aliquot) directly into a large re-sealable bag, 5-gallon bucket, or alternative large container (note the above photos show placing the aliquot into a sampler's hand only for aliquot visualization purposes). Field experience has found that placing samples into a decontaminated 5-gallon bucket and then pouring the whole sample into a bag is a better process. The likelihood of spilling increases with the use of a bag alone because as the bag fills up it is harder to eject additional soil increments into the bag. The bucket is more stable and may prevent loss of fines. The holes left by sampling will be filled using surrounding soil or, if necessary, sand may be used to bring the subsurface sampling areas back to original grade. Soil samples should not include large rocks or pebbles unless they are part of the overall soil matrix. It is not necessary to decontaminate the sampling tool between the increments within a DU or SU.

If collecting an MI sample for volatile organic compound analysis, a wide-mouth glass container and methanol will be obtained from the analytical laboratory for sample aliquot preservation. The collection of the increments will be performed using EnCore™ or TerraCore™ sampling tools, meaning that a much smaller increment volume will be collected, resulting in a smaller total sample volume. The field team will place the 5- to 15-milligram increments into the glass container and care should be taken to follow the health and safety precautions associated with methanol handling. To prevent loss of methanol through volatilization, the sample container will be kept closed as much as feasible and only opened to place sample aliquots within the container.

Prior to the collection of replicate samples or MI samples from another SU or DU, the sampling tool will be decontaminated according to requirements set forth in EA SOP No. 005 – Field Decontamination. The replicate samples from the same SU/DU will be collected following a different path, as shown in Figure SOP No. 057-1. The specific relative location of the replicate increments within each SU cell will be established in a random manner to eliminate potential bias. To select the relative increment location for a replicate increment in a cell, the cell may be divided in turn into sub-grids and a sub-cell may be selected by randomly generating a number on a calculator. Another selection method is performed by rolling a dice for a 6 × 6 sub-grid in the SU cell; the first die would indicate the row and the second die the column of this sub-grid.

The large re-sealable bag containing the total sample volume will be labeled with indelible ink and then double-bagged. The samples will be bubble-wrapped and taped for shipping and placed into iced coolers for transport under chain-of-custody protocol to the analytical laboratory. The field procedures will follow the requirements set forth in EA SOP No. 002 – Chain-of-Custody Form and EA SOP No. 004 – Sample Packing and Shipping. Copies of the chain-of-custody forms and shipping documents will be retained in the project file. Field activities will be documented according to logbook procedures specified in EA SOP No. 016 – Surface Water, Groundwater, and Soil/Sediment Field Logbooks.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Safety precautions documented in the Site Health and Safety Plan will be followed. If sampling procedures are to occur in areas where unexploded ordnance is known or potentially exist, the area will not be entered until unexploded ordnance support is provided. If, at any time, an unsafe condition is identified, stop work immediately until the unsafe condition is mitigated. If sampling for volatile organic compound analysis, follow precautions associated with handling methanol. Also, because much larger quantities of methanol are employed for MI sampling, follow all requirements associated with transportation of these samples. In most cases, these samples are driven to the analytical laboratory rather than shipped via air, which constitutes a limitation in using this method at sites not located in close proximity of a laboratory.

6. REFERENCES

State of Alaska Department of Environmental Conservation. 2009. *Draft Guidance on Multi Increment Soil Sampling.* Division of Spill Prevention and Response Contaminated Sites Program. March.

State of Hawai'i Department of Health. 2009. *Technical Guidance Manual for the Implementation of the Hawai'i State Contingency Plan Interim Final.* Office of Hazard Evaluation and Emergency Response. June.

U.S. Army Corps of Engineers. 2009. Interim Guidance 09-02, *Implementation of Incremental Sampling of Soil for the Military Munitions Response Program.* 20 July.

U.S. Environmental Protection Agency. 2006. *SW-846 Method 8330B, Appendix A Collecting and Processing of Representative Samples for Energetic Residues in Solid Matrices from Military Training Ranges.*

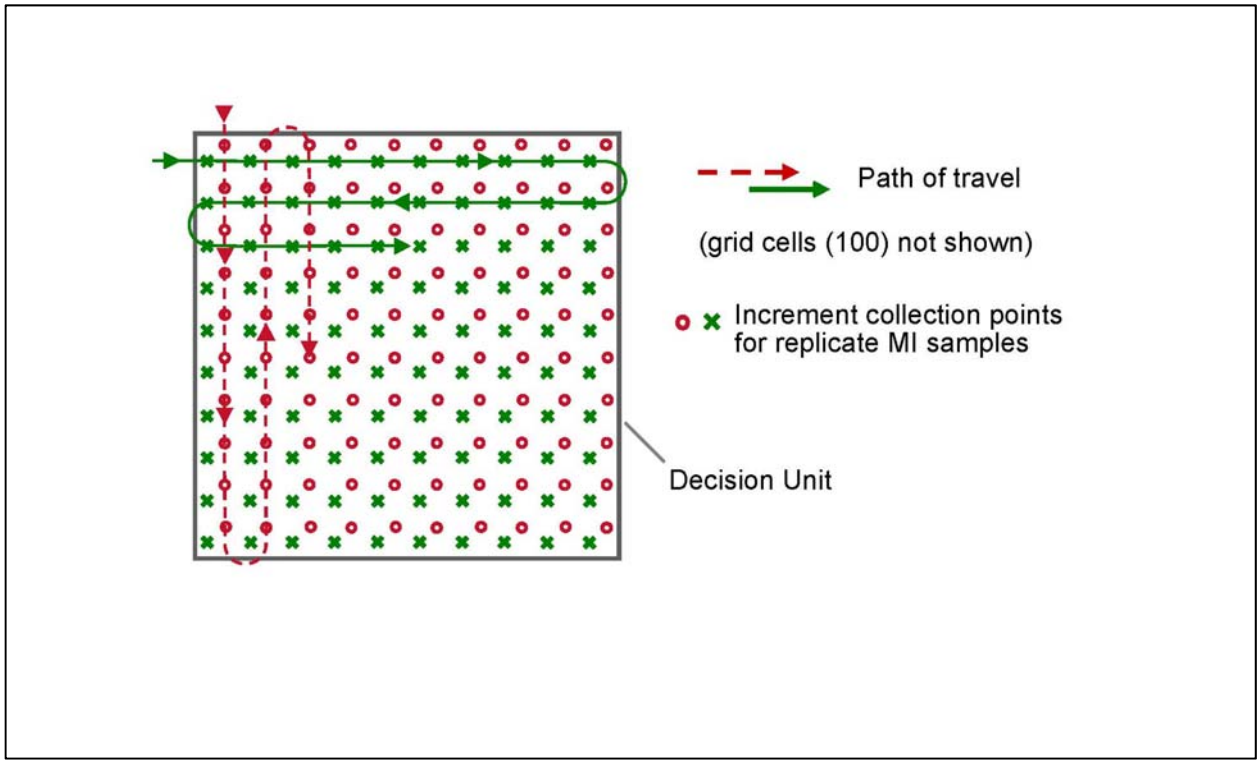


Figure SOP057-1. Example incremental sampling in a Decision Unit.

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Standard Operating Procedure No. 059
for
Field Logbook

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

Revision: 1
December 2014

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1. SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording field survey and sampling information in the Field Logbook.

2. MATERIALS

The following materials may be required:

- Field Logbook (Teledyne 415 Level Book, or equivalent)[1]
- Indelible ink pen (e.g., Sharpie®).

3. PROCEDURE

All information pertinent to a field survey or sampling effort will be recorded in a bound logbook. Each page/form will be consecutively numbered, dated, and signed. All entries will be made in indelible ink, and all corrections will consist of line-out deletions that are initialed and dated. The person making the correction will provide a brief explanation for the change. Entries are factual only. No personal opinions should be entered.

There should be no blank lines on a page. A single blank line or a partial blank line (i.e., at the end of a paragraph) should be lined to the end of the page. If only part of a page is used, the remainder of the page should have an "X" drawn across it. The bottom of each page must be signed and dated by the field personnel entering the information.

At a minimum, entries in the Field Logbook will include but not be limited to the following:

- Date.
- Project number and project name.
- Name and address of field contact.
- Identification of sample crew members.
- Documentation should include model numbers of equipment used (e.g., drilling rigs) and calibration (if applicable). Each day's entry should begin with time onsite, who is onsite (including observers other than the sampling crew), brief description of what work will be performed that day and how, and the weather.

[1] Pre-printed, bound forms are approved as well. See SOP No. 016 for recommended content and format.

- If samples are being taken in or near tidal waters, the time of high and low tide for the site should be determined from local gauges or tables and recorded.

- References such as maps of the sampling site.

- Times of key daily milestones should be entered (e.g., time borings began, times personnel arrived and left site, times subcontractors arrived and left site, etc.). Time should be recorded in the left-hand margin on the page in military time.

- Sample-specific information:

  — Unique, sequential field sample number

  — Purpose of sampling

  — Location, description, and log of photographs of each sampling point

  — Details of the sample site (e.g., elevation of the casing, casing diameter and depth, integrity of the casing, etc.)

  — Documentation of procedures for preparation of reagents or supplies which become an integral part of the sample (e.g., filters and absorbing reagents)

  — Type of media of sample (e.g., groundwater, surface water, soil, sediment, and product)

  — Suspected waste composition

  — Number and volume of sample taken

  — Sampling methodology, including distinction between grab and composite sample

  — Sample preservation

  — Date and time of collection

  — Collector's sample identification number(s)

  — Sample shipment (e.g., name of the laboratory and cartage agent: Federal Express, United Parcel Service, etc.)

  — Field observations (e.g., oily sheen on groundwater sample, incidental odors, soil color, grain size, plasticity, moisture content, layering, Unified Soil Classification System classification, etc.)

— Any field measurements made (e.g., pH, conductivity, explosivity, water depth, organic vapor analyzer readings, etc.)

— Signature and date by the personnel responsible for observations

— Decontamination procedures.

Sampling situations vary widely. No general rules can specify the extent of information that must be entered in a Field Logbook. However, records should contain sufficient information so that someone can reconstruct the sampling activity without relying on the sampler's memory. Further, the project work plan or field sampling plan should be reviewed to identify additional specific information or requirements that should be included in the Field Logbook.

The Project Manager will keep a master list of all Field Logbooks assigned to the Sampling Team Leaders. One Field Logbook kept by the Project Manager will be a master site log of daily activities and will contain the list of Field Logbooks assigned to Sampling Team Leaders.

Project name and number should be clearly marked on the outside cover using indelible ink. If more than one Field Logbook exists for the project, then the number of the Field Logbook should also be clearly marked on the outside cover.

4. MAINTENANCE

At the end of the field sampling effort, the Field Logbook should be scanned and filed in the electronic file for the project and maintained according to the EA Records Retention Policy or contract requirements.

5. PRECAUTIONS

None.

6. REFERENCES

EA Engineering, Science, and Technology, Inc., PBC. 2014. Standard Operating Procedure No. 016 for Surface Water, Groundwater, and Soil/Sediment Field Logbooks. December.

U.S. Environmental Protection Agency. 1980. *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans*, QAMS-005/80.

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Standard Operating Procedure No. 063
Chemical Data Management

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

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1. INTRODUCTION

Many engineering and environmental compliance projects require site sampling and generation of associated chemical analysis data. The chemical data are used for a wide variety of purposes such as site assessments, remedial design, long-term monitoring, litigation support, and human health and ecological risk assessments. A project may often have auxiliary or historical data components that must integrate with the chemical data.

Most project plans include development of a site sampling plan and quality assurance project plan/data quality objectives for the laboratory to ensure the correct sampling and analysis methods are used. There are many related standard operating procedures (SOPs) that specifically address field activities and sampling protocols. Although the field sampling and laboratory specifications are typically well documented, the actual management of the data also requires planning, organization, and documentation. The EA data professionals described in this SOP should be engaged from the proposal stage (to provide accurate estimates of budget, scope, and schedule) through to the execution of the project (to design and implement data processing and storage solutions).

1.1 PURPOSE

This SOP provides requirements, guidelines, and general information to consider in the planning, development, and execution of a chemical data management plan (CDMP). It will provide guidance on:

- Project requirements review
- Field sample plan review
- Laboratory specifications review
- Laboratory deliverables (report and electronic data deliverables [EDDs])
- Development of a CDMP
- Chemical data storage considerations and options
- Chemical data component structure
- Analysis and reporting options
- Commercial and agency-specific database systems.

If the CDMP is not a contract deliverable, one should be generated regardless as an internal document for project staff use.

1.2 SCOPE

The requirements and guidelines are applicable to all projects with chemical data components.

1.3 DEFINITIONS

Auxiliary Data—Other project-specific data that may integrate with the chemical data, i.e., bore log data, well gauging data, geo-spatial coordinate data, and field analysis data.

Historical Data—Previously generated chemical data and associated auxiliary data, i.e., from past site investigations or regular periodic sampling events of monitored sites.

1.4 ROLES AND RESPONSIBILITIES

1.4.1 Project or Task Managers

The Project Manager or Task Manager specifically assigned to oversee the chemical data task is responsible for the planning and implementation of the CDMP that will define the project requirements and final data deliverable specifications. Specific responsibilities are to:

- ***Review Project Data Requirements***—Review the project requirements for the chemical data to ensure all client deliverables for analysis, reporting, and data storage will be met.

- ***Create Sampling Plan***—Design and/or review the field sampling plan to ensure the proper numbers and types of samples will be collected, documented, and tracked.

- ***Select Laboratory and Define Performance Criteria***—Select the laboratory that will meet the project requirements for methods, detection limits, quality control performance, and deliverables. Projects may require complex quality assurance project plan/data quality objectives. Establish point of contact, price, deliverables, and schedule with the laboratory.

- ***Identify Other Data Sources and Plan for Integration***—Determine if auxiliary data or historical chemical data will need to be collected and integrated with the chemical data. Common sources of auxiliary data are bore log data, well gauging data, geo-spatial/ location coordinate data, and field analysis data. Plan for staff to evaluate, process, and integrate data sources.

- ***Create the CDMP***—Prepare the CDMP to define:

  — Data tracking
  — Data processing and storage
  — Analysis and reporting requirements.

- ***Designate Data Support Staff***—Depending on the size and complexity of the project, a Database Administrator (DBA) and/or Data Coordinator may be designated. Consult a DBA to review the data processing and storage options and make recommendations. Plan for the expertise and staffing to meet data processing and deliverable requirements.

- ***Monitor Progress***—Inform DBA, Data Coordinators, and analysis and reporting staff of all data sources, deliverable requirements, and schedules as defined in the CDMP. Monitor the progress and quality of data collection, processing, and reporting. This requires regular communication and status reporting with the designated DBA and Data Coordinators to ensure data tasks are completed on schedule and any problems are addressed in a timely fashion.

- ***Review Final Products***—All final deliverables (reports, data tables, data files, etc.) must be reviewed to ensure project requirements are met.

1.4.2 Database Administrator

The DBA has advanced data evaluation, data management, and programming skills. The DBA is able to evaluate a wide variety of complex data sources and project requirements, and to advise the Project Manager on appropriate solutions and staffing. Specific responsibilities are:

- ***Data Review Consultation***—As requested by the Project Manager, must review all relevant project information and then provide information on data management and staffing options, and work with the Project Manager to create and implement the CMDP.

- ***Data Management***—Design and implement the data processing and storage solutions. The solution may consist of multiple databases and any applications or tools needed to manage the tracking, processing, security, storage, analysis, and reporting of data as assigned by the Project Manager.

- ***General Data Support Services***—As requested by the Project Manager or designated staff, may provide other support, i.e., data searches, queries, ad-hoc reporting, staff training, or other data services as needed.

- ***Data Coordinator Oversight***—May function directly as the Data Coordinator, or may manage other Data Coordinators. The DBA will assign database maintenance or programming tasks as deemed appropriate to the skill level of the Data Coordinator. The DBA and Data Coordinator may share interchangeable tasks. The level of direct involvement and specific project responsibilities of the DBA will be defined by the Project Manager in the CDMP.

- ***Final Data Product Delivery***—Ensure that the final client data deliverable meets all specifications (including those associated with data validation), and provides the data in the designated format.

1.4.3 Data Coordinator

The Data Coordinator is responsible for the actual day-to-day tracking, processing, and reporting of the project data. The specific tasks assigned to the Data Coordinator will depend on the skill

level, tools, and applications provided. The Data Coordinator works closely with the DBA, or the DBA may serve directly as the Data Coordinator. The Data Coordinator should be engaged from project inception through data reporting. Specific responsibilities are:

- ***Field Sampling and Chain-of-Custody Tracking***—Review and compare the field samples to the sampling plan. Review chain-of-custody (COC) for accuracy and completeness.

- ***Staff Communications***—Communicate with the field staff, shippers, and laboratory to ensure samples are collected and received on schedule. Alert the Project Manager, field staff, and laboratory of any discrepancies or problems. Maintain all records related to sampling, shipping, and COC. Communicate with other project staff, i.e., reporting or analysis staff, as needed.

- ***Laboratory Communications***—Serve as the point of contact between the Project Manager and the laboratory. Receive and maintain all laboratory reports, correspondence, COC, and EDDs. Alert the laboratory to any sampling or data issues and document resolution of any problems.

- ***Laboratory Data Quality Review***—Examine all data deliverables and reports from the laboratory to ensure data accuracy, completeness, and adherence to the analysis and reporting requirements.

- ***Data Processing***—Execute all data processing duties as defined in the CDMP. This includes tasks such as: EDD processing, standardizing, and importing chemical data into the final database; organizing and storing original EDD files; and reviewing and preparing historical or auxiliary data to integrate with chemical data.

2. EQUIPMENT

2.1 COMMERCIAL SOFTWARE

A wide variety of generic and program-specific software is available for the storage, analysis, and reporting of chemical data. Some of the more commonly encountered software products are:

- Microsoft Office® Excel, Access, SQL Server, SQL Server Express
- Equis® Chem and Geo
- Automated Data Review – U.S. Army Corps of Engineers
- Environmental Data Management System – U.S. Army Corps of Engineers
- Staged EDD – U.S. Environmental Protection Agency
- Environmental Resources Program Information Management System – Air Force Center for Engineering and the Environment.

2.2 CUSTOM SOFTWARE

Depending on the size and complexity of the project data, custom applications can be defined and developed internally to meet the data tracking, processing, and reporting needs of the project.

2.3 HARDWARE

Not applicable.

3. PROCEDURE

3.1 MANAGEMENT PROCESS OVERVIEW

The management of chemical data is often a component of a much larger engineering or environmental compliance project. The planning of the field sampling effort, selection of a laboratory, and establishment of laboratory data quality objectives must be well defined.

Because the chemical data management component can be a foreign topic to many Project Managers, its complexity can be underestimated, causing negative impacts on the project schedule, budget, staff, and overall project performance. The development of a successful CDMP depends on a full understanding of its precursors: project requirements (scope, budget, schedule, and deliverables), field sampling plan, and laboratory quality assurance project plan/data quality objectives.

The chemical data management process has been divided into four major steps:

1. ***Review Project Requirements***—Scope of work, schedule, budget, data deliverables, analysis, and reporting requirements.

2. ***Review Field Sampling Plan***—Numbers and types of samples, sample schedule, field quality control requirements, and sampling methods.

3. ***Review Laboratory Specifications***—Required certifications, methods, detection limits, analyte lists, validation requirements, reporting and EDD specifications, and quality assurance project plan/data quality objectives.

4. ***Develop and Execute CDMP***—The plan has three components:

   — Data tracking
   — Data processing and storage
   — Analysis and reporting requirements.

These steps are applied universally to all chemical data projects, regardless of size or complexity. Each step will require varying levels of detail as dictated by the objectives and requirements of each project. The chemical data management process overview is presented in Figure 1.

The requirements and guidelines of each step are presented in the following sections.

Attachment A provides additional supporting material and background information for each step.

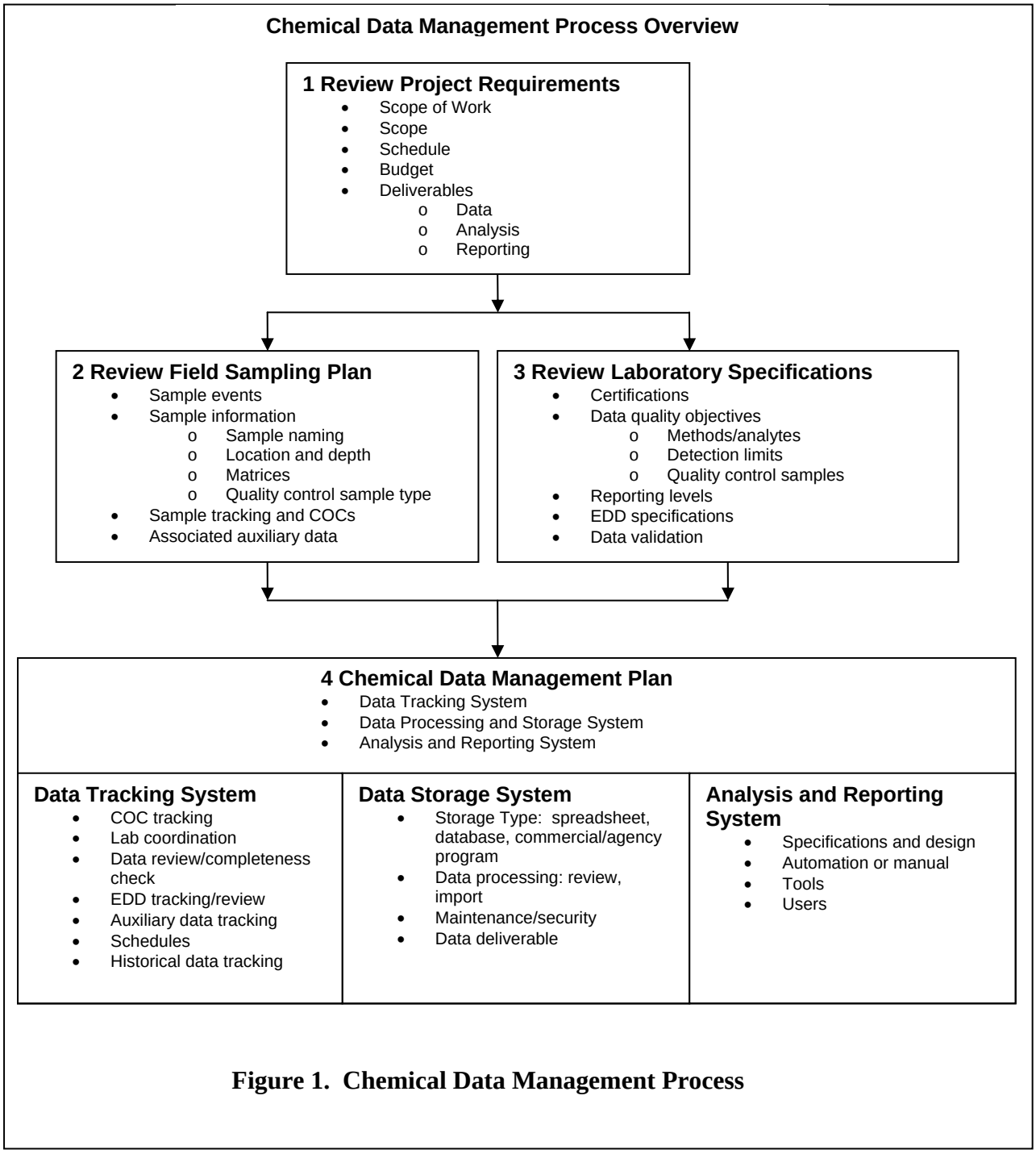


Figure 1. Chemical Data Management Process

3.2 REVIEW PROJECT INFORMATION

The parent project requirements define the project objectives, scope of work, deliverables, schedule, and budget.

Required

- Review the available project information (scope of work, schedule, budget, and deliverables) as they pertain to the chemical data requirements.

- Contact a DBA to review the requirements and assist in preparing the CDMP. Only extremely simple sampling and analysis projects are exempt from DBA review. The DBA will provide:

  — Options and specifications for data tracking and processing, data storage, software, analysis and reporting, and final product delivery

  — Information on staffing and expertise required

  — Estimate of timing and level of effort for each task

  — Evaluation of auxiliary or historical data to be integrated with the chemical data.

- Prepare and review the data management effort estimates and confirm the estimates meet the project requirements. Revise as necessary to define and meet requirements.

Guidelines

Refer to Attachment A, Section 1, for additional support information on reviewing project information and considerations in defining chemical data management requirements.

3.3 REVIEW FIELD SAMPLE PLAN

The Project Manager must plan for field staff, training, equipment, schedules, site safety, and the actual sample collection strategy. The field sampling data will eventually be integrated and matched to its laboratory analysis data.

The sampling plan will include information on:

- Sample events, numbers of samples
- Sample locations and depths
- Sample matrices and field quality control samples
- Sample naming conventions
- Sample tracking and COC policies

- Sample techniques and containers
- Decontamination procedure
- Sampling schedule.

Required

- ***Prepare List of Expected Field Samples***—The list is prepared as an electronic (Excel) file that provides the field information to be linked to the laboratory results. The field sample list includes:

Field Sample Name	Naming system may consist of codes for location, depth, type, etc.
Field Sample Date	Date and time of sample collection.
Sampling Event	For projects that have long-term monitoring or sample collections, the sampling dates may be grouped into distinct events, i.e., quarterly sampling.
Field Sample Location	Location designation from sampling site. Sites may have designated well locations, test pits, vapor points, etc.
Field Sample Matrix	Specific matrix, i.e., groundwater, surface water, sediment, effluent, soil gas, etc.
Field Sample Type	Used to identify field quality control samples, i.e., field duplicates, rinse blanks, trip blanks, etc.
Field Sample Parent	Sample name of parent sample to a field duplicate.
Sample Start Depth	Typically used for soil boring samples, start depth of sample.
Sample End Depth	Typically used for soil boring samples, end depth of sample.
Field Filtered	Typically used for water samples to indicate field filtered for dissolved metals.
Other Data	Other data columns as needed to provide sample-specific information that will be captured in the final database.

- ***Prepare List of Locations***—The list is prepared as an electronic (Excel) file that contains the field location information to be linked to the field samples. The location provides details for each location, i.e., areas of concern, Geographic Information System coordinates, location type, etc. The location list includes:

Location Name	Location naming system may be designated by the client, i.e., existing monitoring wells, or may be designated in the field sampling plan.
Alternate Location Name	Locations may have alternate historical names, or designated identifiers from state or local regulators.
Area of Concern	Large sites may have locations grouped into areas of concern.
Location Type	Designates the type, i.e., monitoring well, vapor point, discharge point, and soil boring.
X coordinate	Latitude coordinate.
Y Coordinate	Longitude coordinate.
Z Coordinate	Elevations.
Coordinate System	Name of standard system for location coordinate values.
Other Data	Other data columns as needed to provide location-specific information that will be captured in the final database.

Guidelines

- If the sampling plan includes auxiliary data to be captured in the database and linked to chemical data (i.e., for soil boring logs, field analyses, and well gauging), plan to organize and capture the data in an electronic format (Excel) to facilitate data integration. Consult a DBA for design specifications.

- For large, complex projects that have major field sampling plans, consult a DBA prior to starting field operations to ensure field data can be collected electronically in a consistent and standardized manner.

- Enforce consistency in naming and coding conventions when collecting all forms of field data. This will facilitate later linking of field sample data to its chemical laboratory results and any auxiliary data.

- Refer to Attachment A, Section 2, for additional support information on reviewing field sampling plans and considerations in defining chemical data management requirements.

3.4 REVIEW LABORATORY INFORMATION

The laboratory performing the sample analysis provides information on methods, reporting limits, analyte lists, and quality control procedures that will be applied to the project samples. The laboratory will produce deliverables, typically a laboratory report of the results (that includes a narrative of any analysis issues), and an EDD file of the results.

Required

- The analysis performance requirements (quality assurance project plan/data quality objectives) must be reviewed by the Project Manager to ensure laboratory performance will meet project requirements. The documentation will define the methods, analyte list, reporting limits, and quality control procedures that will be applied to the project samples.

- All projects will have an EDD file format specified for result delivery. Consult a DBA to confirm the EDD format will meet database import specifications and contain all required laboratory data.

Guidelines

- Selection of a laboratory and preparation of a quality assurance project plan/data quality objectives are not part of the actual CDMP, but are critical precursors to the generation of analytical results that will meet project requirements. The Project Manager should review all available laboratory project information prior to the sampling event to ensure the laboratory results will be acceptable for project use.

- Refer to Attachment A, Section 3, for additional support information on reviewing laboratory specifications and considerations in defining chemical data management requirements.

3.5 CHEMICAL DATA MANAGEMENT PLANNING

After the field sampling and laboratory requirements have been reviewed, the actual CDMP can be developed. The CDMP is divided into three main sections:

Section	Components
Data Tracking System of Sample Delivery Group (SDG) and EDDs	Tracking of field samples and COC EDD tracking and review SDG tracking of validated data Linking field sample and laboratory data Linking auxiliary data Storing source data
Data Storage System	Data storage (spreadsheet versus database) Commercial or agency-specific data program Data review and processing Data security and maintenance Data deliverable
Data Analysis and Reporting System	Analysis requirements and deliverables Reporting requirements and deliverables

Projects can vary greatly in data quantity, complexity, storage, and reporting requirements. Especially for large, complex projects, a DBA can provide valuable information on the options for data storage and processing systems to be defined in the CDMP.

The three main sections of the CDMP are addressed in the following sections.

3.5.1 Data Tracking System

A formal data tracking system must be established to organize and monitor the incoming project data. The main objective of the tracking system is to discover missing, incomplete, erroneous, or otherwise unacceptable data as soon as possible in the project life cycle. Early discovery of problems may allow field crews, laboratories, or other subcontractors (e.g., data validators) to make corrections, or allow the Project Manager to make alternate plans to address project data issues. Data tracking should include a means to verify that data validation, if required, has been performed and reported correctly before final storage of information.

Large projects have many types of data-generating activities. Figure 2 presents a schematic diagram of the various project activities that produce sources of data that may need to be tracked, processed, and incorporated into the final data storage system. The individual files must be checked for accuracy and completeness, and compared against each other to verify the related information can be linked in the future for final data storage and reporting.

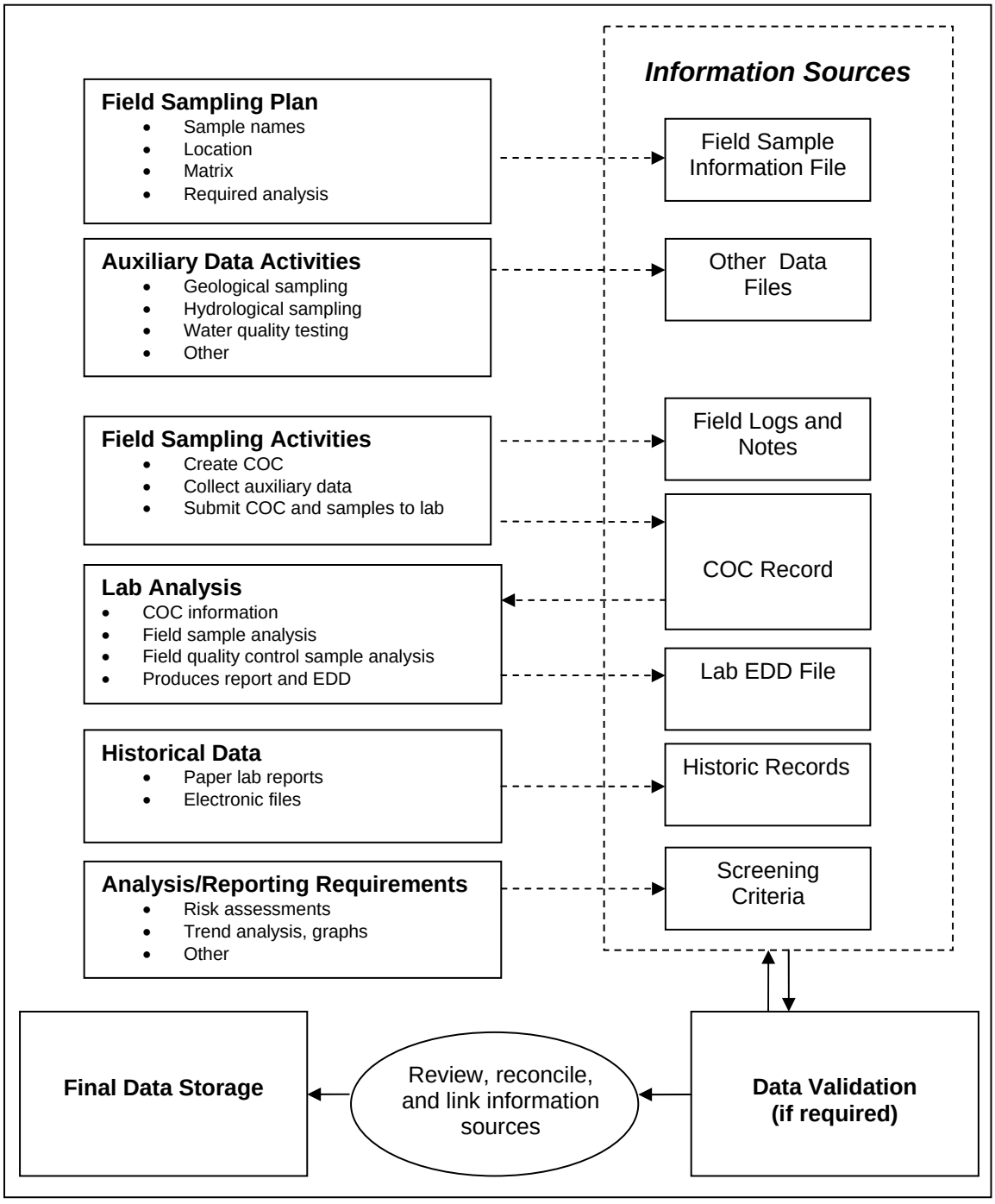


Figure 2. Project Information Sources

Required

- Consult with a DBA to define the project data sources and determine the type of tracking system to be developed. Tracking systems may be as simple as a series of Excel files managed and reviewed by a Data Coordinator, or customized database applications that provide forms, tools, reports, and automation to assist the Data Coordinator.

- A Data Coordinator must be assigned to manage the tracking system.

- The tracking system must perform the following tasks:

Task	Description
Sampling Plan Verification	Correct number and types of expected field samples have been collected and recorded, and sent to the laboratory.
Sample Information Verification	Sample names, sample dates, depths, locations, coordinates, and other sample information are correctly recorded.
COC Verification	Laboratory COC is correct, with expected field samples, dates, matrices, methods for each sample, and signed as required.
Laboratory Deliverable Verification	Reports and EDD files contain all required samples, methods, analytes, and required supporting material. The EDD must be reviewed for accuracy and completeness, including tracking of SDGs through the data validation process.
Auxiliary Data Verification	If well gauging, soil boring, or other field analysis data (i.e., organic vapor analyzer readings, water quality parameters) have been collected, that data must also be verified for accuracy and completeness and standardized for linking to chemical data samples and locations.
Data Linking	There must be a mechanism for linking field samples to laboratory EDD data, and any auxiliary data.
Coordination and Communication	The system must include a mechanism for alerting the Data Coordinator or appropriate project staff, laboratories, other subcontractors regarding missing, incomplete, or incorrect data, and resolving any data tracking issues.
Source Data Storage	All original source files (sample lists, laboratory EDDs, field analysis files, etc.) must be stored in a secure location. Original files allow traceability back to original information sources.

- The laboratory must be notified of any errors in the EDD file. A corrected EDD file must be issued by the laboratory. For example, a field same name or sampling date must not be corrected directly in the database unless a corrected EDD is obtained.

Guidelines

Refer to Attachment A, Section 4, for additional support information on different data sources and considerations in defining chemical data management requirements.

The attachment includes detailed information on:

Data Type	Description
Laboratory EDD Files	EDD files must have a specific format, structure, and content.
EDD Validation Files	EDD files may go through a formal validation process that may change data or designate some data as not useable.
Screening Criteria Data	There are many types of federal, state, and local quality standards that can be used to screen the chemical concentrations in samples.
Historical Data	Some projects may have accumulated years of past chemical analysis data, stored in various file types, or hard copy, that must be merged with the new data. The standardizations and processing of historical are often a major undertaking that requires analysis and planning.

3.5.2 Data Storage Systems

3.5.2.1 Overview

There are many factors to consider when selecting a chemical data storage system. The storage system will receive processed field and laboratory data from the tracking system, provide data to the analysis and reporting system, and may be the final data deliverable to the client. Chemical data storage systems typically fall into three main categories:

- Spreadsheets
- Databases
- Commercial data programs (that typically use an internal database or data files).

Only the simplest of projects store chemical data in a spreadsheet. This document focuses on the management of chemical data projects that require the use of a database or commercial data management product.

3.5.2.2 Implementation of Data Storage System

Required

- The Project Manager must consult with the DBA in the selection and implementation of a database system. After analyzing the project and data requirements, the DBA provides information on staffing and level of effort to implement and maintain the selected data system.

- If the client requires the use of a particular commercial data product, the Project Manager must plan for the staff required to implement and maintain the product. The development of expertise to operate a commercial database system may require extensive staff training.

- Protect the original source data. All original EDDs or other source files used to populate the database must be protected from any type of corruption or editing to allow traceability back to source information and ensure data integrity.

- The database system must be secure, properly maintained, and protected. A professional DBA can provide information on security, maintenance, and disaster recovery policies.

- Regarding data storage systems, the CDMP must address the following topics:

Topic	Description
Storage Selection	Provide criteria used to select particular data storage system (client specified, small project requires Excel only, etc.)
Data Security	Specify types and locations of data users, and data security policies at user and network levels. Determine if external programs or services will require access to the data.
Data Processing	Specify the system for reviewing, importing, and updating data within the data storage system. The processing of EDD data is of particular importance.
Data Maintenance	Specify the plan for short- to long-term maintenance, disaster recovery, and protection of the data.
Final Delivery	Specify the final data deliverable to the client. The client may require data to be delivered in a specific file format external to the storage data system.
Analysis and Reporting Options	Specify if the data storage system will interface with other programs, or produce data for outside programs. A wide variety of commercial and custom programs can be used to generate charts, reports, and tables, and to conduct statistical analysis.

Guidelines

- In general, the use of spreadsheets as a final data repository should be avoided, except in the case of simple projects that have few samples and simple reporting requirements.

- If a DBA is not used to manage the data:

  — Plans for securing and protecting the data should be discussed with the Network Administrator to arrange for proper user access and file backup.

  — Identify the major types of data to be processed; generally, EDD files are the most frequent, and develop a reliable, consistent process for reviewing and processing the data.

  — Protect the source data and data integrity. A common problem to avoid is allowing multiple users to access multiple Excel data files for purposes of table and chart generation. This situation often results in users altering values, cutting and pasting sections of data, and corrupting the original files to make verification of source data impossible.

- There are many options to consider when selecting and implementing a chemical data storage system. Refer to Attachment A, Section 5, for details on the following topics:

Topic	Description
Comparisons of Spreadsheets and Databases	The pros and cons of using spreadsheets or database to store, analyze, and report chemical data.
EDD File Formats and Contents	Details on the EDD formats and fields included in a laboratory EDD. A generic EDD file format example is provided (Attachment B).
Generic Chemical Database Structures (Attachment C)	Description of tables and fields that can be used as a generic chemical database. The actual database is available for use as an Access2007 database.
Commercial/Agency Chemical Data Programs	Details on common commercial or government agency chemical data programs.
Data Processing and Database Updates	Details on updating data, data imports, corrections to data, and maintaining data integrity.
Network and Database Security	Details on network and database level security, user, and program access to data.
Long-Term Data Storage	Policy on long-term data storage and archiving.
Final Data Deliverables	Details on typical client data deliverables.

3.5.3 Data Analysis and Reporting System

A chemical database can be used as the central source data to satisfy a wide array of analysis and reporting requirements. Typically, the requirements consist of report tables, graphs, or data exports created in Excel. The basic approaches for creating tables, charts, and exports are:

- For projects with minimal requirements, the DBA can export data to spreadsheets that allow other users to create tables, charts, and reports from the export.

- For projects that have complex or long-term requirements, custom programs can be written to allow multiple users to select and create a wide variety of reports, tables, and charts directly from the database.

Required

- The Project Manager must have specifications on analysis and reporting requirements of the project.

- The Project Manager must evaluate the size, complexity, and frequency of the analysis and reporting requirements and determine the appropriate mechanism for generating the tables, charts, or exports.

Guidelines

- Using DBAs or skilled Data Coordinators to produce tables and charts directly from the database has several advantages over manually processing spreadsheet data:

  — Eliminates manual transcription or cut/paste errors

  — Database queries are able to produce summary data (sums, averages, counts, pivot tables) directly from the database

  — Database queries provide powerful linking, searching, and filtering options for data presentation

  — The source database remains protected.

- For long-term or complex reporting, implementation of a customized program can allow general users to produce automated tables and charts directly from the database. The programs provide flexibility in selecting sample dates, screening criteria, locations, and other fields contained in the database for reporting purposes. The program allows for multiple users and the source database remains protected.

- If using spreadsheets and manual creation of tables and charts, verification of reported data against the source data should be performed to ensure transcription/cut and paste errors have not occurred.

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Attachment A

Chemical Data Management Plan
Supporting Information

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1. REVIEW PROJECT REQUIREMENTS GUIDELINES

When defining the chemical data management requirements within the parent project, the following topics must be considered:

Topic	Considerations	Impacts
Project Objectives	What is the nature of the overall project? • Phase I investigation • Long-term monitoring • Remediation design and evaluation • Superfund • Commercial or government client? What are the data deliverables and schedules? • Report tables • Graphs/trends • Statistical analysis/modeling • Screening concentrations • Multiple event reporting • Actual data deliverable (database/electronic data deliverables [EDDs])	Reviewing the project plan gives the "big picture" of the scale of the project, requirements, schedule, and budget. Some project plans do not include any details on the chemical data component. Scrutinize any available requirements as early as possible and begin asking questions. Knowing the ultimate use of the data within the project helps to determine the level of technical expertise and staffing needed to manage, track, store, analyze, and report.
Technical Requirements	Are there any requirements supplied by the client such as: • Data Storage: Use of commercial or agency-specific chemical data programs • Are there any historical data to evaluate or incorporate • Data quality objectives: required laboratory certifications, detection limits, methods, types, and numbers of quality control samples • Reporting and Analysis Objectives: complex reports, risk assessments, trend analysis, permit limit evaluations • Final data deliverable specifications Will Information Technology/data technical support staff be required?	Many government agencies require specific data storage formats and programs that are generally very complex. Staff may require considerable training to develop the expertise. Standardization and merging of historical data (paper and electronic records) are generally labor intensive and require experienced database support. Using a non-approved laboratory or failing to provide the laboratory with the specific methods and data quality objectives can generate data that are invalid for project use. Complex reporting and analysis requirements may require Database Administrators (DBAs), statisticians, risk assessors, or report automation development. Some clients require the actual chemical data be supplied as a final product and may require a DBA to produce it. Data management experience levels and staffing costs must be considered.
Schedule, Budget, Logistics	Has the impact of the chemical data component on the overall project schedule, budget, logistics been evaluated? Has the level of effort for data management been realistically addressed in the parent project plan?	Must plan for limitations on laboratory data delivery, sample transport, holding times, laboratory capacity and capabilities, and analysis costs. Complex or long-term projects may require Information Technology support for database planning and report automation.

2. REVIEW FIELD SAMPLING PLAN GUIDELINES

When reviewing the field sampling plan, the following topics must be considered:

Topic	Considerations	Impacts
Sample Events	Will the project be a small single sampling event, or a long-term project, such as quarterly monitoring? What are the projected numbers and matrices of samples? What are the analysis methods (and analyte list) applied to each sample? Is regular analysis and reporting required per event?	Projects with large numbers of samples and methods will generally require a database system and a DBA to maintain it. Long-term projects benefit from the development of a sustainable, repeatable sampling, data processing, and reporting plan. Repeatable data analysis and report generation by staff may require development of an analysis/reporting automation program.
Sample Locations and Depths	Will the data be used by a Geographic Information System? Has client specified a coordinate system? Will soil samples require designation as surface or subsurface soils? Are there associated auxiliary data such as geological, hydrological, biological, or weather data?	Confirm the coordinates system to be used by the Geographic Information System. Defining depth levels for soil samples may be needed for later risk assessments or geological/hydrological studies, and generation of boring logs. The data may include well gauging and soil boring information to be stored and linked to the chemical data.
Sample Matrices and Quality Control Types	Are samples clearly identified by proper matrix identifiers (groundwater, surface water, leachate, etc.)? Will water samples require “total” and “dissolved” parameters? Does project require dedicated field quality control samples such as field and trip blanks, field duplicates, or extra samples for matrix spikes?	Project may require specific matrix identifiers, not just generic soil or water matrix provided by laboratory. Sample data must be coded to differentiate between total and dissolved, particularly for metals. Sample data must be coded to differentiate between normal field samples and quality control samples.

Topic	Considerations	Impacts
Sample Naming and Chain-of-Custody	What is the sample naming system? There are two main approaches to sample naming: • Embed all information in the field sample name • Use a simple code name but store the sample detail in an external file.	The Project Manager may prepare in advance a sample table with pre-designated sample names and sample information (depth, coordinates, location grid name, and matrix code). Some database systems have limits on the length of field sample names.
	How will the complex sample information, i.e., location, depth, matrix, sample date, and type be associated to laboratory sample?	The field sample name must be properly transferred from the container to the chain-of-custody, to the laboratory data system to allow later matching of field sample and laboratory data.
	By whom/how will the chain-of-custodies, laboratory data, and field sample information be tracked and integrated? What field sample information will the laboratory provide?	The laboratory will only provide the field sample name, sample collection date, and generic matrix (solid or water). All other original field sample information (location, depth, matrix, etc.) must be captured and maintained by the Project Manager.

3. REVIEW LABORATORY SPECIFICATIONS GUIDELINES

Environmental laboratories vary greatly in capacity, capabilities, certifications, areas of expertise, level of service, and pricing structures. The choice of a laboratory can be driven by many project requirements, or even specified by the client. After a laboratory has been selected, it is critical to establish a point-of-contact or laboratory Project Manager assigned to the project. The laboratory Project Manager must be informed of all project requirements, including the data quality objectives. For complex projects, the data quality objective plan will specify the methods, analyte lists, detection limits, precision and accuracy, numbers and types of quality control samples, and laboratory deliverable and reporting requirements.

Developing a data quality objective document is a complex process that has been well defined by several agencies. Providing a data quality objective plan to the laboratory is critical to ensure the laboratory has the information it needs to produce the desired data deliverable.

In general, all laboratories produce a hard copy report package that includes sample lists, chain-of-custodies, result tables, a data narrative that describes any sample or analytical issues, and various other supporting tables and appendixes as defined in the reporting requirements.

Although the hard copy report package is a standard deliverable, every laboratory is capable of generating an EDD. The EDD is a file (usually Excel, .csv, or text) that contains the sample and analysis data. Most laboratories have a standard EDD file structure that contains the most commonly used data fields: sample name, sample date, sample type, sample matrix, laboratory sample identification, method, total or dissolved, analysis date, preparation date, result, qualifier, unit. Most laboratories can easily create an EDD structure customized with extra fields as requested by the customer.

All projects should require an EDD as part of the laboratory deliverable.

The laboratory data, whether hard copy or EDD, may include analysis results for field samples, quality control samples, laboratory control samples, dilution, and re-analyses. The Project Manager must be prepared to have the raw data reduced to the final sample results that will be reported to the client.

Some projects require that the laboratory results be validated. Validation is generally performed by a third party validation contractor. The validator performs an extensive review on all results and supporting material to determine if the analyses were performed to meet all performance specifications and analysis requirements. The validator marks the hard copy reports and edits the EDD file to flag the unacceptable results, and issues a validation report.

When reviewing the laboratory requirements, the following topics must be considered:

Topic	Considerations	Impact
Laboratory Certifications	Does a project require specific state or agency certifications? Is the certification current?	The laboratory data may be considered void if the laboratory does not hold the proper certifications, or has an expired certification.
Quality Assurance Project Plan/ Data Quality Objectives	Review the project quality assurance project plan/data quality objectives. Does the laboratory perform the required methods at the required levels of detection? Does the project require use of reporting limits or method detection limits? Has the method analyte list been confirmed? Does the project require its own dedicated sample matrix spikes, duplicates, blanks, or other quality control samples?	Project may have very specific lists of approved methods and reporting limits. Laboratories provide published reporting and methods detection limits. Confirm that the methods will meet the project required detection limits. Confirm if the project requires non-detected results to be reported to the Reporting Limit or the Method Detection Limit. Generally, the Reporting Limit is 2-5 times higher than the Method Detection Limit. The list of chemical analytes for similar methods can vary. Confirm exactly which analytes are to be reported per method. If a project requires its own quality control samples, the laboratory must be informed and extra field samples must be supplied. Otherwise, laboratories batch multiple project samples together and select quality control samples at random.
Laboratory Reports and EDD	Does the report include all supporting material as specified in the quality assurance project plan/data quality objective? Does the laboratory EDD include quality control samples and re-analysis results that will require reduction? Does the standard laboratory EDD structure contain all necessary fields for project?	Clients may require all supporting material. The level of report detail must be specified. Laboratory Information Systems are capable of producing almost any EDD structure specified by the client. The contents of the EDD may also be specified. Inclusion of laboratory quality control samples and re-analysis data require careful sorting and filtering to reduce and extract the desired final data.
Data Validation	Does the data require validation?	Validation increases the data delivery time and may also cause some results to be rejected from project use. As a result, edits may need to be made to the EDD.

4. DATA TRACKING SYSTEM INFORMATION

4.1 OVERVIEW

The Data Tracking System is needed to monitor and review the many types of files generated by project field activities and laboratories. Many projects store diverse types of information in separate files, usually as spreadsheets. In addition to the expected laboratory data, other sources of data include:

.

- ***Location Data***—Geographic Information System coordinates, elevations, areas of concern, parcel designations, etc.
- ***Boring Log Data***—Geological strata, geological samples, organic vapor analyte, or photoionization detector readings, etc.
- ***Well Gauging Data***—Well construction data, water depths, elevations, product thickness, etc.
- ***Water Quality Data***—pH, oxidation reduction potential, turbidity, iron, etc.
- ***Field Analysis Data***—Soil gas analysis, metals by x-ray fluorescence, other mobile laboratory analysis, or field instrument data.
- ***Historical Records***—Paper or electronic files of chemical or hydrogeological data and associated auxiliary data.
- ***Screening Data***—Federal, state, or local limits for chemicals in water, soil, air, and tissue.

For example, within the same project, there may be spreadsheet files for field sample lists, soil boring data with personal digital assistant or organic vapor analyte readings, well gauging data, a list of chain-of-custodies submitted to the laboratory, a list of EDD files produced by the laboratory, actual laboratory EDD files, laboratory report .pdf files, and an Excel file of state water quality standards that will be applied to the chemical data for screening purposes.

These individual files must be checked for accuracy and completeness, and compared against each other to verify the related information can be linked in the future for final data storage and reporting.

4.2 ELECTRONIC DATA DELIVERABLE

EDD files are the preferred delivery and storage mechanism for laboratory data. Laboratories store data in large Laboratory Information Management Systems. They are capable of producing EDD files of almost any configuration to contain as much detail as required. Most laboratories

have a default EDD structure, but customers may specify the file format and content of the EDD file per project.

The use of EDD files has many benefits:

- Prevents manual data transcription errors.
- Allows for easy upload into data systems.
- Produces the EDD file and hard copy laboratory report from the same Laboratory Information Management System and contains identical data
- Produces EDD files on old historical data if they remain in the Laboratory Information Management System or in archive files
- Contains only field sample data, or includes a full array of laboratory and field quality control results.

General project EDD policies:

- All new projects should require EDD files as the part of the laboratory deliverable.
- Some commercial or agency–specific software programs have a required EDD structure that must be provided to the laboratory.
- If exact EDD fields are not specified by a client or software program, use the default EDD file specifications contained in Attachment B to Standard Operating Procedure 063. Other fields may be added to the default EDD structure as required by the project.

4.2.1 Data Validation

EDD files may require validation after the laboratory has produced them. Validation is generally conducted by a third-party company that specializes in laboratory data review. The laboratory data and documentation are reviewed against specific analysis protocols and data quality objectives to determine if the analyses were conducted as required. The validation process is complex and includes detailed review of items such as: instrument calibration logs, standard preparations, sample holding times, laboratory certifications, quality control procedures, and preparation and analysis logs. The validation process may flag and reject some data as not useable.

4.2.2 Other Electronic Files

The other data that may be provided electronically may include:

- ***Location Data***—Geographic Information System coordinates, elevations, areas of concern, parcel designations, etc.

- ***Boring Log Data***—Geological strata, geological samples, organic vapor analyte, or photoionization detector readings, etc.

- ***Well Gauging Data***—Well construction data, water depths, elevations, product thickness, etc.

- ***Water Quality Data***—pH, oxidation reduction potential, turbidity, iron, etc.

- ***Field Analysis Data***—Soil gas analysis, metals by x-ray fluorescence, other mobile laboratory analysis, or field instrument data.

- ***Historical Records***—Paper or electronic files of chemical or hydrogeological data and associated auxiliary data.

- ***Screening Data***—Federal, state, or local limits for chemicals in water, soil, air, and tissue.

These other sources of data are generally supplied as spreadsheet files, or small database files. They may also be files produced from other software programs as text or .csv files.

Regardless of the file type, all sources of data that will be incorporated into the project must be reviewed, standardized, and prepared for linking to the samples and chemical data.

4.2.3 Screening Criteria

Many projects require that the chemical data be linked and compared to various federal, state, local, or permit-driven screening criteria. The screening criteria provide human health- or ecologically-based limit values on the concentrations of chemicals in various matrices. Some projects require multiple sources of limits for each matrix. Generally, the screening criteria chemicals and limit values are available in electronic form from websites. The Project Manager must supply the exact source of screening limit values. The screening criteria data must be processed, standardized, and imported into the database to link properly to the sample matrices and chemical results.

4.2.4 Historical Records

Projects may require the use and integration of historical chemical data.

When working with historical chemical data, it may be necessary to use hard copy project report tables and old laboratory reports as the data source. Hard copy data can exist in several forms. Some of the most common forms are listed below:

- ***Laboratory Reports***—The best source of hard copy data is an actual laboratory report. It is the original source of the raw laboratory data and will not suffer from any post-laboratory edits.

- ***Project Report Tables***—These are tables that have been created from the laboratory data and are generally found in documents produced for the project. They are usually in the form of "crosstab" tables that have samples listed as columns and methods/analytes listed as rows. Report tables vary greatly in quality as described:

  — Tables produced by manual data transcriptions are subject to transcription errors. Those produced by database automation may be reliable, but there is usually no way to confirm the production mechanism.

  — The same report may have several different versions/presentations of the same data (i.e., all results, hits only, hits that exceeded criteria, detects only, critical analytes only, etc.).

  — Some reports tamper with qualifiers, detection limits, and non-detected values. Some non-detected values may be displayed as "ND," thus losing the numeric value of the detection limit. Qualifiers other than "U" (non-detect) may have been removed.

  — Some reports create summed analytes, i.e., "total polycyclic aromatic hydrocarbon"; "benzene, toluene, ethylbenzene, and xylenes"; total volatile organic analyte; etc. that are not part of the original laboratory data. It may not be known exactly which analytes are in the sum or how non-detects were handled.

  — Some reports have converted results from original laboratory units, such as changing milligrams per kilogram to micrograms per kilogram. Conversion errors may have occurred. Some tables may not have the units explicitly stated.

In general, try to select the report table that most closely resembles the results as typically presented in a laboratory report, i.e., where the numeric results and qualifiers appear to be intact.

When converting paper records to electronic files, the general process is to manually type the data into a spreadsheet or desktop database. Additional considerations of data conversion are:

- Any manually transcribed data must have a percentage of the data reviewed for completeness and correctness.

- For very large, complex records, consider the use of a data entry database system to enforce standardization, improve the data review process, and facilitate future data linking.

- Be sure to include auxiliary data that are associated with the analytical results.

4.3 DATA STORAGE SYSTEMS

There are two basic options for data storage: spreadsheet or database. If a database is needed, it can be a small-scale desktop database such as Access, or a large scale server database, such as SQL Server or Oracle. There are also many commercial and agency specific programs, all of which use database systems. There are many storage options described in the following sections.

4.3.1 Spreadsheets and Database Comparison

The first big decision to make in storage selection is to evaluate the need for using either a spreadsheet or database system. A summary of spreadsheet and database pros and cons are listed below.

Spreadsheets

Pros

- Are easy to use, no advanced technical expertise required
- Can cut and paste data to make new tables
- Can apply formulas to cells
- Can use filtering and sorting
- Can use macros for some automation.

Cons

- Poor data integrity: easy to destroy/corrupt original data by sorting, updating, and copying
- Poor standardization: sample, method, units, and chemical names can have multiple variations for same item
- Columns not enforcing data types (can have text in number fields, numbers in date fields, etc.)
- Large datasets cumbersome to store in multiple sheets or files
- Repeated data values: if a sample has 180 results, all of the sample information (location, depth, matrix, types, sample date, etc.) is repeated 180 times
- Data not stored in a relational structure: cannot link data, i.e., linking chemical results to chemical screening limits; requires manual comparison
- Limited security features for data or users.

Databases

Pros

- Provides many powerful benefits for storing data in a relational structure
- Better protects data integrity via enforcement of data types and elimination of redundant data storage
- Provides for data standardization: enforces standard method, chemical, and unit names
- Links and stores large amounts of data together
- Provides linked relationships to allow easy searching and comparisons
- Allows advanced programming, analysis, and report automation
- Provides better security, for users and data.

Cons

- Requires professional data staff to maintain and use the data.
- Requires development of a program interface to allow users to use, search, and report data.

In summary:

- Spreadsheets are extremely easy to use, but do not enforce data integrity/protection, and have no powerful searching, linking, or analysis capabilities. Spreadsheets should only be used on the simplest projects that have small data sets and limited analysis and reporting requirements.
- Databases provide better data integrity, standardization, and powerful searching, linking, analysis, and reporting capabilities, but require professional administration for use. Most projects will require the use of a database and services of a DBA.

4.3.2 Generic Chemical Database Structure

A generic desktop chemical database (Access 2010) is available from the Information Technology Services group. The database incorporates the following features:

- The design incorporates the common data elements captured by most commercial or agency-specific database programs.

- Standardized table and field names are used to denote reference (look-up) tables, field types, and primary/foreign key fields.

- This database is suitable for scaling up to larger database systems, such as SQL Server, if needed.

- This database can be easily modified to include additional tables or fields as needed.

The structure and relationships of the generic chemical database are presented in Figure 1.

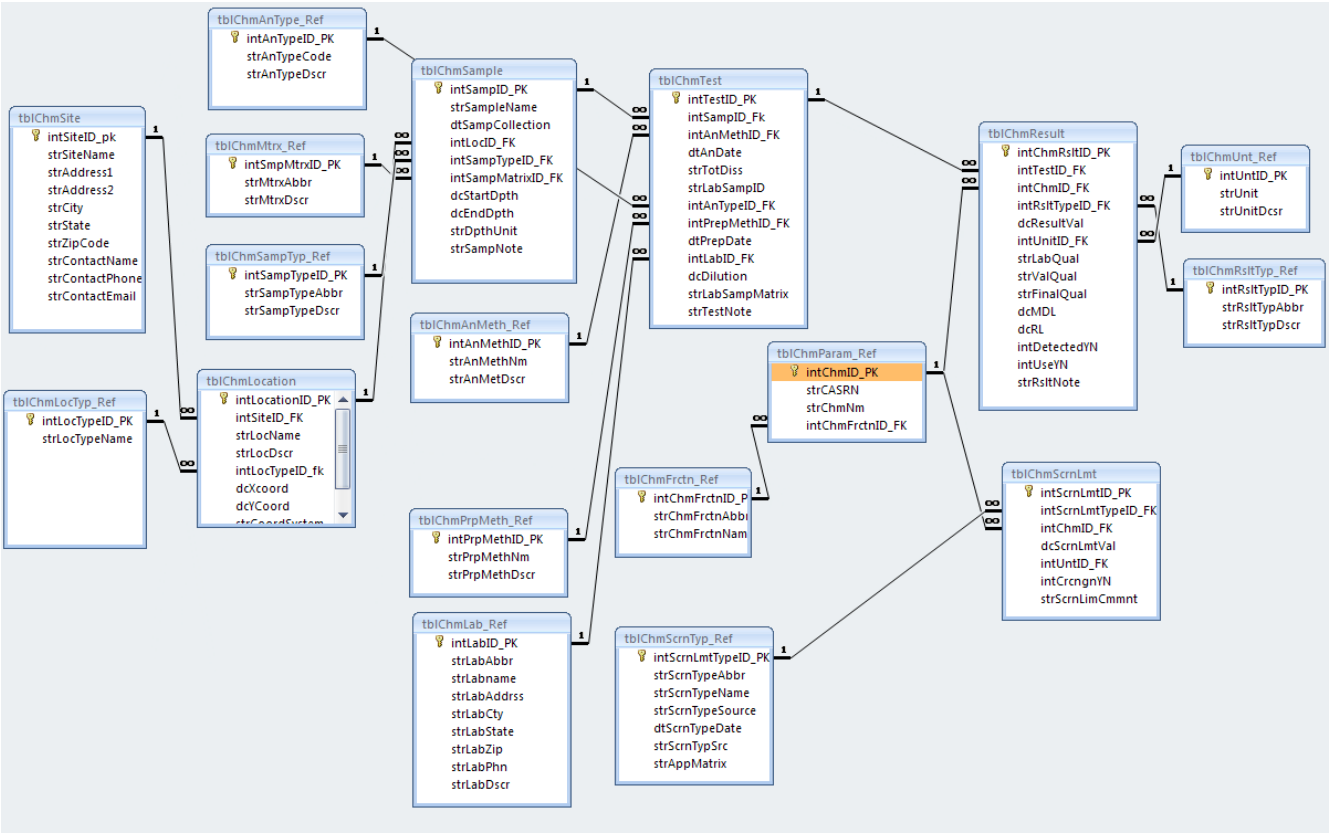


Figure 1. Generic Chemical Database Structure

The list of tables and fields in the generic chemical database are presented in Attachment C to Standard Operating Procedure 063.

4.3.3 Commercial and Agency Chemical Data Programs

There are several commercial and agency-specific chemical database programs available. These programs typically consist of a software application and an underlying database. The programs

are generally complex and tailored to the needs of the agency that produced them. They require extensive training and the development of staff expertise to use and maintain them.

Some of the commonly encountered chemical database products are:

- Equis® Chem and Geo
- Automated Data Review – U.S. Army Corps of Engineers
- Environmental Data Management System – U.S. Army Corps of Engineers
- Staged Electronic Data Deliverable – U.S. Environmental Protection Agency
- Environmental Resources Program Information Management System – Air Force Center for Engineering and the Environment.

These programs vary greatly in the quality and levels of performance, features, documentation, and technical support. Some programs are free, some require formal registration. The Equis® Chem and Geo software products, which are not government agency produced, have become increasingly popular and are in widespread use in many state agencies and U.S. Environmental Protection Agency regions, but are expensive to purchase and maintain.

Some database programs are "closed data source" and do not allow any access to the underlying database except via the software application. The user is limited to the importing, editing, reporting, and analysis features provided by the application. Database programs that provide open access to the database allow other customized tools to be developed and used with the database as a data source.

If a project requires the use of any commercial or agency chemical database programs, the Project Manager must investigate all costs, availability, training, and staffing issues associated with the procurement and use of these programs.

4.4 DATA MAINTENANCE

4.4.1 Database Updates

Many chemical database projects support long-term or periodic sampling programs. The Project Manager and Data Coordinator must plan for tracking and processing of new chemical data, from the laboratory source data to final data storage in the database. Many commercial and agency database programs include import modules to review and process the laboratory data into the database. Generic database systems can also include customized programs to review and process the data.

For large scale projects that may involve the review and processing of many chemical EDD files over time, it is critical to establish a uniform EDD file structure and content with the laboratory. Establishment of a standard, repetitive process for data review and importation will greatly increase the efficiency and quality of final data storage.

Database updates will be performed by the Data Coordinator or DBA.

4.4.2 Corrections and Data Integrity

As data are accumulated and reviewed, errors may be discovered. Depending on the type of error, corrections may be required to the database and to any source data files or documents.

It is of critical importance to maintain a chain of data integrity from the original data source to the database. If transcription errors were made on the chain-of-custody, laboratory report, or laboratory EDD file, the laboratory must be contacted to make the corrections and re-issue the source document or file. Making corrections to the database without notifying the laboratory will create discrepancies between the source data and the database.

Any reports generated from the database may be used for legal purposes and all results must be verifiable against the original source. Most chemical databases include fields to store information on the source of chemical data and, therefore, the database and the original data source must be kept synchronized; a change to the source data or a change to the database must be reflected in both to ensure data integrity.

The roles of Data Coordinator and DBA are designed to address the issues of tracking, coordinating, and documenting any data corrections.

4.4.3 Data Security

Access to the database and the source data must be controlled. There are many options available to protect data, depending on the type of database or data files used. Security guidelines are as follows.

4.4.3.1 Network Security

Most projects have a system of project folders established on a secure network. At a minimum, the chemical data source files and associated database can be organized and stored in folders accessible only to designated project personnel. Original source files must be protected from any modifications, and access to the database should be controlled using internal database security features.

4.4.3.2 Database Security

Many database programs have integrated security systems that allow secure user login and permissions for data operations within the database. Most database systems (generic,

commercial, or agency programs) have features to long-in users, and assign editing or read-only permissions to various users. Many "front-end" user programs limit users to the reporting and analysis features only, and allow only assigned DBAs permission to import or edit data within the database.

4.4.3.3 Long-Term Data Storage

Some chemical data projects can be active for many years. At the completion of any project, it is company policy that electronic files will be maintained for 4 years. If the database and associated source EDD files are not part of the client deliverable, the files will eventually be destroyed when the storage time limit is reached.

Refer to the EA Company "Records Retention Policy."

4.4.3.4 Final Deliverable

Most project plans will clearly state if the database or other data files are part of the final project deliverable. Some clients require only the analysis and reports of the data as the final deliverable, but not the data files. The Project Manager must confirm if any data files are required as a deliverable, and obtain the specifications for the files. In some cases, the client may require the original laboratory EDD files and the final database, or other final deliverable files that are created from the database.

Final deliverable files must be stored or archived in a secure location and are subject to the data storage policies of the company.

4.5 ANALYSIS AND REPORTING SYSTEMS

A database can be used as the source data to satisfy a wide array of analysis and reporting requirements. The Project Manager must define the analysis and reporting objectives. Typically, the requirements consist of report tables, graphs, or data exports. Suggested approaches for addressing those requirements are as follows.

For projects with minimal requirements:

- The DBA can export simple data exports to spreadsheets that allow other users to create tables, charts, and reports from the export.

- The DBA or other programmer can be directly used to create tables, charts, and graphs.

For projects that have complex or long-term requirements, custom programs can be written to allow multiple users to select and create a wide variety of reports, tables, and charts using the database as the data source. This approach is useful for long-term projects that have cyclical reporting of a complex nature. These customized programs allow users to select data by

locations, samples, date ranges, analytes to generate reports, tables, graphs, and even support automated document production.

Although programming the analysis and reporting process may not seem to be necessary for some projects, any report, table, or graph produced directly from the database eliminates the possibility of manual typing or transcription errors.

Attachment B

Generic
Electronic Data Deliverable Structure

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GENERIC ELECTRONIC DATA DELIVERABLE STRUCTURE

Laboratories are able to create a wide variety of electronic data deliverables from the Laboratory Information Management Systems. Many have default electronic data deliverables structures if one is not specified by the laboratory client. A generic electronic data deliverable structure is presented below that will serve most chemical data projects.

Column		Description	Column Name	Column Type
1	Field Sample Name	Name of sample as recorded on the chain-of-custody.	Fld_Samp_Name	Text
2	Sample Date/Time	Date (and time) of sample collection in field.	Fld_Samp_Date	Date/time
3	Lab Sample Identification	Laboratory sample identifier.	Lab_Samp_ID	Text
4	Lab Sample Matrix	Sample matrix, as assigned by the laboratory. Laboratories use a generic code to designate solid or liquid, and do not code for detailed matrix types such as groundwater, surface water, wastewater, etc.	Lab_Samp_Matrix	Text
5	Lab Sample Type	Sample type as assigned by the laboratory to identify laboratory quality control samples such as duplicates, matrix spike, and matrix spike duplicate. Laboratories should be blind to field blanks and field quality control samples.	Lab_Samp_Type	Text
6	Prep Method	Sample Preparation method code.	Prep_Method	Text
7	Prep Date/time	Sample Preparation date (and time).	Prep_Date	Date/time
8	Analysis Method	Sample Analysis method code.	An_Method	Text
9	Analysis Date/Time	Sample Analysis date (and time).	An_Date	Date/time
10	Analysis Type	Analysis Type such as normal, dilution, and re-analysis.	An_Type	Text
11	Total or Dissolved	Used to designate total or dissolved chemicals, usually metals in water samples.	Tot_Diss	Text
12	CAS Number	Chemical Abstracts Service (CAS) unique identifier for chemical. Some parameters such as total organic carbon, chemical oxygen demand, and oxidation reduction potential will not have CAS numbers.		Text
13	Chemical Name	Standard chemical name of analyte.	Chem_Name	Text
14	Result Value	Analysis result value, usually a concentration.	Res_Value	Number
15	Units	Result units of measure.	Res_Units	Text
16	Lab Qualifier	Laboratory assigned qualifier to the result, used to indicate details about the result. A "U" qualifier generally indicates a non-detected result.	Lab_Qual	Text
17	Method Detection Limit	The laboratory determined limit of detection for the given method, matrix, and analyte. The Method Detection Limit is generally 3-5 times lower than the Reporting Limit.	Method Detection Limit	Number
18	Reporting Limit	The laboratory Reporting Limit of detection for the given method, matrix, and analyte. The Reporting Limit is generally 3-5 times higher than the Method Detection Limit.	Reporting Limit	Number
19	Lab Name	Name or Code to identify laboratory.	LabID	Text
20	Validation Qualifier	Used for validated electronic data deliverable data only. The validation qualifier is used to flag results that do not pass the validation review, or to correct laboratory qualifiers.	Val_Qual	Text

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Attachment C

Generic Chemical Database Structure and Data Dictionary

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GENERIC CHEMICAL DATABASE STRUCTURE AND DATA DICTIONARY

The generic database was created using MS Access, but can be scaled up for use on larger database systems, such as MS SQL Server.

The tables and fields are defined in the following data dictionary.

tblChmAnMeth_Ref: Reference list of analysis methods, such as SW-8260, SW-8270

Name	Type	Size	Description
intAnMethID_PK	Long Integer	4	unique ID
strAnMethNm	Text	50	method name
strAnMetDscr	Text	50	method description

tblChmAnType_Ref: Reference list of analysis codes, used to sample designate tests as initial, re-analysis, dilution, etc.

Name	Type	Size	Description
intAnTypeID_PK	Long Integer	4	unique ID
strAnTypeCode	Text	255	Analysis type code, such as IN, DL, RE
strAnTypeDscr	Text	255	Analysis type description

tblChmFrctn_Ref: Reference list of chemical fractions used to group the chemical parameter list by VOA, SVOA, METALS, etc.

Name	Type	Size	Description
intChmFrctnID_PK	Long Integer	4	unique ID
strChmFrctnAbbr	Text	10	Analysis fraction (method group), such as VOA, SVOA, etc.
strChmFrctnName	Text	50	Analysis fraction description

tblChmLab_Ref: Reference list of laboratories, with lab contact information

Name	Type	Size	Description
intLabID_PK	Long Integer	4	unique ID
strLabAbbr	Text	10	short code for lab
strLabname	Text	50	long name of lab
strLabAddrss	Text	50	lab address
strLabCty	Text	50	lab city
strLabState	Text	50	lab state
strLabZip	Text	50	lab zip code
strLabPhn	Text	50	lab phone
strLabDscr	Text	255	lab fax

tblChmLocation: List of sampling locations including location coordinates.

Name	Type	Size	Description
intLocationID_PK	Long Integer	4	unique ID
intSiteID_FK	Long Integer	4	assigned site
strLocName	Text	255	location name
strLocDscr	Text	255	location description
intLocTypeID_fk	Long Integer	4	assigned location type (well, boring, vapor point, etc)
dcXcoord	Double	8	x-location coordinate
dcYCoord	Double	8	y-location coordinate
strCoordSystem	Text	255	standard coordinate system
dcZcoord	Double	8	z-location coordinate (elevation)

tblChmLocType_Ref: List of sampling locations types, such as wells, borings, vapor point, etc.

Name	Type	Size	Description
intLocTypeID_PK	Long Integer	4	unique ID
strLocTypeName	Text	255	Location type name (monitor well, discharge point, etc.

tblChmMtrx_Ref: List of sampling locations types, such as wells, borings, vapor point, etc.

Name	Type	Size	Description
intSmpMtrxID_PK	Long Integer	4	unique ID
strMtrxAbbr	Text	5	short code for matrix (GW, SO, SS, SED, etc)
strMtrxDscr	Text	70	matrix description

tblChmParam_Ref: List of chemical analytes, and other parameters such as DO, ORP, turbidity.

Name	Type	Size	Description
intChmID_PK	Long Integer	4	unique ID
strCASRN	Text	20	CAS registry number
strChmNm	Text	100	parameter name
intChmFrctnID_FK	Long Integer	4	assigned chemical fraction

tblChmPrepMeth_Ref: Reference list of preparation methods, such as SW-5030, etc.

Name	Type	Size	Description
intPrpMethID_PK	Long Integer	4	unique ID
strPrpMethNm	Text	50	method name
strPrpMethDscr	Text	255	method description

tblChmResult: Chemical analysis results for sample tests

Name	Type	Size	Description
intChmRsltID_PK	Long Integer	4	unique ID
intTestID_FK	Long Integer	4	assigned test identifier
intChmID_FK	Long Integer	4	assigned chemical or parameter ID
intRsltTypeID_FK	Long Integer	4	assigned result type (target, surrogate, normal)
dcResultVal	decimal	4	analysis result value
intUnitID_FK	Long Integer	4	assigned result unit (mg/L, ug/kg, etc.)
strLabQual	Text	10	laboratory result qualifier
strValQual	Text	10	validation result qualifier
strFinalQual	Text	10	final result qualifier
dcMDL	Double	8	method detection limit
dcRL	Double	8	reporting detection limit
intDetectedYN	Integer	2	detect/non-detect flag (yes/no)
intUseYN	Integer	2	reportable/ useable result flag (yes/no)
strRsltNote	Text	255	result note

tblChmResultType_Ref: List of analysis result types (TIC, Surrogate, normal)

Name	Type	Size	Description
intRsltTypID_PK	Long Integer	4	unique ID
strRsltTypAbbr	Text	10	result type code (TIC, SURR, N)
strRsltTypDscr	Text	50	description (tentatatively identified compound, surrogate, etc.)

tblChmSample: List of analysis result types (TIC, Surrogate, normal)

Name	Type	Size	Description
intSampID_PK	Long Integer	4	unique ID
strSampleName	Text	255	field sample name
dtSampCollection	Date/Time	8	date/time of sample collection
intLocID_FK	Long Integer	4	assigned location ID
intSampTypeID_FK	Long Integer	4	assigned sample type ID
intSampMatrixID_FK	Long Integer	4	assigned sample matrix ID
dcStartDpth	Double	8	sample start depth
dcEndDpth	Double	8	sample end depth
strDpthUnit	Text	255	depth unit (feet, meters, etc)
strSampNote	Text	255	sample note

tblChmSampleType_Ref: List of sample types (normal, field duplicate, trip blank, etc)

Name	Type	Size	Description
intSampTypeID_PK	Long Integer	4	unique ID
strSampTypeAbbr	Text	10	sample type code (N, FB, TB, etc)
strSampTypeDscr	Text	255	description

tblChmScreenLmt: regulatory limit values, per chemical

Name	Type	Size	Description
intScrnLmtID_PK	Long Integer	4	unique ID
intScrnLmtTypeID_FK	Long Integer	4	assigned screen limit type ID
intChmID_FK	Long Integer	4	assigned parameter ID
dcScrnLmtVal	Decimal	16	screening limit value
intUntID_FK	Long Integer	4	assigned unit ID
intCrcngnYN	Byte	1	carcinogen yes/no
strScrnLimCmmnt	Text	50	screen limit note

tblChmScrnType_Ref: type of limit, such as Federal MCL, regional PRGS, etc.

Name	Type	Size	Description
intScrnLmtTypeID_PK	Long Integer	4	unique ID
strScrnTypeAbbr	Text	20	short code for limit type
strScrnTypeName	Text	75	long name of limit type
strScrnTypeSource	Text	255	limit source, such as document or web site.
dtScrnTypeDate	Date/Time	8	limit issue/ effective date
strScrnTypSrc	Text	250	limit source, such as document or web site.
strAppMatrix	Text	255	applicable matrices for limit type

tblChmSite: Stores list of sites, for projects that may have sample locations at multiple sites defined in the project.

Name	Type	Size	Description
intSiteID_pk	Long Integer	4	unique ID
strSiteName	Text	255	site name
strAddress1	Text	255	site address 1
strAddress2	Text	255	site address 2
strCity	Text	255	site city
strState	Text	255	site state
strZipCode	Text	255	site zip code
strContactName	Text	255	site contact person name
strContactPhone	Text	255	site contact person phone
strContactEmail	Text	255	site contact person e-mail

tblChmTest: Sample test, consists of sample ID, analysis and prep method, analysis date, and other testing information.

Name	Type	Size	Description
intTestID_PK	Long Integer	4	unique ID
intSampID_Fk	Long Integer	4	assigned sample ID
intAnMethID_FK	Long Integer	4	assigned analysis method ID
dtAnDate	Date/Time	8	analysis date
strTotDiss	Text	1	total or dissolved method (for metals)
strLabSampID	Text	255	laboratory sample name
intAnTypeID_FK	Long Integer	4	analysis type ID
intPrepMethID_FK	Long Integer	4	preparation method ID
dtPrepDate	Date/Time	8	preparation date
intLabID_FK	Long Integer	4	laboratory ID
dcDilution	Double	8	dilution factor
strLabSampMatrix	Text	255	laboratory matrix code (usually W or S)
strTestNote	Text	255	test note

tblChmUnit_Ref: list of result units

Name	Type	Size	Description
intUntID_PK	Long Integer	4	unique ID
strUnit	Text	20	unit (mg/L, ug/kg, etc)
strUnitDcsr	Text	100	description

Standard Operating Procedure No. 064
Sediment Boring Logs

Prepared by

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031

Revision No. 0
December 2014

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1. INTRODUCTION

This Standard Operating Procedure (SOP) describes EA Engineering, Science, and Technology, Inc., PBC's (EA's) standard format for the completion of sediment boring logs. Applicable sample collection techniques considered for this SOP include traditional/sonic drill rig, sediment corers (manual, piston, vibracore, etc.), or grab type (Van Veen, Ponar, Peterson, etc.) sampling equipment. Adherence to a standard log format is necessary to ensure completeness of the log and to facilitate the comparison and correlation of logs completed by different personnel.

Other relevant EA SOPs potentially relating to sediment site characterization activities include:

SOP No.	Title	Revision	Date
001	Labels	0	August 2007
002	Chain-of-Custody Form	0	August 2007
003	Subsurface/Utility Clearance	0	August 2007
004	Sample Packing and Shipping	0	August 2007
005	Field Decontamination	0	August 2007
008	pH Measurement	0	August 2007
009	Temperature Measurement	0	August 2007
010	Water Level and Well Depth Measurements	0	August 2007
011	Photoionization Detector (MiniRae)	0	August 2007
015	Document Control System	0	August 2007
016	Surface Water, Groundwater, and Soil/Sediment Field Logbooks	0	August 2007
021	Sediment Sampling	1	August 2010
022	Sediment and Benthic Macroinvertebrate Sampling with Eckman Grab	0	August 2007
023	Organic Vapor Analyzer (Foxboro 128 GC)	0	August 2007
024	Photoionization Detector (Microtip HL-200)	0	August 2007
035	Small Boat Operations	1	August 2010
036	Turbidity Measurements (DRT 100)	0	August 2007
037	Dissolved Oxygen Measurements (YSI Model 57)	0	August 2007
038	Redox Potential Measurements	0	August 2007
039	Sample Preservation and Container Requirements	1	April 2012
041	Sludge/Lagoon Sampling	0	August 2007
042	Disposal of Investigation-Derived Material	0	August 2007
046	Aqueous Diffusion Samplers	0	August 2007
047	Direct-Push Technology Sampling	0	August 2007
052	Generic Quality Control Plan for Ecosystem Restoration Project Plans and Specifications Phase	0	August 2007
054	Collecting Fish Tissue for Chemical Analysis	0	August 2009
059	Field Logbook	1	November 2012
060	Avian Egg Collections	0	March 2012

Project-specific plans will supplement and may modify this standard format. Generally, elements of a project-specific plan that modify and supersede the standard format are identified as such in the Project Plan. EA recognizes that other protocols have been developed that meet the criteria of quality and reproducibility. Clients may have their own sediment sampling protocols that contain methodologies and procedures that address unique or unusual site-specific

conditions or may be in response to local regulatory agency requirements. In such cases, EA will compare both EA's and the client's protocols. The goal is to provide the client with the highest quality; therefore, if the client's protocols provide as much or more quality assurance than EA's protocols for the particular site or project, EA will adopt those specific protocols and this SOP will be superseded in those respects. If EA is required to implement the client's protocols in lieu of EA's protocols, EA will make the client formally aware of any concerns regarding differences in protocols that might affect data quality and will document such concerns in the project file.

A pre-mobilization conference is generally held to ensure that all personnel understand the project objectives and protocols. During the pre-mobilization conference, the Project Manager and/or Principal Investigators will review the project plans and discuss their impact or lack thereof on EA's SOPs. Prior to the pre-mobilization conference, the field geologist/engineer must develop a thorough understanding of all project-specific plans, as well as EA's SOPs, for the planned field activities. This should ensure that any potential conflicts can be resolved before initiating work.

An EA geologist/engineer shall be present on each operating drill rig or sampling vessel and will be responsible for ensuring the proper equipment is onsite (Attachment A), logging of samples, monitoring of sampling operations, recording of relevant field conditions, and preparing the boring logs. Attachment B provides a checklist of field geologist/engineer activities during sampling. Each geologist/engineer shall have a copy of the Sampling Plan and the approved Safety and Health Plan onsite.

Figure 1 illustrates the standard form for sediment boring logs. Examples of completed logs for a drilling, core, or grab sample are provided in Figures 2 through 4. Logs shall be recorded directly on the standard forms in the field without transcribing from a field logbook or other documents. This procedure reduces offsite work hours for the field geologist/engineer, reduces the potential for errors of manual copying, and allows the completed document to be field reviewed closer to the time of collection.

2. PURPOSE

This SOP provides requirements, guidelines, and general information to consider in the planning, development, and collection of a sediment sample via drilling, core, or grab. It will provide guidance on:

- Standard log completion
- Soil/sediment classification
- Field condition assessment
- Documentation requirements.

3. SCOPE

The requirements and guidelines are applicable to all sediment site investigation projects with soil/sediment characterization components.

4. DEFINITIONS

Drilling—For purposes of this SOP, a boring generally refers to a sediment sample location where a drill rig is employed for sample collection. However, the term "boring log" is used to describe the documentation collected and standard form used at all sediment sampling locations independent of the sample collection method.

Core—Sediment cores provide a cross section of site sediment and allow for vertical delineation of site parameters. Core samples can be collected through a variety of methods such as manual coring, piston coring, and vibracoring. Core tubes may include a flexible or rigid liner that can be extracted for visual observation and/or subsampling.

Grab—Grab samplers are typically used for collecting surface sediments. Grab samplers can provide a horizontal delineation of surficial materials or can be subsampled with core tubes or other subsampling equipment.

5. PROCEDURE

A boring log is completed for all sediment borings collected for site characterization purposes and projects with sediment characterization components. All items are completed in the field by the responsible geologist/engineer. The first line of the log shall be completed to indicate the: **Client and Project Name**, assigned **Location/Boring Name**, and **page number and total number of pages**.

The upfront section of the log includes information on the sample location, sampling equipment and methodology, surface conditions, and other general information on Location/Boring that may be useful for interpreting results. Following the general information section of the log is the Description of Materials section. This portion of the log is designed to collect required information on sediment characteristics and sediment classification.

5.1 GENERAL INFORMATION PORTION OF SEDIMENT BORING LOG

The items listed below follow the field numbering and categories as presented on the sediment boring log template (Figure 1).

1. ***Geologist Name/Signature***—The field geologist/engineer completing the log shall sign his/her full name on the first page of the log for each boring in a clear and legible fashion. Initials will suffice on succeeding pages of the log. The signature/initials are placed upon completion of each page of the log as certification of the accuracy and completeness of

the log by the field geologist/engineer. In the event there is a personnel change prior to completion of the boring log, personnel involved, date, and time (24-hour clock) of change shall be documented in the descriptive portion of the log at the depth where the change occurred.

2. ***Drilling Subcontractor/Equipment Operator***—The full name (legal, business name) of the drilling/sampling company shall be placed on the first page of the log for each boring. For projects where a regulatory agency or EA personnel are operating the sampling equipment, Item 2 shall be completed with the name of the Equipment Operator (e.g., "EPA GLNPO Mudpuppy" or "EA"). Any change shall be documented as per Item 1.

3. ***Operator Name and License (if required)***—The full name of the individual operating the sampling equipment shall be placed on the first page of the log for each boring. In states that require a licensed driller for the type of work in progress, the driller's license number shall also be placed on Line 3 of the first page of the log for each boring. Any change shall be documented as per Item 1.

4. ***Sampling Equipment and Methodology***—The drilling/sampling equipment and methodology shall be summarized on the first page of each boring log (and continued on succeeding pages as necessary). Record the type of sediment sampler used (drill rig, core, manual, and grab sampler) and any modifications made to the sampler.

    - ***Drill Rig Borings***—Record the barrel length, diameter, and sample interval. The field logbook should include general information on the drill rig manufacturer and model. Note such information as rod size, bit type and size, internal and external diameter of hollow stem augers, pump or compressor size, etc.

    - ***Core Samples***—Record the length and diameter of the core barrel and circle the type of corer used.

    - ***Grab Samplers***—Record the dimensions of the grab sampler and circle the type of grab sampler used (Van Veen, Ponar, Peterson, etc.).

    - ***Other***—Use the other row to indicate alternative sampling equipment.

    - ***Sampling Methodology***—Indicate the sample collection methodology intended for the core section. The method(s) for obtaining samples and subsamples shall be identified on the first page of each boring log (and continued on succeeding pages as necessary). For drilling operations, the citation of ASTM International designations on this portion of the log constitutes the field geologist/engineer's certification that the ASTM standard was met.

5. ***Project Number***—EA's alpha-numeric job code shall be indicated on each page of each boring log.

6. ***Latitude/Northing/Grid***—Coordinates of latitude/northing/grid shall be indicated on the first page of the log for each surveyed boring. This information may be acquired by on-vessel Global Positioning System equipment or a site survey if sediment sampling is occurring in a marsh, shallow stream, or other accessible location. Surveyed information may be added in the office or to a database in the field depending on project requirements. In either case, all quality assurance/quality controls for the survey data must be met. The use of a site datum shall be indicated on the log. If a site grid is utilized, the site grid coordinates shall be indicated on the field log and identified as such.

7. ***Longitude/Easting/Grid***—Coordinates of longitude/easting/grid shall be indicated on the first page of the log for each surveyed boring. This information may be acquired by on-vessel Global Positioning System equipment or a site survey if sediment sampling is occurring in a marsh, shallow stream, or other accessible location. Surveyed information may be added in the office or to a database in the field depending on project requirements. In either case, all quality assurance/quality controls for the survey data must be met. The use of a site datum shall be indicated on the log. If a site grid is utilized, the site grid coordinates shall be indicated on the field log and identified as such.

8. ***Start-Stop (Date/Time)***—The time (24-hour clock) and date drilling/sampling operations begin and end, including grouting or completion of well installation, shall be indicated on the first page of each boring log. The time and date of completion of sampling activities shall be documented in the descriptive portion of the log at the depth of penetration of the last sample or sample attempt. For borings completed in more than 1 day, the time and date drilling operations stop and resume shall be indicated to the descriptive portion of the log at the appropriate depth.

9. ***Sediment Surface Elevation***—The elevation of the sediment surface at the sample location shall be indicated on the first page of each boring log. This information may be acquired using on-vessel equipment or a site survey if sediment sampling is occurring in a marsh, shallow stream, or other accessible location. Sediment surface elevation must be tied to a coordinate system. Water depth measurements (see Item 11 below) can be used to calculate sediment surface elevations if they are referenced to regulated gauging station and corrected for water level fluctuations. The appropriate gauging station should be identified in the Project Plan. Surveyed information is added or checked as per Item 7.

10. ***Coordinate System***—Both horizontal (H) and vertical (V) control data shall be indicated on the first page of the log.

11. ***Depth of Water (Start)***—The water depth shall be determined and recorded at the beginning of sampling operations.

12. ***Depth of Water (End)***—The water depth shall be determined and recorded at the completion of sampling operations.

13. ***Sunny/Cloudy/Rain***—Surface conditions at the sampling site shall be indicated on the first page of the log and continued on succeeding pages.

14. ***Temperature (Degrees Fahrenheit)***—Air temperature at the sampling site shall be indicated on the first page of the log and continued on succeeding pages. Temperature should be recorded as degrees Fahrenheit.

15. ***Wind Direction***—Wind direction at the sampling site shall be indicated on the first page of the log and continued on succeeding pages.

16. ***Total Boring Depth***—The total depth (+0.1feet [ft]) of penetration at the time of the sampling attempt shall be reordered for each sampling attempt. For drilling operations, casing depth shall be no greater than the shallowest portion of the attempted sample interval.

17. ***Recovery Depth***—The total length of recovery should be recorded and the percent recovery should be calculated and indicated on the boring log.

18. ***Location Notes***—Item 18 on the log provides a space for additional observations at a location. These observations may include but are not limited to:

    - A narrative description of problems and their resolutions, e.g., refusal, sample wash-out, hole caving, "running sands," recurring problems at a particular depth, excessive grout takes, unrecovered tools, casing or screens, etc.

    - Observations of surface features adjacent to a location (piers, pilings, tributaries, outfalls, etc.)

    - Field measurements collected at the location (e.g., photoionization detector, pH, redox, etc.).

5.2 DESCRIPTION OF MATERIALS

1. All information in the descriptive portion of the log is placed with reference to the depth scale in the **Interval (ft)** column. The field geologist/engineer shall indicate units on the depth in feet scale as appropriate. The sample interval shall be indicated on the left side of the column as shown on Figures 2 through 4.

2. Observations on the length and appearance of recovered cores shall be recorded in the **Recovery (ft & %)** Column.

3. During drilling operations (this item does not apply to core or grab samples), for each sediment sampling attempt, the type of sampler shall be indicated at the appropriate depth.

4. For drilling operations (this item does not apply to core or grab samples), the total number of inches the sampler is advanced (actual penetration) into undisturbed sediment and the total number of inches of actual sample recovered shall be recorded for each sampling attempt.

5. For drilling operations between sampling attempts, wash samples, drill, or auger cuttings shall be described as to color and grain size, along with a description of drill action and water loss gains for the corresponding depth. The brand name and amount of any bentonite used for each boring, reason for use, and start (by depth) of this use shall be recorded. A narrative description of the grouting of the bore hole shall be recorded on the boring log (below the depth of completion and/or on succeeding pages).

6. The depth of each significant lithologic change shall be drawn to scale (+ 0.1 ft) on the **Description of Materials** column. Lithology shall be designated by the appropriate Unified Soil Classification System symbol (Attachment C). Changes observed in samples shall be indicated with a solid line. Changes inferred on the basis of cuttings or action of the drill rig shall be indicated with a dashed line on the graphic log and described in the narrative log. Gradational changes shall be indicated by a dashed, diagonal line extending over the depth of the gradational interval.

7. For drilling operations, the number of hammer blows required to advance a split-spoon sampler shall be recorded for each 0.5-ft advance for each sampling attempt. The number of blows and number of inches penetrated for a completed 0.5-ft interval shall be recorded (e.g., 75/3 inches [in.]). The letter "P" shall indicate that the sampler was advanced by the weight of the drill stem or the weight of the drill stem and hammer without driving. For the Standard Penetration Test (and only for the Standard Penetration Test), when less than 18 in. (but greater than 12 in.) are penetrated by a total (maximum allowable) of 100 blows, the number of blows for the last 12 in. of penetration (N) shall also be recorded (e.g., N=63).

8. The vertical location of samples shall be indicated in the **Sample ID Sample Interval** column as shown on Figures 2 through 4.

9. Each core/sample recovered shall be fully described on the log (for the complete depth of sediment collected at a location (i.e., if a 10-ft core was collected, the entire core should be logged including any intervals that were sampled). The descriptions of intact samples shall include in sequence the following:

   - ***Color (e.g., gray or reddish brown)***—Some project plans may specify the use of the Munsell Soil Color Chart or the Geological Society of America Rock Color Chart. If so, the chart shall be identified in the **Description of Materials** and both narrative and numerical descriptions of color shall be recorded in the log.

- ***Moisture Content (e.g., dry, moist, or wet)***—Below the water table, moisture content is noted only for samples less than completely saturated.

- ***Unified Soil Classification (e.g., sandy clay)***—Attachment D summarizes the Unified Soil Classification System Field Classification. Additional guidance is provided in Tables 1 and 2.

- ***Secondary Components (e.g., with some silt)***—Descriptive terms for relative proportions of secondary components are provided in Table 1.

- ***Unified Soil Classification Symbol (e.g., CL)***—Refer to Attachment D.

- ***Density (non-cohesive soil) (e.g., medium dense)***—Refer to Table 1.

- ***Consistency (cohesive soil (e.g., stiff)***—Refer to Table 1.

- ***Other Observations***—Presence of biota or debris, oily sheen, the presence/location/thickness of the redox potential discontinuity layer.

5.3 ASTM DESIGNATIONS D-2487 AND D-2488 DEFINE STANDARD ENGINEERING PRACTICE

1. Samples that are retained in jars and/or tubes (or other appropriate containers as per the Project Plan) shall be numbered sequentially down the core. Unsuccessful sampling attempts shall not be numbered. For drilling operations, individual samples from one sampler drive shall be numbered individually. The sample number and depth (+ 0.5 ft) of the top of that portion of the sample that is retained shall be recorded for each sample.

   Each sample container shall be labeled. The label shall be permanently marked (e.g., Sharpie) and shall identify the following:

   - Client and project name
   - Location/boring name
   - Collected by
   - Date of sample collection.

   Chain-of-custody requirements may also apply as per the Project Plan. Containerization and handling of sediment samples scheduled for chemical analysis are defined in the Project Plan.

2. A number of field determinations may be made in the field as per the Project Plan. These include but are not limited to:

- Sediment temperature
- Dissolved oxygen concentration in the water column above the sediment surface
- Salinity or conductivity of the overlying water column
- Sediment redox potential
- Pocket penetrometer readings
- Screening for organic vapors with a photoionization detector or flame ionization detector
- pH
- Specific conductance.

Protocols are established in the Project Plan. As appropriate, the protocol shall be identified in Item 18 and the data recorded in the **Description of Materials** column with reference to the depth scale.

3. Each boring log shall be checked for completeness and edited as appropriate by a qualified geologist or engineer (reviewer) to be assigned by the project manager or Director of Geotechnical Services. The review shall be completed prior to preparation of final boring logs in report format. Editing of sample descriptions and soil classifications shall be performed as appropriate for all samples for which laboratory physical testing (e.g., grain size distribution by sieve and hydrometer) has been performed. Sample descriptions and soil classification shall also be checked by visual examination of jar samples. Typically, a minimum of 25 percent of the jar samples are reviewed. The reviewer shall initial and date Item 1 (Geologist Name/Signature) of each edited page of the log he/she reviews.

6. DOCUMENTATION

When sampling has been completed, the sampling technician should ship the samples or deliver them to the laboratory in accordance with project procedures. Appropriate sampling documentation should be provided to the project data manager in accordance with applicable project procedures.

7. REFERENCES

ASTM International. 1993. Standard Guide for Collection, Storage, Characterization and Manipulation of Sediments for Toxicological Testing (EL-391-93). American Society for Testing and Materials, Philadelphia, Pennsylvania.

Murdoch, A. and S. MacKnight. 1994. Handbook of Techniques for Aquatic Sediment Sampling 2nd Edition. Lewis Publishers. Boca Raton, Florida.

U.S. Environmental Protection Agency. 2001. Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual. EPA-823-B-01-002. Office of Water.

Figures

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Figure 1 Sediment Boring Log Template

LITHOLOGIC LOG *Sediment Collection Log* *EA Engineering, Science, & Technology, Inc.*	Client Name and Project Name	Location/Boring Name	Sheet of
1 Geologist Name/Signature	5 Project Number	8 Start - Stop (Date/Time)	
2 Drilling Subcontractor/Equipment Operator	6 Latitude/Northing/Grid	9 Sed Surface Elevation *ft* 10 Coordinate System H V 11 Depth of Water (start) *ft*	
3 Operator Name *(License # If Required)*	7 Longitude/Easting/Grid	12 Depth of Water (end) *ft* 13 Sunny/Cloudy/Rain 14 Temperature (start/high) *F*	
4 Sampling Equipment and Methodology (Check One) Rotosonic: ___ -ft barrel ___ -in diameter _____ -ft spoon/sample Core: ___ -ft barrel ___ -in diameter _____ -VPM Manual/Vibracore/Other Grab Sample: -ft x -ft x -ft Box/Ponar/Van Veen/Other Other: Sample Collection Method:		15 Wind Direction 16 Total Boring Depth *ft* 17 Recovery Depth ft *%* 18 Location Notes	

Interval *(Depth)*	Recovery *(ft & %)*	Description of Materials Munsell Color; Moisture; Density; Consistency (Other Remarks)	Sample ID Sample Interval	PID *(ppm)*	USCS *Code*
1					
2					
3					
4					
5					
6					
7					
8					
9					
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Figure 2 Example Sediment Boring Log for Drilling

LITHOLOGIC LOG *Sediment Collection Log* *EA Engineering, Science, & Technology, Inc.*	Client Name and Project Name **GLNPO/Spirit Lake**	Location/Boring Name **GL-DS-01-001**	Sheet **1** of ***1***

1	Geologist Name/Signature **Jaime Smith**	5	Project Number **1234567**	8	Start - Stop (Date/Time) **6/19/14 12:00** — **6/19/14 15:00**
2	Drilling Subcontractor/Equipment Operator **Drill Company A**	6	Latitude/Northing/Grid **649999.89**	9	Sed Surface Elevation **580.018** *ft*
				10	Coordinate System H **NAD83** V **NAVD88**
				11	Depth of Water (start) **20** *ft*
3	Operator Name *(License # If Required)* **Joe Smith 08976**	7	Longitude/Easting/Grid **10649999.89**	12	Depth of Water (end) **20** *ft*
				13	Sunny/Cloudy/Rain
				14	Temperature (start/high) **65** *F*

4	Sampling Equipment and Methodology (Check One)			15	Wind Direction **NE**
X	Rotosonic: **20** -ft barrel **5** -in diameter **2** ft spoon/sample			16	Total Boring Depth **20** *ft*
	Core: ___ -ft barrel ___ -in diameter ___ -VPM Manual/Vibracore/Other			17	Recovery Depth **20** ft **100** %
	Grab Sample: ___ -ft x ___ -ft x ___ -ft Box/Ponar/Van Veen/Other			18	Location Notes **Location was adjacent to a cluster of pilings, just north of West Ditch Tributary.**
	Other:				
	Sample Collection Method: **2 ft sample intervals collected from split spoon**				

Interval *(Depth)*	Recovery *(ft & %)*	Description of Materials Munsell Color; Moisture; Density; Consistency (Other Remarks)	Sample ID Sample Interval	PID *(ppm)*	USCS *Code*
1 (0-3)	2/100%	Strong Brown (7.5YR 5/6); dry; SILT and fine SAND; non-plastic; soft		0.0	ML-SW
2		Poorly graded.		0.1	
3				0.1	
4 (3-5)	2/100%	Brown (7.5YR 4/3); moist; SILT little SAND and CLAY; nonplastic; soft	*GL-DS-01-03-05*	0.0	ML
5		well graded.		0.2	
6 (5-6)	1/100%	Light Greenish Gray (Gley 1 10YR); moist; fine SAND and SILT; nonplastic; med stiff.		0.0	SM
7 (6-10)	4/100%	Dark Greenish Gray (Gley 1 4/1); fine SAND some SILT; m. dense;		0.1	SM
8		well graded.		0.1	
9				0.1	
10				0.1	
11 (10-15)	4/80%	Greenish Gray (Gley 1 6/1); fine SAND some SILT, m. dense; well graded.		0.2	SM-ML
12				0.1	
13			*GL-DS-01-13-14*	4.5	
14		Increasing silt percentage.		0.1	
15				0.1	
16 (15-19)	5/100%	Light Yellowish Brown (2.5Y 6/4) with Light Greenish Gray (Gley 1 10/1)		0.2	CL
17		mottles; CLAY some SILT trace fine SAND; low plasticity; stiff; well graded.		0.1	
18				0.2	
19				0.5	
20			*GL-DS-01-19-20*	1.1	
21		*Total depth = 20 feet below top of surface.*			
22					
23					
24					
25					
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27					
28					
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30					
31					
32					
33					
34					
35					

Figure 3 Example Sediment Boring Log for Core Samples

LITHOLOGIC LOG *Sediment Collection Log* *EA Engineering, Science, & Technology, Inc.*	Client Name and Project Name **GLNPO/Spirit Lake**	Location/Boring Name **GL-SD-01-001**	Sheet **1** of **1**

1 Geologist Name/Signature **Jaime Smith**	5 Project Number **1234567**	8 Start - Stop (Date/Time) **6/19/14 12:00** — **6/19/14 15:00**	
2 Drilling Subcontractor/Equipment Operator **Drill Company A**	6 Latitude/Northing/Grid **649999.89**	9 Sed Surface Elevation: **580.018** *ft* 10 Coordinate System: H **NAD83** V **NAVD88** 11 Depth of Water (start): **20** *ft*	
3 Operator Name *(License # If Required)* **Joe Smith 08976**	7 Longitude/Easting/Grid **10649999.89**	12 Depth of Water (end): **20** *ft* 13 Sunny/Cloudy/Rain 14 Temperature (start/high): **65** *F*	
4 Sampling Equipment and Methodology (Check One) Rotosonic: ___ -ft barrel ___ -in diameter ___ -ft spoon/sample **X** Core: **10** -ft barrel **3** -in diameter **5000** -VPM Manual/Vibracore/Other Grab Sample: ___ -ft x ___ -ft x ___ -ft Box/Ponar/Van Veen/Other Other: Sample Collection Method: **Lexan liner capped, transported vertically to shore for subsampling on 2 ft intervals**		15 Wind Direction: **NE** 16 Total Boring Depth: **10** *ft* 17 Recovery Depth: **9** ft **90** % 18 Location Notes: **Location was adjacent to a cluster of pilings, just north of West Ditch Tributary.**	

	Interval (Depth)	Recovery (ft & %)	Description of Materials Munsell Color; Moisture; Density; Consistency (Other Remarks)	Sample ID Sample Interval	PID (ppm)	USCS Code
1	(0-3)	2/100%	Strong Brown (7.5YR 5/6); dry; SILT and fine SAND; non-plastic; soft		0.0	ML-SW
2			Poorly graded.			
3						
4	(3-5)	1/50%	Brown (7.5YR 4/3); moist; SILT little SAND and CLAY; nonplastic; soft	*GL-DS-01-03-05*	0.0	ML
5			well graded.		0.1	
6	(5-6)	1/100%	Light Greenish Gray (Gley 1 10YR); moist; fine SAND & SILT; nonplastic; med stiff.		0.0	SM
7	(6-9)	4/90%	Light Yellowish Brown (2.5Y 6/4) with Light Greenish Gray (Gley 1 10/1)		0.1	CL
8			mottles; CLAY some SILT trace fine SAND; low plasticity; stiff; well graded.		0.0	
9				*GL-SD-01-08-09*	0.2	
10						
11			*Total depth = 10 feet below top of surface. Recovery 9 feet.*			
12						
13						
14						
15						
16						
17						
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Figure 4 Example Sediment Boring Log for Grab Samples

LITHOLOGIC LOG *Sediment Collection Log* *EA Engineering, Science, & Technology, Inc.*	Client Name and Project Name **GLNPO/Spirit Lake**	Location/Boring Name **GL-DS-01-001**	Sheet **1** of ***1***
1 Geologist Name/Signature **Jaime Smith**	5 Project Number **1234567**	8 Start - Stop (Date/Time) **6/19/14 12:00** — **6/19/14 15:00**	
2 Drilling Subcontractor/Equipment Operator **Drill Company A**	6 Latitude/Northing/Grid **649999.89**	9 Sed Surface Elevation **580.018** *ft* 10 Coordinate System H **NAD83** V **NAVD88** 11 Depth of Water (start) **20** *ft*	
3 Operator Name *(License # If Required)* **Joe Smith 08976**	7 Longitude/Easting/Grid **10649999.89**	12 Depth of Water (end) **20** *ft* 13 Sunny/Cloudy/Rain 14 Temperature (start/high) **65** *F*	
4 Sampling Equipment and Methodology (Check One) Rotosonic: ___ -ft barrel ___ -in diameter ___ -ft spoon/sample Core: ___ -ft barrel ___ -in diameter ___ -VPM Manual/Vibracore/Other X Grab Sample: **0.5** -ft x **0.5** -ft x **0.5** -ft Box/Ponar/Van Veen/Other Other: Sample Collection Method: **Sample collected with stainless steel scoop from top six inches of box corer. Location offset 10 ft from proposed.**		15 Wind Direction **NE** 16 Total Boring Depth **20** *ft* 17 Recovery Depth **0.5** ft **100** % 18 Location Notes **First two attempts at this location washed out due to debris caught in jaws**	

	Interval *(Depth)*	Recovery *(ft & %)*	Description of Materials Munsell Color; Moisture; Density; Consistency (Other Remarks)	Sample ID Sample Interval	PID *(ppm)*	USCS *Code*
1	(0-0.5)	2/100%	Strong Brown (7.5YR 5/6); dry; SILT and fine SAND; non-plastic; soft		0.0	ML-SW
2			Poorly graded.			
3						
4						
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Tables

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TABLE 1 FIELD APPLICATION OF UNIFIED SOIL CLASSIFICATION SYSTEM

Description Order:																		
(Depth Interval) Color (Munsell); Moisture; Principal components with descriptors; Minor Components with descriptors; Sorting; Density/Consistency																		
Separate each description using a semicolon;					*Constituents should be capitalized (i.e., SILT, CLAY, SAND, etc.)*													
Moisture:	**Dry** – Absence of moisture, dry to touch, dusty.					**Moist** – No visible moisture, not dry.						**Wet** – Visible free water (typically saturated).						
Minor Component Percentages:	0-10% *(Trace);* 10-20% *(Little);* 20-35% *(Some);* 36-50% *(And).*																	
COARSE-GRAINED SOILS																		
Symbol	***Grain Size***		***Primary***		***Fines***		***Grading***		***Clean/Fines***		***Description***							
GW	Coarse		Gravels		Little-None		Well		Clean		Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.							
GP	Coarse		Gravels		Little-None		Poor		Clean		Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.							
GM	Coarse		Gravels		Some Silt		Poor		Fines		Silty gravels, gravel-sand-silt mixtures.							
GC	Coarse		Gravels		Some Clay		Poor		Fines		Clayey gravels, gravel-sand-clay mixtures.							
SW	Coarse		Sands		Little-None		Well		Clean		Well graded sands, gravelly sands.							
SP	Coarse		Sands		Little-None		Poor		Clean		Poorly graded sands, gravelly sands.							
SM	Coarse		Sands		Some Silt		Poor		Fines		Silty sands, sand-silt mixtures.							
SC	Coarse		Sands		Some Clay		Poor		Fines		Clayey sands, sand-clay mixtures.							
Density:	Very Loose		N<4		Loose		5<N<10		Medium Dense	11<N<30		Dense		30<N<50		Very Dense		50<N
FINE-GRAINED SOILS																		
Symbol	***Grain Size***		***Primary***		***Strength***		***Dilatency***		***Plasticity***		***Consistency***	***Description***						
ML	Fine		Silt		None-Slight		Slow Quick		Low		V. Soft-Soft	Inorganic silts, clayey silts of low-med plasticity.						
CL	Fine		Clay		Med-High		None V. Slow		Low		M. Stiff-Stiff	Inorganic clays of low-med plasticity (gravelly/sandy/silty clays).						
MH	Fine		Organic		Slight-Med		Slow Quick		Low		Soft-M. Stiff	Inorganic silts, micaceous/diatomaceous silty soils, elastic silts.						
OL	Fine		Organic		Slight-Med		None Slow		Low		Soft-Stiff	Organic silts/clays of low-med plasticity, sandy organic silts/clays.						
CH	Fine		Clay		High-V.High		None		High		Stiff-Hard	Inorganic or sandy clays of high plasticity, fat clays.						
OH	Fine		Organic		Med-High		None V. Slow		High		M. Stiff-Hard	Organic silts/clays of high plasticity; sandy organic silts/clays.						
Pt	Fine		Peat		Odor and spongy and fibrous texture						Not Applicable	Peat.						
Plasticity:											***Consistency:***							
Non-	3-millimeter thread cannot be rolled at any moisture content.										Very Soft	N<2	Easily penetrated several inches by thumb.					
Low	Thread barely rolled; lump cannot form below plastic limit.										Soft	2<N<4	Easily penetrated 1 inch by thumb.					
Med-	Barely able to be rolled; lump cannot form below plastic limit.										Medium Stiff	5<N<8	Thumb penetrates 0.5 inches with difficulty.					
High	Thread is easy to roll; lump formed without crumbling.										Stiff	9<N<15	Thumb penetrates 0.25 inches with difficulty.					
											Very Stiff	16<N<30	Indented readily by thumbnail.					
											Hard	30<N	Indented with difficulty by thumbnail.					
Dilatency:											***Examples:***							
None		Water not observed when shaken/squeezed.									*(10-20) Brown (7.5YR 4/3); moist; SILT little SAND and CLAY; non-plastic; soft; well graded.*							*ML*
Slow		Water appears/disappears slowly when shaken/squeezed.																
Rapid		Water appears/disappears quickly when shaken/squeezed.									*(20-30) Strong Brown (7.5YR 5/6); dry; fine SAND; dense; well graded.*							*SW*

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TABLE 2 COMPARISON OF GRAIN SIZE SCALES FOR SEDIMENTS

Grade Limits		U.S. Standard Sieve Sizes	Grain Size Classification System				
Millimeters (mm)	Inches		Modified Wentworth			Unified Soil Classification System	
4096	161.3	---	Very large	Boulders	Gravel	Boulders (greater than 300 mm)	
2048	80.6	---	Large				
1024	40.3	---	Medium				
512	20.2	---	Small				
256	10.1	---				Cobbles (75-300 mm)	
128	5.0	---	Large	Cobbles			
64	2.52	63 mm	Small				
32	1.26	31.5 mm	Very Coarse	Pebbles		Coarse Gravel (19-75 mm)	Gravel (4.75 mm No. 4 sieve to 75 mm)
16	0.63	16 mm	Coarse			Fine Gravel (4.75 mm No. 4 sieve to 19 mm)	
8	0.32	8 mm	Medium				
4	0.16	No. 5	Fine			Coarse Sand (2.0 mm No. 10 sieve to 4.75 mm No. 4 sieve)	Sand (0.075 mm No. 200 sieve to 4.75 mm No. 4 sieve)
2	0.08	No. 10	Very Fine	Sand	Sand		
1	0.04	No. 18	Very Coarse			Medium Sand (0.425 mm No. 40 sieve to 2.0 mm No. 10 Sieve)	
1/2 or 0.500	---	No. 35	Coarse				
1/4 or 0.250	---	No. 60	Medium			Fine Sand (0.075 mm No. 200 sieve to 0.425 mm No. 40 sieve)	
1/8 or 0.125	---	No. 120	Fine				
1/16 or 0.062	---	No. 230	Very fine			Silt (no specific grain size use Atterberg Limits)	Fines (less than 0.075 mm No. 200 sieve)
1/32 or 0.031	---	---	Coarse	Silt	Mud		
1/64 or 0.016	---	---	Medium				
1/128 or 0.008	---	---	Fine				
1/256 or 0.004	---	---	Very Fine				

Grade Limits		U.S. Standard Sieve Sizes	Grain Size Classification System				
Millimeters (mm)	Inches		Modified Wentworth			Unified Soil Classification System	
			Coarse	Clay Size		Clay (no specific grain size use Atterberg Limits)	
1/512 or 0.002	---	---					
			Medium				
1/1024or 0.001	---	---					
			Fine				
1/2048 or 0.0005	---	---					
			Very Fine				
1/4096 or 0.00025	---	---					

Attachment A

Equipment that May Be Required for Core Logging

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ATTACHMENT A

EQUIPMENT THAT MAY BE REQUIRED FOR CORE LOGGING

- Sample Location Coordinates and Figure
- Safety Equipment
- Global Positioning System
- Pencil
- Log of Core Boring Forms
- Notebook
- Hand lens
- Geologist's pick
- Knife
- Needle
- Magnet
- Core splitter
- Ruler (graduated in tenths of a foot)
- Steel tape (graduated in tenths of a foot)
- Tape recorder
- Camera
- Clinometer/protractor
- Waterproof marking pen (for core boxes)
- Assisting muscle power (to move core boxes)

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Attachment B

Checklist for Sediment Boring Log

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ATTACHMENT B

CHECKLIST FOR SEDIMENT BORING LOGS[1]

The Sediment Boring Log should include the following items:

- Project Name/Number
- Project Location
- Client
- Date/Time Collected
- Drilling/Sampling Contractor (Company and name of Team Member)
- Drilling/Sampling Equipment
- Drilling/Sampling Method
- Person completing the log
- Sample Coordinates
- Sediment Surface Elevation
- Surface Conditions
- Water Depth
- Penetration Depth
- Sample Recovery Depth
- Field Measurements (collected during boring)
- Information as to location and possible cause of core losses
- Details of delays and breakdowns
- For Drilling Only

    - Date and depth of sample/hole at start and end of working day or shift
    - Depth of start and finish of each core run
    - Depth and size of any casing at start and end of each core run
    - Core diameter and changes in core size
    - Type and condition of bit
    - Start and stop time of each core run
    - Time and description of interruptions in coring
    - Depths of changes in coring rate
    - Gain or loss of water, mud, or air flush; type of cuttings
    - Standing water level at start and end of each working period
    - Backfilling and grouting

[1] This list excludes any special items that may be required for contractual record purposes or for special engineering tests (e.g., Project Plan).

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Attachment C

Unified Soil Classification System
Field Identification Procedures for
Fine-Grained Sediments/Soils or Fractions

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ATTACHMENT C

UNIFIED SOIL CLASSIFICATION SYSTEM FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SEDIMENTS/SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 inches. For field classification purposes, screening is not intended; simply remove by hand the coarse particles that interfere with the tests.

DRY STRENGTH (CRUSHING CHARACTERISTICS)

After removing particles larger than No. 40 sieve size, mold a pat of soil/sediment to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil/sediment. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dry specimen. Fine sand feels gritty, whereas a typical silt has the smooth texture of flour.

Calcium carbonate or iron oxides may cause higher dry strength in dried material. If acid causes a fizzing reaction, calcium carbonate is present

DILATANCY (REACTION TO SHAKING)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil/sediment with a volume of approximately 0.5 cubic inches. Add enough water if necessary to make the soil/sediment soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat that changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil/sediment.

Very fine clean sands give the quickest and most distinct reaction, whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)

After removing particles larger than No. 40 sieve size, a specimen of soil approximately 0.5 cubic inches is molded to the consistency of putty. If too dry, water must be added and, if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. The specimen is then rolled out by hand on a smooth surface or between the palms, into a thread about one-eighth inch in diameter. The thread is then folded and rerolled

repeatedly. During this manipulation, the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil/sediment. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay or low plasticity, or materials such as kaolin-type clays and organic clays that occur below the A-line.

Highly organic clays have a very weak and spongy texture at the plastic limit.

Non-plastic soils cannot be rolled into a thread at any moisture content.

The toughness increases with the Plasticity Index.

Attachment D

Unified Soil Classification System

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ATTACHMENT D

UNIFIED SOIL CLASSIFICATION SYSTEM

Field Classification				Symbol				Symbol
COARSE-GRAINED SOILS More than half of material (by weight) is of individual grains visible to the naked eye	GRAVEL AND GRAVELLY SOILS More than half of coarse fraction (by weight) is larger than 0.25-in. size		CLEAN GRAVELS Will not leave a dirt stain on a wet palm	Wide range in grain sizes and substantial amounts of all intermediate particle sizes				GW
				Predominantly one size or range of sizes with some intermediate sizes missing				GP
			DIRTY GRAVELS Will leave a dirt stain on a wet palm	Non-plastic fines or fines with low plasticity (for identification of fines, see characteristics of CL below)				GM
				Plastic fines (for identification of fines, see characteristics of CL below)				GC
FINE-GRAINED SOILS More than half of material (by weight) is of individual grains not visible to the naked eye	SAND AND SANDY SOIULS More than half of coarse fraction (by weight) is smaller than 0.25-in. size		CLEAN SANDS Will not leave a dirt stain on a wet palm	Wide range in grain size and substantial amounts of all intermediate particle sizes missing				SW
				Predominantly one size or a range of sizes with some intermediate sizes missing				SP
No. 200 sieve size is about the smallest particle visible to the naked eye	For visual classification, the 0.25-in. size may be used as equivalent to the No. 4 sieve size		DIRTY SANDS Will leave a dirt stain on a wet palm	Non-plastic fines or fines with low plasticity (for identification of fines, see characteristics of ML below)				SM
				Plastic fines (for identification, see characteristics of CL below)				SC
	SILTS AND CLAYS (low plastics)		Slight	Rapid	Low to none	None	Dull	ML
			High	Medium to None	Medium	Weak	Slight to shiny	CL
		Pronounced	Medium	Slow to none	Low	None		

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Field Classification				Symbol				Symbol
	SILTS AND CLAYS (highly plastic)	ODOR Pronounced	DRY CRUSHING STRENGTH Medium	DILATANCY (SHAKE) Very slow to none	TOUGHNESS Medium	RIBBON (near the plastic limit) Weak	SHINE (near the plastic limit) Dull to slight	OL
			Very High	None	High	Strong	Slight	MH
			High	None	Low to medium	Weak	Shiny	CH
							Dull to Slight	OH
HIGHLY ORGANIC SOILS				Readily identified by color, order, spongy feel, and frequently by fibrous texture.				Pt

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TABLE D-1 CRITERIA FOR DESCRIBING DRY STRENGTH

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between the thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

TABLE D-2 CRITERIA FOR DESCRIBING DILATANCY

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface on the specimen during shaking and disappears quickly upon squeezing.

TABLE D-3 CRITERIA FOR DESCRIBING TOUGHNESS

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and lump have very high stiffness.

TABLE D-4 CRITERIA FOR DESCRIBING PLASTICITY

Description	Criteria
Non-Plastic	A 1/8-inch (3-millimiter) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

TABLE D-5 IDENTIFICATION OF INORGANIC FINE-GRAINED SEDIMENTS/SOILS FROM MANUAL TESTS

Soil Symbol	Dry Strength	Dilatancy	Touch
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

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